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(B.Sc. – CBZ)

Plant Diversity
(DBSZCO102T24)

Self-Learning Material
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Course Code: DBSZCO102T24
Plant Diversity

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COURSE INTRODUCTION

The course being an essential part of our surroundings and our survival, many biologists fail to recognize the beauty and diversity of plants. With a focus on nonvascular and vascular plants, this course offers an overview of the amazing biology and diversity of inanimate forms of life, such as bacteria, protists, fungi, algae, and archaea. It will look at the traits that these species have in common and that set them apart. The course will cover topics related to metabolism, physiology, ecology, and evolution and will cover levels of organization ranging from the cell to tissues, organs, and the entire organism. About how plants develop, procreate, and react to their surroundings. Plants are essential to ecosystems for reasons other than just being suppliers and the base of food webs.

Course Outcomes:

1. Acquire knowledge of the composition, color, food sources, and reproduction processes of fungi.
2. Understand the significance of lichen, fungi, and algae economically
3. Examined many plant diseases, paying particular attention to the underlying causes, signs, and prevention strategies
4. Discover the general traits, K.R. Sporne's categorization, heterospory, stelar evolution in Pteridophytes, and the development of seed habit.
5. Understand the composition, life cycle, and economic significance of gymnosperms. Examined the processes of fossilization of extinct plants.

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UNIT – 1

Introduction toViruses

Objectives

At the end of chapter student will be able to learn:

- The basic structure and function of virus.
- Categorize the diversity of virus.
- Understand the general structure of viroids and prions

Keywords: Virus characteristics, classification, viroids and prions

1.1 Viruses

Microscopic organisms which are non-cellular agents of infection are called viruses. They cannot be classified as living or non-living since they exhibit some specific characteristics features of the living and some of non-living forms e.g., unlike living organisms, viruses can be crystallized.

To summarize viruses are acellular, infectious agents consisting of outer protein coat and nucleic acid as genetic material. The nucleic acid may be DNA or RNA. They have the ability to enter and reproduce only in a living bacterial, plant or animal host cell. Viruses are unable to multiply outside of the host cell because they do not have the necessary cellular machinery. It uses the host's machinery to copy its genetic material once it has entered a particular host cell. Once the process of multiplication is finished and the nucleic acid and proteins are assembled, the host cell ruptures, releasing the newly formed viruses.

1.2 Discovery

When reasearchers removed bacteria from infected tissues by using special filters, they found that the filtered tissues continued to be infectious. This contradicted the theory that bacteria were responsible for the specific infection and indicated that there existed some entity which was even smaller than the bacteria which had caused the infection.

In 1915, Frederick Twort, a bacteriologist from England, noticed bacterial colonies with minute apparent spots. He hypothesised that these bacteria were being killed by some even smaller entity. For the first time, scientists were able to view viruses when the electron microscope was developed in the 1930s. In 1935, the Tobacco Mosaic viral was identified as the first virus to be observed.

1.3 Origin

Regarding the genesis of viruses, there are two important theories. Both theories provide probable explanations for the genesis of distinct viral species.

- The first hypothesis states that nucleic acid fragments on escaping from living cells such as bacteria gave rise to minute viruses.
- The second hypothesis states that parasitic cells housed in larger host cells, gave rise to large viruses. These cells over long periods of time, lost the ability to reproduce and live outside the host cell.

1.4 Characteristics

The discovery of viruses is credited to D.J. Iwanowsky, a Russian Scientist who discovered virus in the year 1892 while studying an infected tobacco plant. The name 'virus' was however given by M.W. Beijerink in the year 1898. In 1935, W.M. Stanley, an American Chemist concluded that viruses consisted of nucleoproteins when he was able to isolate and segregate a crystal of the tobacco mosaic virus.

1.5 General Characteristics

Characteristics of viruses are:

1. Non- cytoplasmic, Non cellular agents of infection
2. Minute entities permeable to bacteriological filters
3. Transmitted from diseased to healthy organisms.
4. Capable of reproduction only when inside the living host cells (Obligate parasites).
5. Contain only one nucleic acid, DNA/ RNA.
6. Infect specific cells of a single species of a host organism (host specific)
7. Efficient in minute doses.
8. Show resistance to germicides and extreme physical environments.

1.6 Structure

i. Viruses may be categorized as big or small. Plant viruses are generally smaller in size than bacteria. They have a variety of shapes including helical, polyhedral, rod like, tadpole shaped or golf ball shaped.

ii. A protein coat known as the capsid covers viruses. It is further subdivided into several identical protein subunits known as capsomeres. One or several proteins may constitute the capsomeres which are arranged symmetrically and are responsible for giving the virus its specific shape and host specificity.

iii. The virus core consists of one kind of nucleic acid DNA/RNA which is responsible for the ability of the virus to cause infections.

1.7 Biological Position

Viruses cannot be classified as living or non-living because they can only reproduce within a living host cell, have genetic material, lack basic cell components like the cytoplasmic membrane, have specific races and strains, and exhibit mutations. At the same time, they may crystallize, precipitate, and behave like inert chemicals outside the host cells, showing no signs of growth, reproduction, nutrition, or development.

1.8 Baltimore's Classification

David Baltimore created a classification scheme based on the virus's DNA and how it replicates by using the host's cellular structure

Since the virus does not have protein for translation so, uses the host cell's machinery for translation.

Baltimore's classification scheme placed the mRNA at the center, with distinct classes being identified by following different pathways from DNA / RNA genomes to the mRNA. Initially, viruses were classified into six classes. A seventh class was included later.

1. **Viruses with double stranded DNA (dsDNA)**

   Before the virus is able to begin replicating, it has to get inside the host cell's nucleus. Host polymerases are used to replicate the virus's genome. This makes the virus dependent upon the cell cycle of the host. Replication may only occur when the cell itself is replicating.

   Class I viruses include Herpesviridae, Adenoviridae, and Papoviridae.

2. **Single stranded DNA (ssDNA) viruses**

Replication of these viruses occurs inside the nucleus via a rolling circle mechanism since most ssDNA viruses have genomes which are circular.

Anelloviridae, Parvoviridae and Circoviridae are example of Class II viruses.

3. **Viruses with double stranded RNA (dsRNA)**

Similar to DNA viruses, viruses of this family replicate in the cytoplasm of their host cells and need host polymerases to do so. Class III viruses have segmentable nucleic acids and a more straightforward translation mechanism in which a single gene codes for a single protein.

Class III viruses include the *Rheoviridae* and *Birnaviridae* families.

4. **Viruses with single stranded RNA (ssRNA)**

ssRNA viruses are classified into two groups: **Class IV**: those with polycistronic mRNA and those with complex transcription. Their genomes are positive-sense RNAs, which ribosomes can read directly and convert to proteins. When polycistronic mRNA is translated, polyproteins are created, which are then cleaved to produce distinct proteins. Viral infections that create numerous proteins from the same gene sequences use ribosomal frame shifting with proteolytic processing.

Class IV ssRNA viruses include the following: Astroviridae, Coronaviridae, Picornaviridae, and Flaviviridae.

Class V: The genomes of viruses in this class might be nonsegmented or segmented, have a negative-sense RNA genome, a viral polymerase is required to transcribe their DNA into a readable mRNA strand.

Rhabodviridae, Orthomyxoviridae and Paramyxoviridae are examples of class V viruses.

6. Reverse transcriptase viruses with positive-sense ssRNA

The viruses in this class replicate by creating an intermediary DNA strand, while having a single-stranded, appositive RNA genome. The RNA is transformed into DNA by a reverse transcriptase, and the DNA is then spliced into the host's genome. Following this, transcription and translation take place, with the integrase enzyme being utilized in the procedure.

Group VI includes retroviruses like HIV as well as Pseudoviridae and Metaviridae.

Class VII: Reverse transcriptase viruses containing double stranded DNA (dsDNA)
Despite having a genome made of double-stranded DNA, these viruses vary from Class I viruses in that they replicate via a ssRNA intermediaryThe viral mRNA is created by breaking apart and then filling in the gaps in the dsDNA genome, forming a closed circle that acts as a template for the replication of the viral genome by reverse transcription back into DNA. A virus belonging to class VII is hepatitis B.

1.9 General structure with special reference to viroids and prions

Although viruses can have different structures, the majority of them are made of a capsid, a protein coat that carries DNA and RNA. The difference in the capsid's shape from one virus to another may be used for classification of viruses. The proteins of the capsids are coded for by viral genes in their genome.

Capsids are formed when virally coding proteins self-assemble. Fig. 1.2 shows a capsid which is icosahedral. Phospholipids and proteins form an envelope in some viruses. The envelope that surrounds the capsule and shields it from the host's immune system is made partially from the membrane of the host cell. The receptor molecules on the envelope attach to the host cells, facilitating the virus's ability to infect host cells.

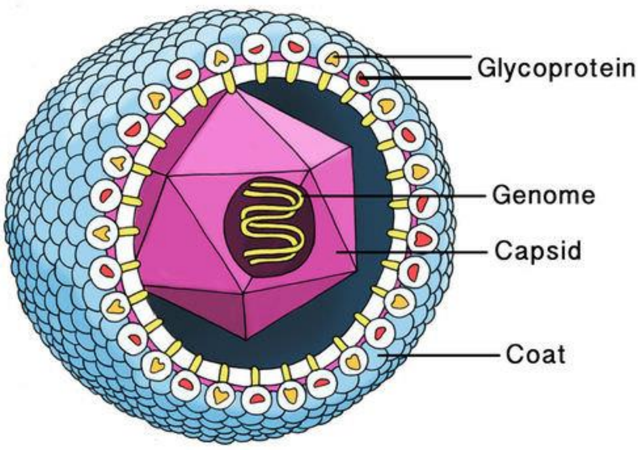


Figure 1.2: The Cytomegalovirus

The envelope of the capsid, which contains proteins and phospholipids from the host cell's membrane, encloses nucleic acids. All viruses may or may not contain the viral envelope (Figure 1.2).

1.10 Helical Viruses

Helical capsids resemble hollow tubes because they contain helical structures made of stacked units of a single protein type arranged around a central axis (Figure 1.3). The rod-shaped or filamentous virions that are produced by this arrangement can be either short and stiff or long and flexible. The following picture shows an example of a helical virus, Tobacco mosaic virus (TMV):

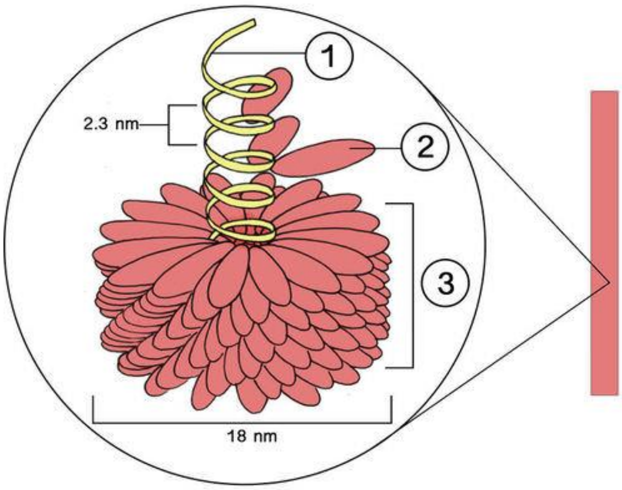


Figure 1.3: Tobacco mosaic virus, the causative agent of tomato, cucumber, pepper, and tobacco mosaic disease (1. The nucleic acid 2. Units of viral protein 3. The capsid)

1.11 Icosahedral Viruses

Low magnification makes these viruses appear spherical, yet the regular geometric arrangement of the protein subunits is comparable to that of a soccer ball. The virus's form is produced by continually using the same basic protein unit in several copies. This effectively forms a strong shape. It also aids in conserving genetic space for the virus.

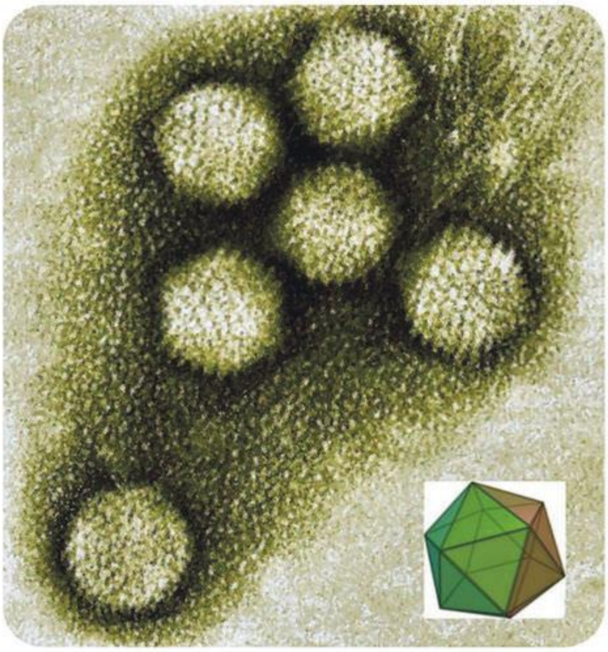


Figure 1.4: Adenovirus

This virus is icosahedral, with twenty equilateral triangles making up its three-dimensional form

1.12 Complex Viruses

These complex viruses are neither icosahedral nor helical, nor do they exhibit extra features like complex exterior walls or protein tails. Viral proteins aid in the construction of the viral capsid because the nucleic acid of complex viruses codes for proteins in addition to the self-assembly of viral protein subunits. Phage viruses can have tail fibers or not, but the ones that do have a base plate with protein tale fibers on it (Figure 1.5).

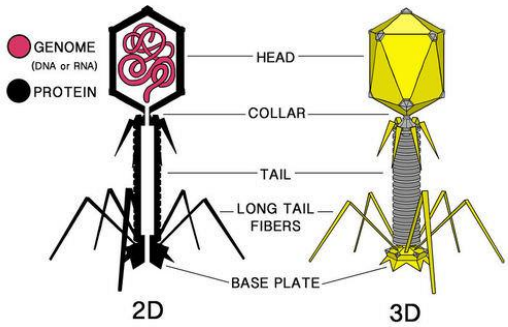


Figure 1.5: *Escherichia coli* bacteria are infected by a sophisticated virus shaped like a "moon lander."

1.13 Enveloped Viruses

Some portions of the host cell's membrane are encased by these viruses. The virus may also employ an internal membrane, such as the nuclear membrane or endoplasmic reticulum, which results in the formation of a lipid bilayer known as the viral envelope. Both the viral and host genomes code for different proteins on this membrane. However, the carbohydrates in the envelope and the lipid membrane are derived from the host cells, such as the Varicella zoster virus, HIV, and Influenza viruses (Figure 1.6).

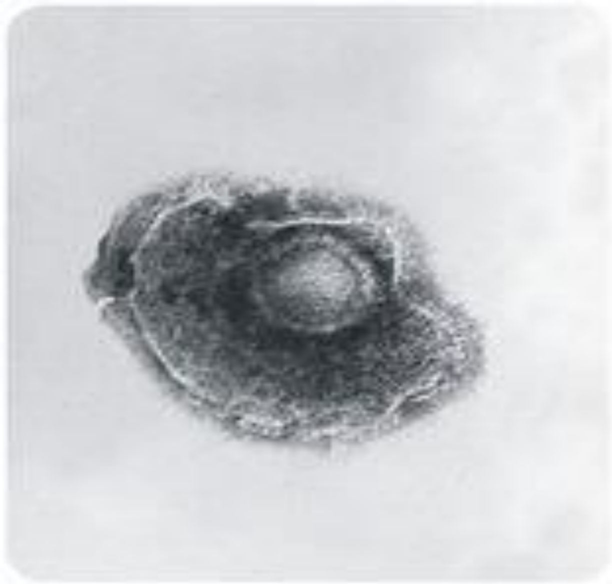


Figure 1.6: The causal organism of chicken pox and shingles is *Varicella zoster*, an enveloped virus.

The viral envelope confers benefits such as enhanced defense against the host's immune system, enzymes, and some chemicals. Furthermore, proteins on the envelope, like glycoprotein, function as receptor molecules that the host cells recognize, allowing for easy uptake into the host cells and interaction with the virions. However, in certain instances, the lipids on the envelope make the virus more susceptible to being rendered inactive by outside substances like detergents that disturb the lipids.

Despite having simpler structures than viruses, pathogens such as prions and viroids can nevertheless be lethal.

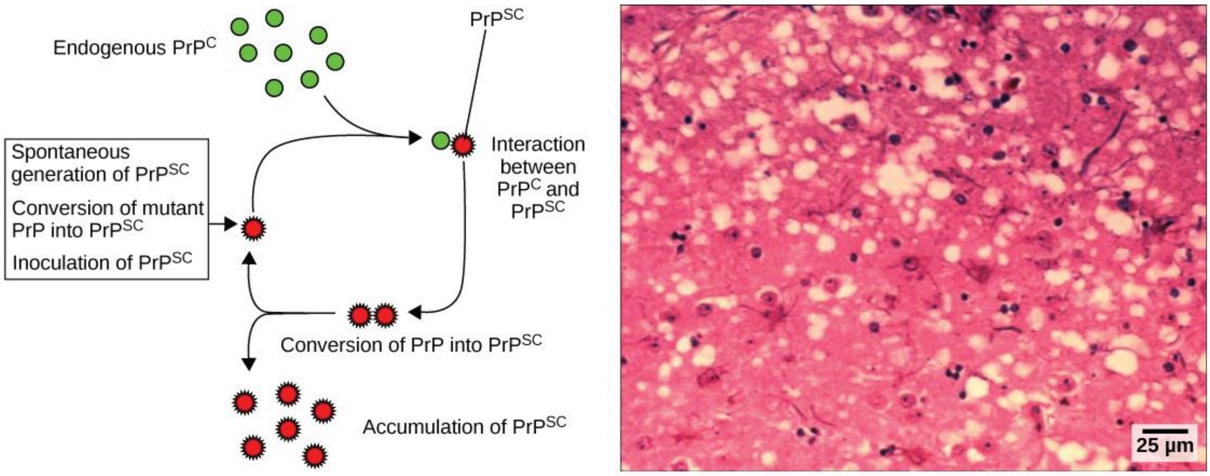
1.14 Prions

Scientists believed it was impossible for an infectious agent to exist that did not require nucleic acids. Stanley Prusiner, a noble prize-winning Biologist however, has done pioneering work on prions convincing Biologists regarding their existence. This infectious particle made from protein which is neither DNA nor RNA is much smaller than a virus.

In humans, prions cause Kuru, and in cattle, they cause bovine spongiform encephalopathy, or "mad cow disease." These fatal neurodegenerative diseases spread through the consumption of visceral organs and nervous tissue. Symptoms include unusual behaviour and loss of motor control followed by death.

Creutzfeldt-Jakob disease (CJD) is a disease similar to BSE which spreads in humans by consumption of animals infected with BSE which was initially believed to affect only cattle. Many nations all over the world banned the import of beef from Britian where BSE was widespread leading to economic slowdown in the cattle industry of Britain.

Kuru and BSE are among the diseases that are spread by prion protein (PrP), a variation of a cellular protein. This protein exits as PrP^{c} (normal form) and PrP^{sc} (the variant infectious form). If the variant is introduced into the body it combines with the normal form and converts it into the infectious form causing an exponential increase in the PrP^{sc} proteins resulting in lesions in the brain of infected cattle and humans with CJD (Figure 1.7).



(a) (b)

Figure 1.7: (a) Endogenous normal prion protein

(b) This brain tissue afflicted with prion disease, displaying the light-colored holes, or vacuoles, that give it a spongy texture characteristic of transmissible spongiform encephalopathies.

1.15 Viroids

These are plant diseases that have tiny, single-stranded circular RNA particles. They can only replicate within a host cell because they lack an exterior envelope or capsid. To date, no human disease has been found to be caused by virioids; instead, virioids produce only one particular RNA molecule and no proteins.

These organisms infect plants causing crop failure and loss of agricultural revenue annually. Plants infected by viroids include cucumbers, chrysanthemums, potatoes, tomatoes, coconut palms and avocados.

1.16 Virus Replication

The reason for this specificity is that only host cells having viral receptors may be used by the virus. The kind of cells targeted by the virus also depends upon the differences in the immune responses and metabolic responses of different types of cells caused by differential gene expression. A permissive cell produces all the substances a virus needs else it may not be able to reproduce within it.

A virus's reproduction-related host cells experience significant biochemical and structural alterations known as "cytopathic effects," which have the potential to harm, alter, or even destroy the host cell. When a cell infected with the rhinovirus (common cold virus), for instance, undergoes lysis or

Apoptosis (cell suicide), it releases offspring virions that infect additional cells. The symptoms of a viral disease are brought on by the infected body's immune system's attempt to eradicate or regulate the virus. Even if they are still alive, the injured cells might never be able to perform their usual functions. For instance, the HIV virus enters immune system cells through budding, and virions exit each cell separately. The contaminated cells are unable to operate normally yet do not die.

1.17 Summary:

Acellular, microscopic infectious entities that can only reproduce within a host cell (bacteria, plants or animals) are called viruses. They cannot be categorised as living or non-living from the biological point of view, since they possess some characteristic features of the living and others of the non- living.

Because a virus lacks the cellular machinery needed for protein synthesis, it is unable to replicate itself outside of its host cell. By introducing its genetic material into the host cell and using the host's cellular machinery for reproduction, it completes its reproductive cycle and releases new viruses when the host cell cracks open.

Like the non-living viruses may be precipitated and crystallized which causes their classification in category between living and non-living.

1.18 Fill in the blanks

1. ....group is gram negative and oxygenic in monera
2. .... Archaebacteria is obligate anaerobe
3. Mesosomes have ...., ... and .... Shape
4. .... structure bear pigments in cyanobacteria
5. Streptomycin and ....are gram positive and belong to actino mycetes
6. Linkage present between NAG and NAM is ....
7. ....antibiotic prevent cross linking in amino acid chain of peptidoglycan
8. ....is example of peritrichova bacteria and it is ....
9. Chemoautotroph involve in recycling of minerals.....................
10. Autotroph involve in conversion of nitrite into nitrate are.................
11. Gas vacuole present in..................bacteria
12. In ....monera Chla and PS II present
13. In heterocyst ....enzyme present and ....structure/pigment absent
14. ....chemical made endospore resistant
15. ....inclusion bodies are storage of carbohydrate and .... for lipid in monera
16. ....monera is connecting link between virus and monera
17. ....structure form when plasmid fuse with genomic DNA
18. ....protein help in packaging in prokaryotes
19. ...., ... and .... Features are of gram negative bacteria
20. ....is example of saprophytic bacteria

1.19 Short Answer Question

1. Define capsid. What is the chemical composition of the capsid?
2. Why complex viruses important for ecosystem?
3. What is difference between Enveloped and Non-enveloped virus.
4. Define Prions. Suggest type of diseases caused by prions.
5. What is apoptosis ? How it is difference between cytopathic and apoptosis.

UNIT - 2

Replication inViruses

Objectives

At the end of chapter student will be able to:

- Describe the genetic material of virus.
- Explain the replication process of virus genetic material.
- Assemble the knowledge for the prevention and control of crop losses due to virus infection
- Classify viruses (plant and animal) and to relate their economic importance.

Keywords: Bacteriophage, genetic material, lytic and lysogenic cycle, diseases, application

2.1 Definition

A bacteriophage infects and reproduces within the bodies of bacteria. Felix d'Herelle in France and Frederick W. Twort in the United Kingdom made separate discoveries of bacteriophages. The terms "bacteria" and "phagein," which both imply "to devour," are the roots of the phrase "bacteriophage."

They can survive in different environment so they are the most prevalent living organisms throughout the world. In term of biomass they are most abundant living organism in water and second most abundant on land following prokaryotes. The Archeae are also infected by the similar phase that infects bacteria.

The shape, size and genomic organization of bacteriophages varies with the bacteria they infect, but the basic structure remains the same consisting of nucleic acid enclosed in capsid proteins. In different types of phage their head differ in structure and shape ranging from 24-200 nm in length.

In previous years the research on bacteriophages increased rapidly so their application has also been increased. It has been analyzed that they can be used as antibiotic agent to kill the infectious bacteria.

The mechanism action for all bacteriophages is almost similar i.e., they first attach to host cell, insert their genome in host cell to prevent the activity of host cellular machinery

2.2 Structure of Bacteriophages

All phages possess certain similar properties, despite the fact that they are diverse in nature based on the type and group of bacteria they infect. Among these characteristics or properties some of them are:

- Specific to species they infect. A particular strain of phage is infectious to a single species or strain of bacteria.
- Fundamental structure: same for all bacteriophages having an outer protein capsid containing genetic material.
- Basic structural forms: there are three forms- filamentous, icosahedral head with a tail, and without a tail.
- Genetic material: DNA or RNA, single or double stranded **(**Figure 2.1)
- Intracellular obligate parasite, latent in the outside environment, uses cellular machinery of host to reproduce.
- May be classified based on physical characteristics and genetic material into different orders and family including Inoviridae, Tectiviridae, Microviridae, and Rudiviridae.

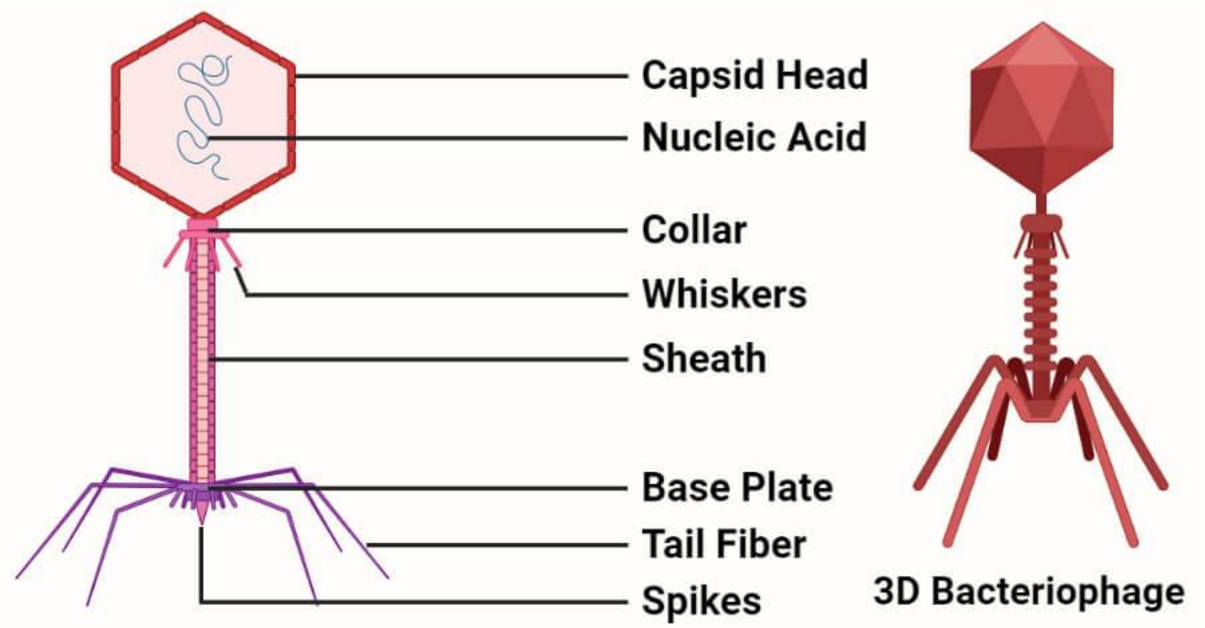


Figure 2.1: Structure of Bacteriophage

2.3 Types of Bacteriophage

a. λ phage

- Also called as coliphage λ this virus infects bacteria from the bacterial species ***Escherichia coli*** **(*E. coli*)**.
- In 1951 Esther Lederberg a US scientist discovered lambda phage during UV rays studies on *E. coli.*
- Family: Siphoviridae, order: Caudovirales, characterized by non-contractile tail, a linear double-stranded DNA and absence of envelope.
- Researched for lytic and lysogenic lifestyle, studies on viruses and as model virus.
- Shows a temperate life cycle which allows entry into both the lytic phase or residence in the genome of the host through lysogeny.
- Structure: protein head or capsid enclosing the viral genome with a non-contractile tail and tail fibre.
- Unable to force itself through the bacterial cell membrane due to non- contractile tail. Uses existing pathways to enter host cell.
- Single DNA molecule in phage head with over 1000 protein molecules of 12-14 different types of proteins constituting the virus.

b. T4 phage

- Species of bacteria infected- E.coli (called Escherichia virus T4).
- Delbruck and coworkers discovered the virus in 1944 with seven other *Escherichia* coliphages.
- Family: Myoviridae, Order: Caudovirales characterized by a contractile tail and non-enveloped head.
- Structure: linear double-stranded DNA molecule enclosed in protein capsid or head.
- Bound to the tail is a contractile tail (925 Å long and 520 Å diameter) attached to the base of the head by a special portal.
- Arising from the baseplate are six tail fibres which are capable of recognizing the receptor molecule on the surface of the host.
- Most popularly studied bacteriophages (Bacteriophage T-even viruses).

- 300 genes are a part of the genetic makeup of this group of viruses making them most complicated and largest group.

2.4 Life Cycles of Bacteriophage

The bacteriophage may conduct its life cycle in two ways

- The genetic material of the host becomes integrated with the viral material.
- Viral DNA reproduces separately from the host's genetic material.

Different bacteriophages may show these life cycles independently or alternatively. The entry of the virus causes infection in the host cell. This is followed by replication of Genetic material and its exit from the host cell.

a. Lytic Cycle

- Here the DNA of bacteriophages acts as a free-floating molecule and replicates independently from the DNA of the bacteria.
- This cycle found in the virulent phages also causes the destruction of the infected cell with the release of the viral particles. Such phage or viruses are known as Virulent phages.
- It causes destruction of the host cell **(**Figure 2.2).

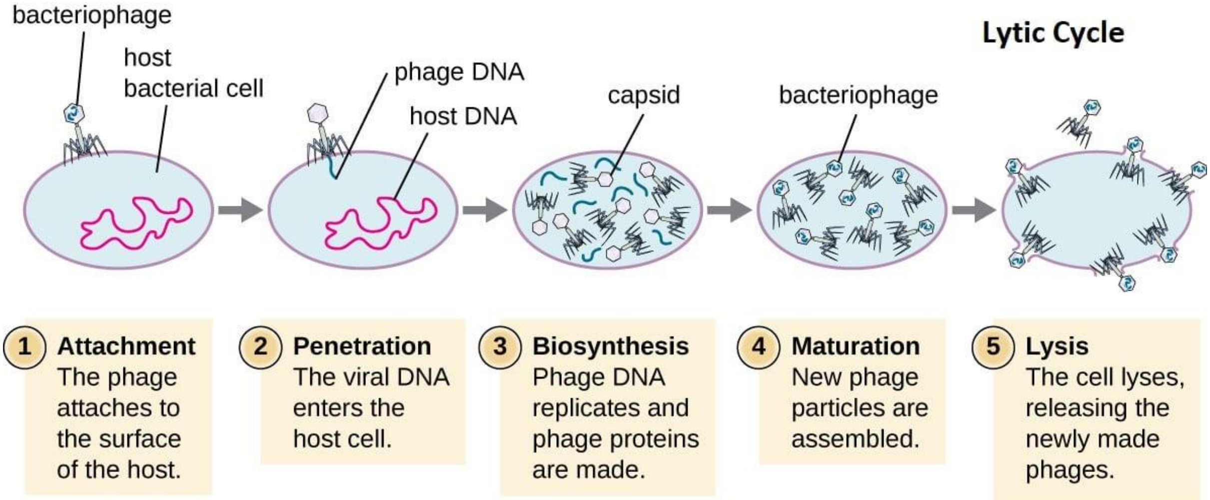


Figure 2.2: Lytic Cycle of Bacteriophage. Image Source: Openstax Microbiology.

i. Steps of the Lytic cycle:

a. Attachment and Penetration

- In step one, ligands on the surface of the virus found on specific molecules get attached to receptors on the cell membrane of the host cell.
- Various viruses employ distinct receptors. For instance, terminal sialic acid on the oligosaccharide side chain of cellular glycoprotein is utilised by orthomyoviruses.
- The ligand of the trimeric viral hemaglutinin glycoprotein is an aperture located at the distal end of each monomer.
- Receptors and ligands show a high degree of specificity however the same receptors may be used by a number of viruses.
- Also, other glycoproteins on the membrane may be used by bacteriophages as their receptors. Nuclear material is injected by virus into the cytoplasm of the bacterial cell which remains in the cytoplasm for take on a circular shape like the bacterial plasmid.

b. Biosynthesis and Transcription

- Virus uses the host to replicate and produce more viruses.
- Messenger RNA are produced as the DNA of the viruses undergoes transcription. The messenger RNA starts directing the ribosome of the host cell.
- The mRNA in the case of the lytic cycle codes for many polypeptides, the first polypeptide destroys the DNA of the host.
- Transcription of the viral RNA into DNA in the case of RNA viruses is done by an enzyme called reverse transcriptase.
- In the next step, the DNA is once again transcribed into mRNA, which orders the destruction of the DNA of the host.
- Now, the host cell is under the control of the viral DNA and directs the production of various proteins which are required for production of fresh viruses.
- New viral particles have produced as viral DNA replicates repeatedly to produce more genetic material.
- Different genes and enzymes participate in this process of biosynthesis and DNA replication.

c. Assembly and Lysis

- More and more viral genomes and proteins are produced as the biosynthetic process and replication continues.
- As the amount of virus particles increases and matures, these particles begin to assemble, incorporating the genetic material of the virus into the capsid's viral protein.
- The bacterial cell wall is destroyed and the freshly generated bacteriophages are liberated when the newly manufactured bacteriophages release the enzyme lyase into the cytoplasm.
- The cell membrane and bacterial cell are both destroyed in the lytic cycle.

b. Lysogenic Cycle

- The lysogenic cycle is different from the lytic cycle in that even after replication of the bacteriophages, the host bacteria continues to live and reproduced normally.
- During this cycle, the DNA of the bacteriophage gets incorporated into the DNA of the bacteria. This is called prophage. This DNA during bacterial cell division may be transmitted to the daughter bacterial cells.
- Since the bacteriophage does not destroy host cell, the lysogenic cycle is said to be temperate and non-virulent **(**Figure: 2.3).

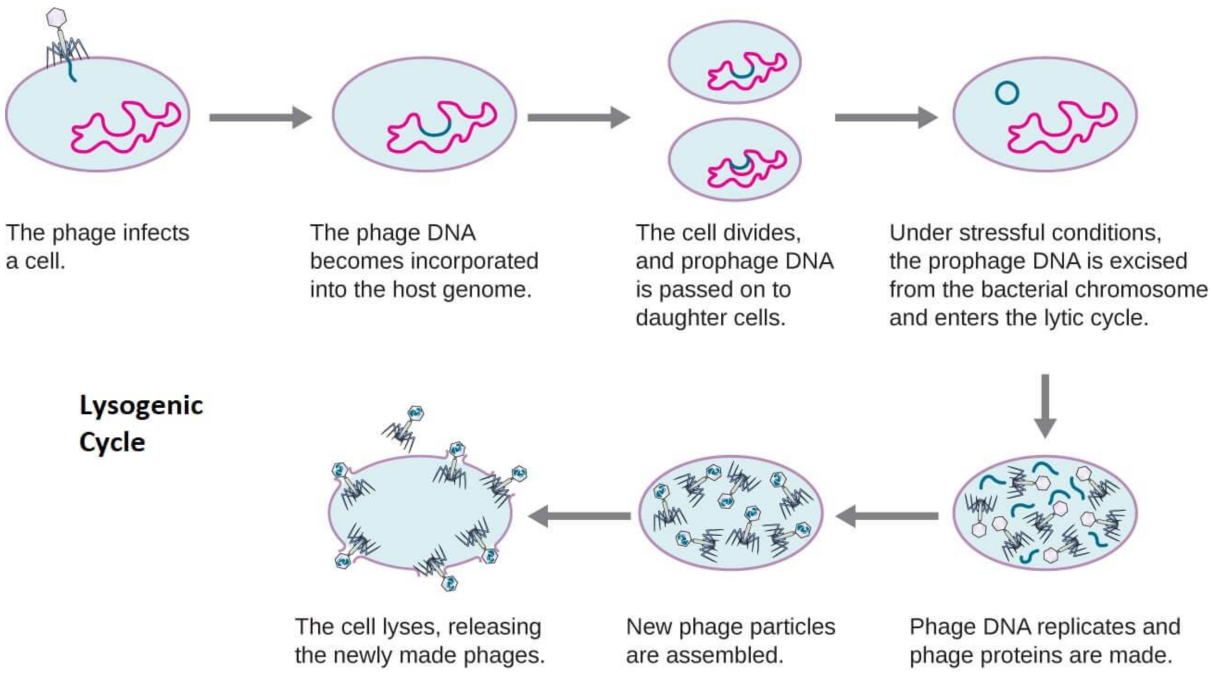


Figure: 2.3 Lysogenic Cycle of Bacteriophage.

Steps in the lysogenic lifecycle:

i. Attachment and Penetration

- The first phase of the lysogenic life cycle is analogous to the initial phase of the lytic life cycle. The virus parts, called bacteriophage ligands, attach to specific places on the outside of a bacterial cell.
- This attachment is very specific because it depends on how the virus parts and the places on the bacterial cell fit together.
- Once stuck, the virus's DNA gets pushed into the inside of the bacterial cell.
- The virus's DNA then becomes part of the bacterial cell's own DNA, making it a part of the cell's genes. This changes the virus from being able to infect other cells to being inactive inside the cell.

ii. Replication

- The viral DNA copies itself using the host's tools while the cell divides.
- Sometimes, the inactive viral DNA inside the cell might leave the cell's DNA, and the virus starts its active phase.
- Unlike when the virus is active, during this inactive phase, the virus doesn't take over the cell's machinery, and no new viral parts are made.
- But, the inactive virus can still be passed down to new cells when the cell divides.
- This copying process keeps going until something stresses the cell, like UV light, not enough food, or certain chemicals. This stress can switch the virus from the inactive to the active phase.
- When this happens, the viral DNA is used to make new viral parts. These parts join together to make new viruses, which then burst out of the cell, breaking it open.

2.5 Lytic Cycle vs Lysogenic Cycle

Characteristics	Lytic Cycle	Lysogenic Cycle
Definition	In the lytic cycle, a kind of life process for viruses called bacteriophages, the virus's DNA inside the cell does not integrate with the host genome and makes copies of itself	In the lysogenic cycle, which is another way viruses called bacteriophages live, the virus's genes get added into the host cell's genome.
Also called	Infective cycle or virulent cycle.	Temperate cycle or a avirulent cycle.
Viral DNA	In the cytoplasm of the host cell	Is incorporated into the host chromosome in the lysogenic cycle.
Prophage	Absent	Present
Host DNA	Damaged by the viral DNA	Not pretentious by the viral DNA.
Viral replication	Independently from the host DNA replication.	DNA gets copied at the same time as the host cell's DNA.
The productivity of viral DNA	High	Low
Host cellular mechanism	Completely taken over by the viral DNA.	Remain same
Duration	Completed within a short period of time.	Takes a longer period of time.
Transition	Cannot shift into a lysogenic cycle.	Can shift into the lytic cycle.

Infection	Symptoms of viral infections can be observed.	The cycle is a non-infective cycle that doesn't result in symptoms.
Transfer	Virus's DNA can't move from the original cell to its offspring.	The virus's DNA can move into the new cell when it divides.
Genetic recombination	Host chromosome's genes don't mix or swap with the virus's genes.	The genes from the virus and the host can mix or swap with each other.
Lysis of host cell	The lytic cycle ends with the lysis of the host cell.	The lysogenic cycle doesn't result in the lysis of the host cell.

2.6 Bacteriophages' application

Bacteriophages have been seen as possible treatments of bacterial diseases in both humans and animals. At first, they were mainly used to treat gut and skin infections then, doctors started using them in surgeries to treat intractable infections. Here are some areas where bacteriophages can be used:

a. Treatment of bacterial infections

As several antibiotics have become bacterial resistance, the potential use of bacteriophage a possible treatment has been explored. Bacteriophage can be used to kill such bacterial cell which are lethal to human cells as bacteriophages do not effect human cell i.e. they effect only disease causing bacterial cell. Bacteriophages can be used to treat burn wounds where chances of infections are higher i.e. they reduce the chances of sepsis.

b. In food hygiene and safety

Bacteriophages are employed in the management and eradication of food-contaminating microorganisms. Ready-to-eat goods including milk, vegetables, and meat products are sanitized using bacteriophages. A large number of bacteriophages have been marketed for use as spray sanitizers in slaughterhouses to disinfect and lower the level of contaminants in the meat. Since some bacteriophages can disinfect stainless steel just as effectively as a quaternary ammonium compound, they are also helpful as surface and environmental decontaminants.

c. In agriculture

Certain bacteriophages that are unique to plant bacteria have also been used in the field of agriculture.

The phages are used for the treatment and prevention of bacterial diseases in plants instead of antibiotics preventing the clumping of antibiotics on the plant surface, which then might be harmful to the health of the consumers.

2.7 Phage Therapy

The use of bacteriophages to treat various bacterial infections is known as Phage therapy or viral therapy. The concept of using bacterial viruses to treat bacterial infections has a contentious history in western medicine and now a days it is also being used to treat bacterial infections instead of antibiotics. However, the current knowledge and application of phage therapy have advanced well beyond traditional methods. The bacteriophages first discovered by Twort and d'Herelie in 1917 and concept of phase therapy actually began with this. Firstly the use of phage therapy has been sustained for a range of clinically significant pathogens using animal models. Then human trials for phage therapy began almost a century ago, and it is currently used for the treatment of common bacterial pathogens like *Staphylococcus aureus, Enterococcus, Proteu*s, and *Pseudomonas aeruginosa*. The effective applications of phage therapy varies from surgical to gastroenterological treatment that can be both therapeutic and prophylactic. Even though no phage therapy products are yet permitted for clinical use in humans, commercial phage provisions have been used as biocontrol agents in the food industry. These provisions are used against common food pathogens like *Salmonella, Campylobacter*, and *Listeria monocytogenes*. Phage therapy is repeatedly compared with antibiotics, and it has been noted that phage therapy has various advantages over antibiotics.

- There are almost no side effects of phage therapy, and phages are even effective against the bacterial population present in biofilms.
- The use of phage-encoded lytic enzymes is also conducted along with use of phages against bacterial infections. These enzymes are similar to the antimicrobial eukaryotic enzyme lysozyme which is responsible for lysis of the bacterial cells.

2.8 Tobacco mosaic virus (TMV)

Tobacco mosaic virus (TMV) is a plant virus that infects mostly tobacco, tomato, potato and other members of solanaceae family. It belongs to the genus *Tobamovirus*. Mottling and discoloration of the leaves, mosaic like pattern are the main symptoms of this infection. Discovery Structure and lifecycle of the virus is as follows **(**Figure: 2.4):

Figure: 2.4 TMV Life Cycle

2.9 Discovery

Adolf Mayer, a German scientist, started studying tobacco plant diseases in 1879. In 1886, he was able to clarify how leaf mottling disease, similar to bacterial infection, might move from diseased to healthy plants by only rubbing the affected plant's juice over the healthy one.

Russian microbiologist Dmitri Ivanowsky started researching tobacco mosaic disease in 1887 and continued until 1890. He concluded that the infectious agent wasn't bacterial because the causal organism could pass through the porcelain filter, which was thin enough to hold the bacterial species.Later, Martinus Beijerinck independently recreated Ivanowsky's research and demonstrated that the causal agent could grow and replicate in the host cell of the tobacco plant. In order to demonstrate that tobacco mosaic disease is not bacterial, he so created the term "virus."

2.12 Structure

- The virus known as tobacco mosaic virus (TMV) resembles a rod. The genetic content of the virus is enclosed within a protein shell known as the capsid.
- Its diameter is 18 nm, and its length is around 300 nm.
- The virus's genetic material is a single-stranded RNA molecule that is encased in a capsid, a protein shell. The RNA that is found within the capsid has an mRNA count of around 6395 bp.
- The capsid has almost 2130 identical proteins subunits called capsomeres. These coat proteins arranged themselves in helical manner and forming the rod like shape of the virus.
- The tight coiling of the RNA molecule and protein subunits together contribute to the stability of virus which is called viron (Figure: 2.5).

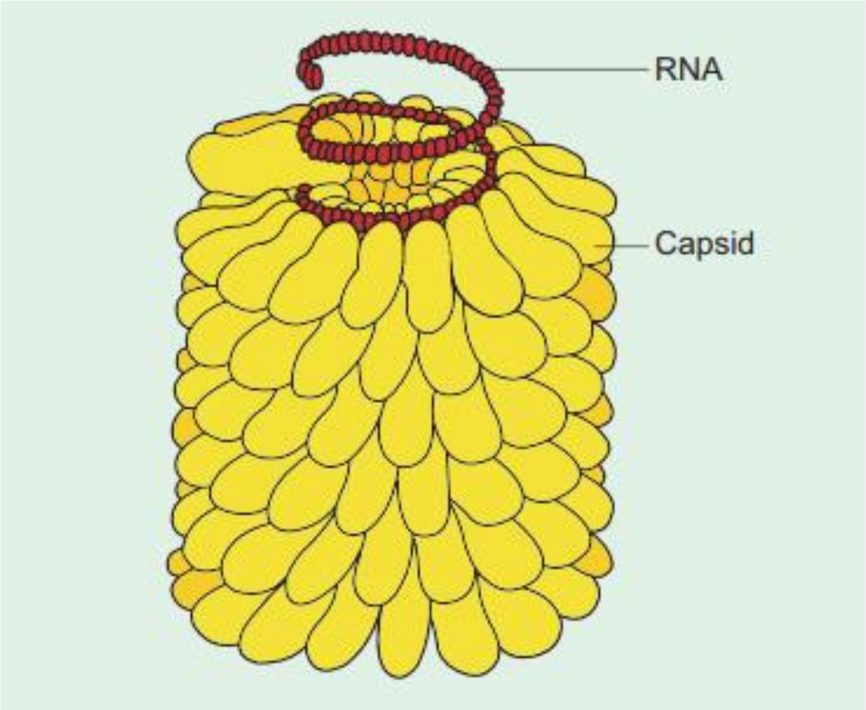


Figure: 2.5 structure of Tobacco mosaic virus (TMV)

2.10 Life Cycle

Insects like flies, aphids, and other vectors introduce the virus onto host cell. Here, the virus grows and uses plasmodesmata to infect neighboring cells. Additionally, the virus spreads to healthy plants by direct contact with diseased plants.

Inside the plant cell the protein coat of the viron breakdown and release the viral RNA (Single stranded RNA). The viral RNA uses the host cell machinery to make copies of itself and produce the viral proteins. These proteins include and RNA replicase enzyme, a movement protein (MP) and a coat protein (CP) this process is known as replication.

The viral RNA and coat proteins self-assemble to form new TMV particles. The movement protein helps the newly formed TMV particles move from one plant cell to another through plasmodesmata (channels that connect to plant cells)

The TMV particles the exit the plant cell through wounds or when the plant cell dies.
The cycle start again when the virus particles come in to contact to another plants.

2.11 Applications

Tobacco mosaic viruses are frequently employed as viral vectors to introduce desired genes into plant cells and enhance the quality and yield of plants. It is also utilized in various nanotechnology and biomaterial devices.

Virus as foes and friend

Viruses are incredibly little infectious agents that cause enormous financial damages. Viruses are significant pathogens, but they are also very helpful for medical study and diagnosis.

Plant Diseases

- Several plant diseases are caused due to virus whic result in decreased grain production, poor quality seed and poor quality fruits etc.
- Virus damaged plants hindering their growth and ability to produce fruits, vegetables or grains.
- Infected crops maybe unmarketable due to poor quality or safety concern.
- Farmers may need to spend more on measures to control virus such as pesticides or resistance crop varieties.
- Few of the plant disease caused by plant viruses are Tobacco Mosaic Virus, Potato Virus and Cauliflower Mosaic Virus, Mosaic virus of cucumber and lettuce, yellow disease of Potato, Tomato bunchy top disease, Cotton leaf curl Viruses (LCV), Necrotic Diseases and tumours.

Animal Diseases

- Viruses can cause illness and death in livestock, leading to lost animals and their potential products (meat,milk,and eggs)
- Even if animals survive a viral infection, they may experience decreased milk production, slower weight gain or lower egg laying rates.
- Veterinary care and medication for sick animals add to the financial burden .
- Countries may restrict imports of animal products (meat,milk) from regions experiencing viral outbreaks. This can hurt farmers profit and disrupt food supply chain.

- Public concerns about consuming meat and dairy from animals exposed to viruses can lead to decrease demand and lower prices for farmers.
- Few examples of viral infected diseases in animals are foot and mouth disease in cattles (FMD),It is caused by picorna virus,Avian influenza commonly known as bird flu(influenza virus),Rabies(Rhabdo viruses),Bovine viral diarrhea(pestivirus),New castle disease in poultry (paramyxovirus) etc.

Human Viral Diseases

It is common knowledge that viral illnesses like AIDS, influenza, dengue, polio, diarrhea, smallpox, and hepatitis can cause great distress. Emerging viral diseases have an impact on national health systems and the relationship between affluence and health. One of these is the unexpected appearance of the Ebola virus, which results in severe internal and external hemorrhage. The coronavirus that causes severe acute respiratory syndrome (SARS) is the source of another similar illness. Vaccination is still the best course of action for managing viral infections.

Virus as friends

Vaccine production:

Vaccines offer protection against viral illnesses. Conventional vaccinations are inexpensive and simple to make, as they are synthesised from live attenuated viruses, which have lost some of their force or effect.

Gene therapy: As everyone knows, a gene is a section of DNA that codes for an RNA or protein. Disease is brought on by a faulty gene that results in a faulty or nonfunctional protein product. Gene therapy is the process of introducing functional genes into human cells in order to replace or repair damaged genes. A bone marrow transplant for blood cancer is one example of how gene therapy is widely employed in cancer treatment.

Cancer therapy: Oncoviruses are a subclass of viruses that cause cancer. Because viruses are the source of anti-cancer vaccinations, such as those against the hepatitis B virus (which causes hepatic cancer)and the human papillomavirus (which causes cervical cancer), they can be used directly to prevent cancer.

Bacteriophage therapy: Bacteriophages can be employed to eliminate bacterial pathogens. This treatment looks highly promising and has been used to treat staphylococcal infections successfully.

Role of viruses in research: Since viruses can infect any of the three domains of life—bacteria, archaea, and eukaryota—they have been used widely in study.

Viruses are frequently employed as vectors in recombinant DNA technologies and research techniques due to their unique capacity to introduce genetic material into host cells. The viral vectors commonly utilized in genetic engineering are bacteriophages.

Viral biopesticides: Compared to bacterial pesticides, they are far less important. Numerous viruses are continuously being studied and developed as possible bio-control agents. The most significant class of viruses utilized as biopesticides are baculoviruses.

2.12 Summary

Protein (capsid) and nucleic acid (viral genome) are two basic components of viruses. Protein coat of the virus (Capsid) protect the viral genome from chemical and physical damage. Capsid is made up of proteins subunits capsomeres. The capsid and the viral genome are together called the nucleio capsid.

The three distinct symmtery groups of viruses—icosahedral, helical, and complicated symmtery—are caused by these capsomeres. Spikes are unique capsid proteins that are found on the viral capsid and serve as the virus's binding sites, allowing the virus to link to certain host cell receptors. Viruses are responsible for many types of diseases in plants, animals and humans that’s why they are economically important. The viral nucleic acid or genome is made of either de-oxy ribonucleic acid (DNA) or ribonucleic acid (RNA).

Viruses with DNA as their genetic material are called DNA viruses and viruses with RNA as genetic material are called RNA viruses. The DNA and RNA viruses are further subgrouped into 7 classes (Baltimore classification). T-phages are a particular kind of huge, complex bacteriophages that have double-stranded DNA, icosahedral heads, and distinctive head and tail structures. The helical structure of the tobacco mosaic virus contains single-stranded (ss) positive sense (+) RNA in the center.

2.13 Self Assessment Questions:

1. Archaebacterial cell lacks

    (1) Peptidoglycan

    (2) Ether linkage

    (3) Ribosomes

    (4) Branched Chain Lipids

2. Which is not true about Ribosomes of prokaryotes are

    (1) without membrane

    (2) 70 s type

    (3) size 20nm

    (4) inclusion body

3. Which of the following are gram negative bacteria

    (1) Mycoplasma

    (2) Rhizobium

    (3) Cyanobacteria

    (4) all

4. Mark the incorrect –

    (1) Bacteria is sole member of Monera

    (2) All bacteria is not oxygenic

    (3) Chemoautotrophic bacteria is Nitrosomonas

    (4) PPLO ribosome is not 70s type

5. Mark the incorrect –

    (1) Chl a present in nostoc

    (2) Nostoc and anabena have chromatophore

    (3) Lactobaccilus is saprophytic

    (4) Inclusion body in bacteria have single membrane

6. Mark the incorrect –

(1) Most common shape in bacteria is bacillus

(2) Most common nutrition is Saprophytic

(3) Mycoplasma is without cell wall

(4) Mycoplasma cannot survive without oxygen

7. Mark the correct –

(1) Gametes absent in Protista

(2) True sexual reproduction absents in Protista

(3) True sexual reproduction present in Monera

(4) primitive method of DNA transfer occur in bacteria

8. Not true for virus –

(1) Intracellular parasite

(2) Size is smaller than smallest bacteria

(3) Crystalline structure

(4) inert both inside and outside cell

9. TMV have similarity with Viroid in –

(1) Genetic material

(2) Protein coat

(3) Size

(4) All

10. Which of the following cause neurological disease –

(1) Prions

(2) Viroid

(3) HIV

(4) All

2.13 Short Questions

1. Define Bacteriophage. Give a detailed structure.
2. What is difference between Lysogenic and lytic life cycle of bacteriophage.
3. Who discovered TMV? Give structure.

CHAPTER - 3

Bacteria

Objectives

At the end of chapter student will be able to:

- Demonstrate microscope handling techniques and staining procedures.
- Describe the general characteristics of bacteria.
- Differentiate the various forms of bacteria.
- Gain the knowledge of bacterial structure and nutritional requirement.

3.1 Bacteria-Discovery, general characteristics

Most primitive creature to evolve on planet was perhaps the unicellular entities like modern bacteria. Since then, countless generations, life has evolved into a wide variety of forms. Still, we are enabling to connect ourselves to this one-celled creature. Despite the infectious effects of bacteria, they have mutual useful relation with human being which sometimes essential for the survival. Before discussing the various applications of bacteria to plants and human first we should know the structure, categorization, and diagram of bacteria.

Bacteria Definition

"Bacteria being unicellular organisms belonging to the prokaryotic group which lack true nucleus and membrane bound organelles".

3.2 Bacteria

The figure 3.1 illustrates the different parts of a normal bacterial cell. The positions of the flagella, cytoplasm, plasmid, and cell wall are well defined.

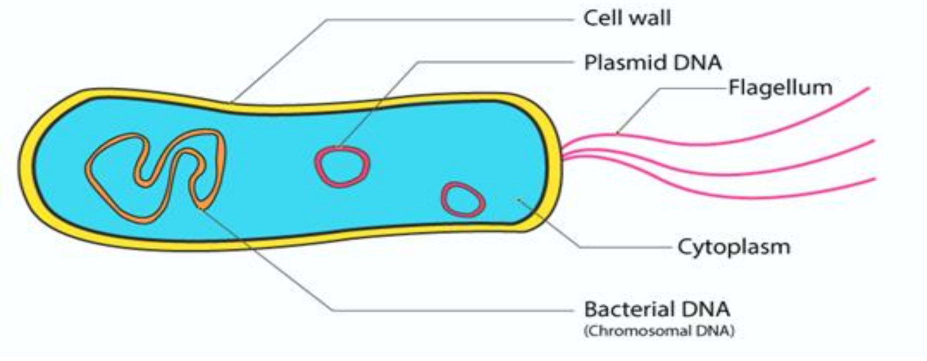


Figure 3.1: Diagram representing the Structure of Bacteria.

It is known that bacteria have a well defined structure.As bacteria are single-celled microorganisms without nucleus are classified as prokaryotic organisms. These are very adaptable creature surviving in enormously unfavourable condition named as extremophiles. Bacteria are further divided into different types based on the atmospheres in which they can survive:

1. Thermophiles
2. Acidophiles
3. Alkaliphiles
4. Osmophiles
5. Barophiles
6. Cryophiles

Bacteria have cell wall consisting of peptidoglycan which is an unique feature. The cell wall provides a crucial foundation for bacteria to divide. Some bacteria lack cell wall while others have a defensive layer named as capsule. They also contain flagella and pili for locomotion, Pili also help bacteria to attach to host cell. All the membrane bound organalles are absent except ribosomes which are primary site for protein synthesis.

Bacteria have the following distinguishing characteristics:

- Bacteria are prokaryotic, unicellular creatures.
- They could appear as groups or be spherical, comma-shaped, rod-like, or elliptical.
- Binary fission is a rapid method of reproduction.
- Certain bacteria are highly beneficial to humans; one well known process is production of curd, whereas others are the source of diseases like cholera and typhoid.

3.3 Discovery of Bacteria

Bacteria were discovered by Antonie van Leeuwenhoek, also called as father of microbiology. He had also discovered protozoa- single celled creature and named them animalcules. He was pioneer of microbiology and made advancements by developing first ever microscope. Despite lacking formal education or scientific training, his astute observations, insight, and unwavering curiosity enabled him to surpass all expectations and earn a place in the Olympus of great scientists. The world was introduced to microscopic life by him, which transformed biological research.

3.4 Classification of Bacteria

Based on the traits and attributes, bacteria can be divided into a number of groups. Following are basis of the classification of bacteria:

- Shape
- Composition of the cell wall
- Mode of respiration
- Mode of nutrition

Classification of bacteria based on Shape

Type of Classification	**Examples**
Bacillus (Rod-shaped)	*Escherichia coli*
Spirilla or spirochete (Spiral)	*Spirillum volutans*
Coccus (Sphere)	*Streptococcus pneumoniae*
Vibrio (Comma-shaped)	*Vibrio cholerae*

Classification of bacteria based on the Composition of the Cell Wall

Type of Classification	**Examples**
Peptidoglycan cell wall	Gram-positive bacteria
Lipopolysaccharide cell wall	Gram-negative bacteria

Classification of bacteria based on the Mode of Nutrition

Type of Classification	**Examples**
Autotrophic Bacteria	Cyanobacteria
Heterotrophic Bacteria	All disease-causing bacteria

Classification of bacteria based on the Mode of Respiration

Type of Classification	**Examples**
Anaerobic Bacteria	Actinomyces
Aerobic Bacteria	Mycobacterium

Reproduction in Bacteria

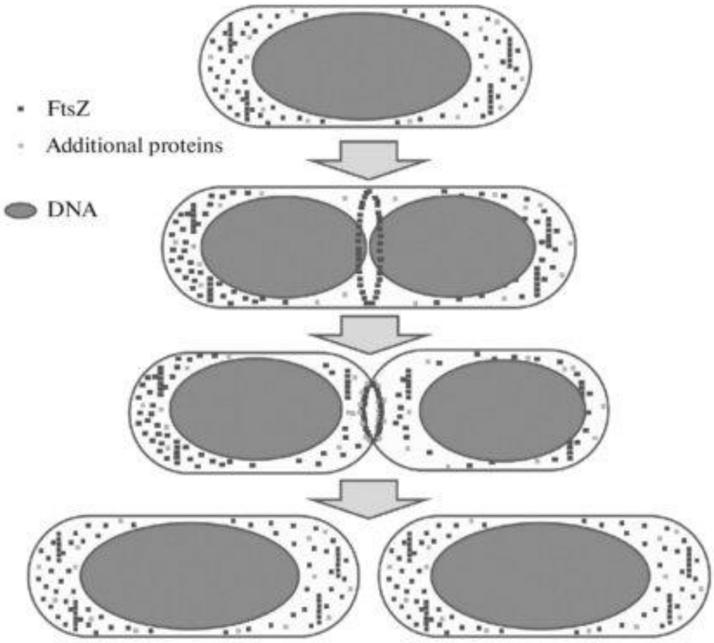


Figure 3.2: Reproduction in Bacteria by binary fission

Bacteria employ binary fission as an asexual reproduction mechanism (Figure 3.2). A bacterium divides into two offspring cells that resemble the parent. When DNA replication takes place inside the parent bacterium, the fission begins. Eventually, the cell divides into two daughter cells by elongating.

The pace and timing of reproduction are influenced by factors including temperature and the availability of nutrients. *Escherichia coli* may produce around 2 million cells every seven hours under ideal circumstances. Reproduction in bacteria is exclusively asexual, albeit it can occasionally take place sexually.

In bacteria, conjugation, transformation, or transduction can result in genetic recombination. As a result of the genetic variety in these situations, the bacteria may develop an antibiotic resistance (in contrast to asexual reproduction, in which the genetic material remains unchanged over generations).

3.5 Archaebacteria

The earliest known living cells on Earth are thought to be archaebacteria. They belong to the kingdom Monera but differ entirely from prokaryotes. They do, however, have a few minor traits in common with eukaryotes.

These are called extremophiles because they can readily thrive in extremely hostile environments like the ocean floor and volcanic vents (Figure 3.3).

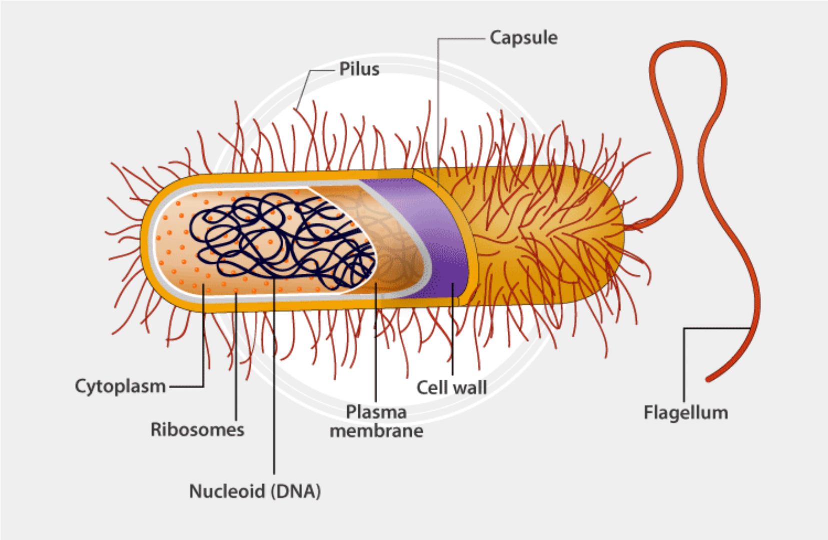


Figure 3.3: Structure of archaebacteria

The crucial traits of archaebacteria are as follows:

- Only archaebacteria can undergo methanogenesis because they are obligate or facultative anaerobes i.e., can thrive in the absence of oxygen.
- Cell membrane consist of lipid.
- Cell wall consist of Pseudomurein and rigid which gives shape and support and prevent the cell from bursting in hypotonic conditions. Cell wall protects the bacteria from lysozyme, secreted by immune cell of host which damage the bacterial cell wall.
- They lacking organelles like mitochondria, lysosomes, endoplasmic reticulum, nuclei, and chloroplasts. All the substances needed for nourishment and metabolism are found in its dense cytoplasm.
- They can survive in extremely high temperature, pressure acidic and alkaline condition.
- As bacteria carry plasmids with antibiotic resistance enzymes, archaebacteria are resistant to major antibiotics.
- They have an asexual reproduction process called binary fission.

- Variations in their ribosomal RNA indicate that they underwent divergence from both prokaryotes and eukaryotes.

3.6 Types of Archaebacteria

Phylogenetic history is used to categorize the archaebacteria. The different types archaebacteria are discussed below:

Crenarchaeota

The Crenarchaeota are found in wide variety of environment. They are tolerant to extreme heat or high temperatures. They may endure high temperatures or intense heat. The ability to function at temperature 230℃ is possible due to having distinctive proteins. These are found in areas with superheated water, such as hot springs and deep-sea vents. These are consist of thermoacidophiles, thermophiles, and hyperthermophiles.

Euryarchaeota

Unlike any other living thing on the planet, they can thrive in extremely alkaline environments and generate methane. Among them are halophiles and methanogens.

Korarchaeota

Both Euryarchaeota and Crenarchaeota have a different genome structure. These are said to be the planet's oldest living things. Thermophiles are also one of them.

Thaumarchaeota

Ammonia oxidizing archea are included in this class.

Nanoarchaeota

These are obligate symbiont belonging to the genus Ignicoccus.

3.7 Significance of Archaebacteria:

- These are a group whose members exchange genes with one another. The gene flow among the species of archaebacteria is evident.

- The Archaebacteria have the ability to produce methane, making them methanogens. Methane, which is utilized for cooking and lighting, is released when they act on the organic materials and break it down.
- The important examples of archaebacteria are:

Lokiarcheota

This thermophilic archaebacterium is located in the Loki's castle, a system of deep-sea vents. Its DNA is distinctive. Certain genes of the genome are engaged in the process of phagocytosis. They are also endowed with the eukaryotic genes that allow them to regulate their form. It is thought that many billion years ago, eukaryotes and Lokiarcheota have been originated from common ancestor.

Methano brevibactersmithii

It is a type of bacteria that produces methane in the human stomach. It extracts energy from the food, aids in the breakdown of complex plant carbohydrates. A few helps to prevent colon cancer in obese cancer patients. Euryarchaeota bacteria are present in extremely high concentrations. They are found to non-photosynthestic but have potential to gene transfer within ancestries. The ability of Archaebacteria to grow in unfavourable condition reinforced scientific community to belief that life may persist under harsh environment.

3.9 Eubacteria

Eubacteria are member of class of bacteria, single celled without a nucleus, cell walls, flagella, and circular DNA.

Eubacteria

The kingdom Monera comprises the complex domain known as Eubacteria (true bacteria), which includes all varieties of bacteria (both Gram's positive and negative) with the exception of archaebacteria. They are single-celled prokaryotic found in different environments all over the world. Which is the three domains of life—Archeae, Eukaryota, and Eubacteria—are used to categorize all living things.

3.10 Characteristics of Eubacteria

- Despite being unicellular, prokaryotic, a bacterial population may be identified as filamentous or aggregated forms
- Their ability to move from one place to another by the help of flagella.
- Eubacteria can proliferate through budding or binary fission.
- The pili (tiny projections) on the cell surface helps in sexual reproduction.
- The peptidoglycan (murein) in the cell wall is composed of a cross-linked chain pattern.
- A single circular chromosome is present, lack true nucleus. However certain bacteria (such *vibrio cholera*) have two, while other species have a linear chromosome and maybe nucleosomes.
- The size ranges from 0.2 to more than 5 µm
- Cell wall contains peptidoglycan and can be classified as gram positive and negative on the basis of Gram's staining.
- The cytosol of cell comprising of the water, nutrients, DNA, cytoskeletal elements and 70s ribosomes, having RNA and protein and are essential for protein sysnthesis. Introns are absent and conduct both glycolysis and kerb's cycle
- Various shapes of eubacteria- cocci, bacilli, rods, vibrio, filament, or spirochetes.
- Under harsh condition they undergo spore formation and remain dormant causing serious infections.

3.11 Structure of Eubacteria

Capsule

- Some bacteria possess outer layer made up of polypeptides or polysaccharides called capsule which prevents bacteria from phagocytosis and also causes disease in other bacteria e.g., Pneumococcus.
- The capsule serves as a location for the removal of waste with the capacity to accommodate food.

Cell wall

- Cell wall is found to be rigid, present below capsule which is made up of peptidoglycan. It provides features like structure, or shape to the cell.
- It helps the cell to survive under high osmotic pressure.

Flagella

- Flagella are extensive projections made of chemicals called flagellin.
- The movement of bacteria is attributed to their flagella, which travel in a manner akin to a longitudinal wave. The number and location of flagella vary throughout bacteria, with some having one, a few, or many on the cell surface (Figure 3.4).

Pilli or fimbriae

- These are small, hair-like projections, emerge from the cell membrane and protrude outside the cell wall (Figure 3.4). They are made up of the protein fibrillin, or pilin. Fimbriae serve as crucial for conjugation and aid in attachment within the host.

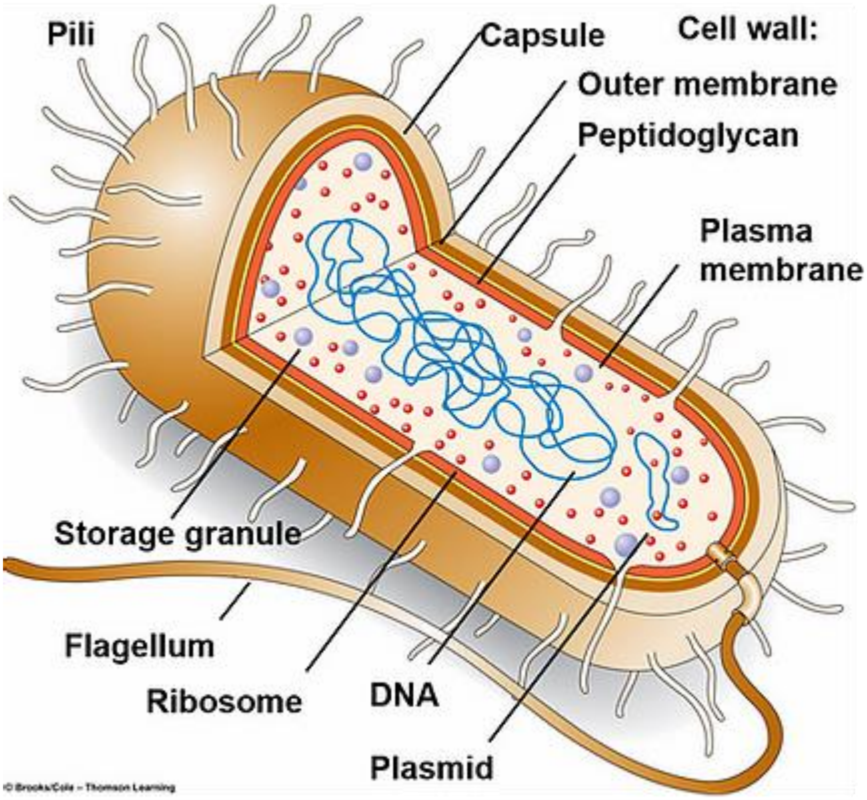


Figure 3.4: Structure of Eubacteria

Plasma membrane

- It is lipid bilayer semi-permeable membrane, consisting of lipids and proteins. It can transport specific ions, molecules, nutrients, and water across it.

Ribosome

Ribosomes- 70s, play role in translation

Nucleoid

Single circular chromosomes are present without the presence of true nucleus.

Mesosome

- It is found in the form of tubules and vessels.Provides surface for single peptide site of attachment, assisting in the creation of septa during cell division, and controlling the activity of autolytic enzymes one of major roles played by mesosomes.

3.12 Types of Eubacteria

Two categories of bacteria are defined based on Gram's stain:

1. **Gram's positive:**

- They possess a robust bacterial cell wall, with ~80% of its composition being peptidoglycan (Figure 3.5).
- When stained with Gram's stain, they maintain their blue, violet, or purple color.
- Gram-positive bacteria have mesosomes and have a low lipid content, which makes them susceptible to lysozyme and antibiotics.

  Examples*: Azotobacter*, *Mycobacterium.*

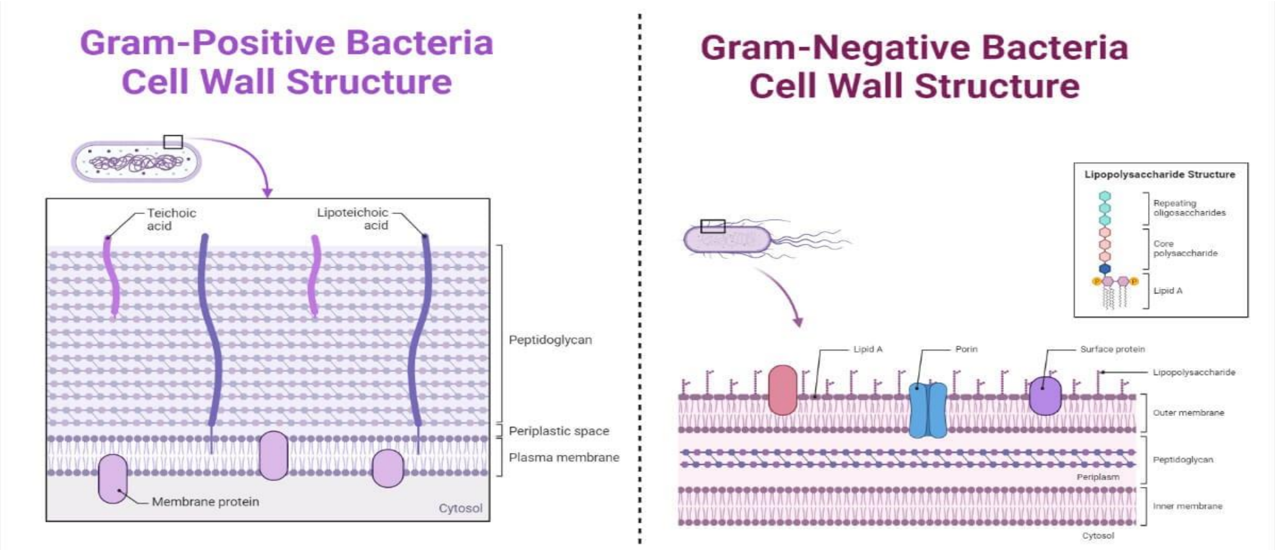


Figure 3.5: Structure of Gram-positive and gram-negative

2. **Gram's negative:**

- The cell wall is thin having low (~20%) peptidoglycan and high lipid content which prevent them from lysozyme and antibiotics effects.
- They maintain the pink or red color of the safranin instead of the blue color.

- Mesosomes are generally absent.
- Example: Salmonella, *E.coli*.

3.13 Classification of Bacteria based on their shapes and arrangement

Coccus: May be spherical, rounded or oval-shaped bacteria.

Monococcus: appear singly. Eg: *Micrococcus*

Diplococcus: exist in pairs. Eg: *Pneumonia*

Tetracoccus: exist in a group of four. Eg. *Tetracoccuscechi*

Chain arrangement: *Streptococcus*

Grapes-like arrangement: *Staphylococcus* sps

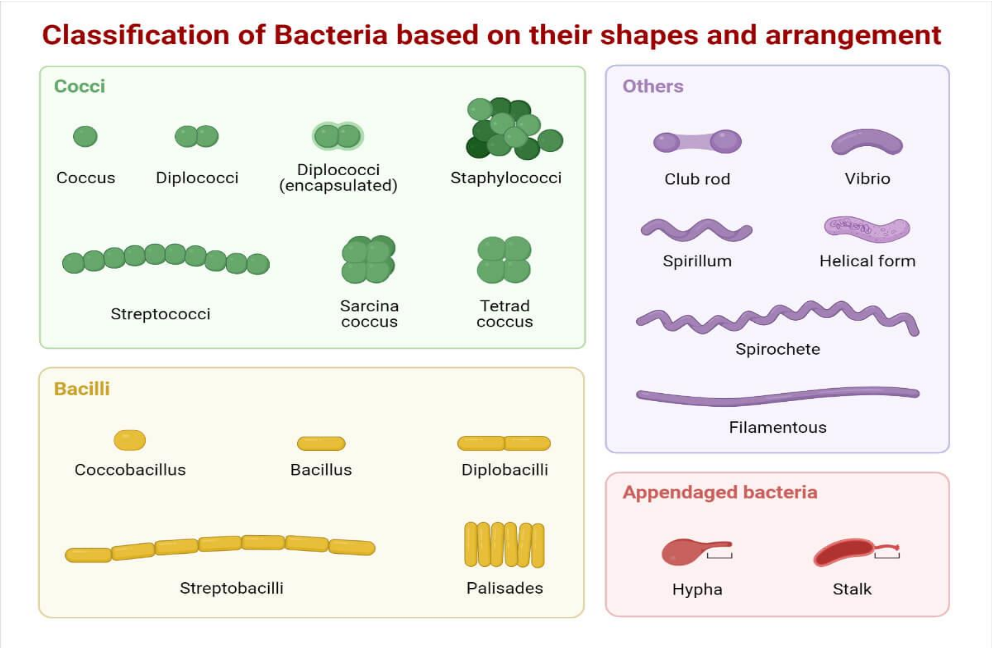


Figure 3.6: shapes and arrangement of bacteria

Bacillus or rod-shaped bacteria

Rod-like or elongated-shaped. Sometime very short rod shaped bacteria are appear similar to cocci called Coccobacilli (Figure 3.6).

Monobacillus: Singly. E.g. *Lactobacillus*

Diplobacillus: In pairs. E.g. *Moraxella*

Steptobacillus: In chain, E.g. *Streptobacillus*

Helical bacteria

They are coiled or twisted, may be spiral (Spirochete) and vibrio (comma-shaped e.g. *Vibrio cholera*).

3.14 Evolution of Eubacteria

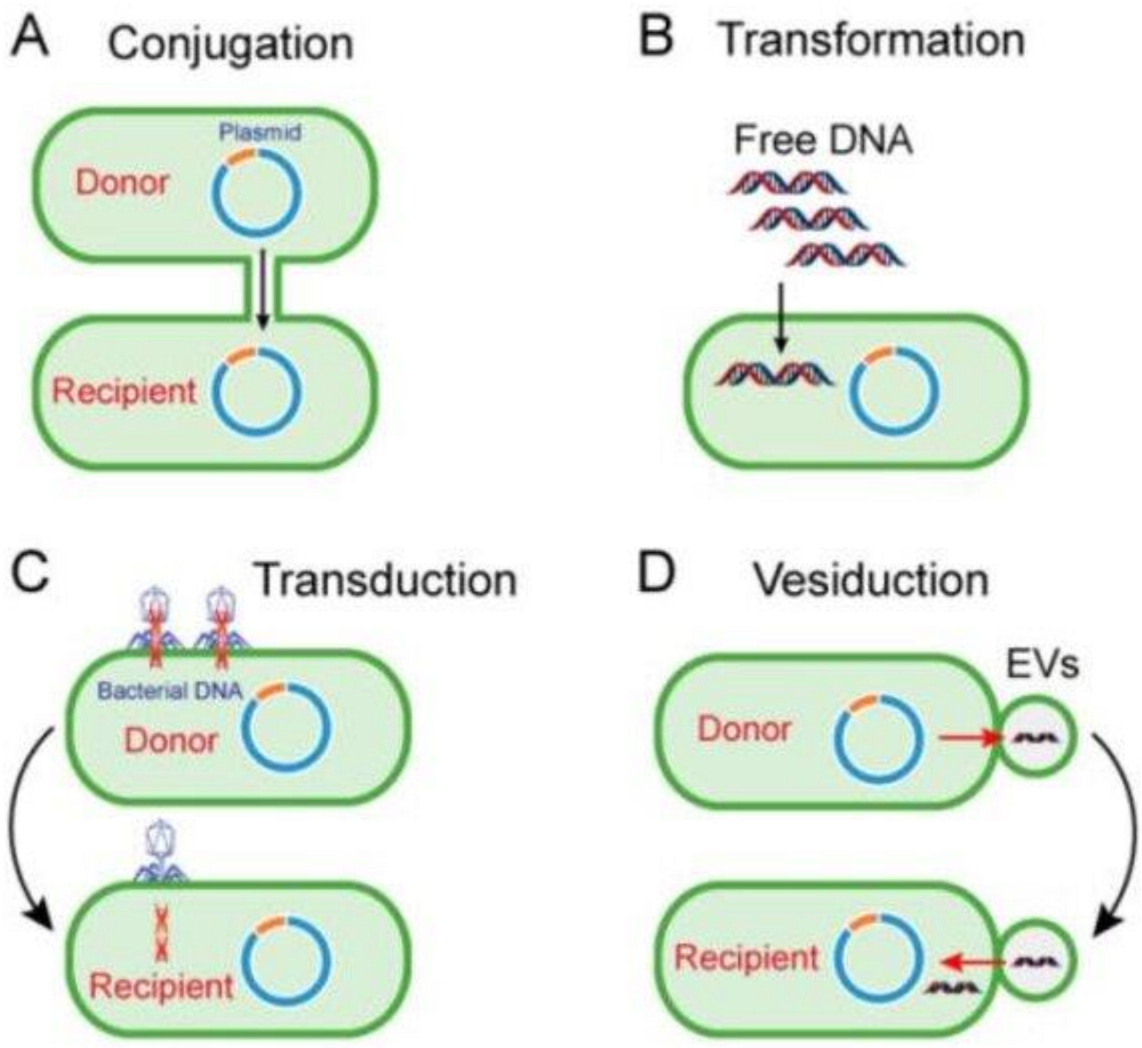
- Prokaryotes include bacteria and cyanobacteria.
- These cells lack introns and nuclear membrane that separates DNA from the cytoplasm.
- The progenote has evolved into: Archaebacteria, Eubacteria, and Eukaryotes. various molecular hypotheses revealed that, genes were transported horizontally between these cells, influencing the evolution of life.
- According to endosymbiotic hypothesis, mitochondria and chloroplasts are transported through gene transfer throughout their evolution.
- Eubacteria include Cyanobacteria, Chloroxybacteria, Paracoccus, Non-sulphur bacteria, sulfur bacteria, green filamentous bacteria, green sulfur bacteria, Spirochetes, and Desulphovibrio.

3.15 Reproduction in Eubacteria

- Eubacteria usually reproduce asexually through processes such as binary fission and budding, which divide the parent cell into two daughter cells subsequent to genetic replication.
- Under unfavourable situations like nutrients deficiency, radiation exposure, chemical, and extreme temperature bacteria produce spores, which are resistant to heat, chemicals, toxins, and dryness and are unable to reproduce. They can only reproduce on return of favourable conditions.
- Sexual reproduction takes place by conjugation, transformation, and transduction (Figure 3.7).

3.16 Mode of nutrition of Eubacteria

- The majority of eubacteria exhibit heterotropy i.e., they are unable to generate their food and obtain from other sources (plants, animal, or organic carbon sources). Heterotrophs break down dead matter or parasites that reside within their hosts.
- Some bacteria are autotrophic and use photosynthetic or chemosynthetic processes to synthesis their food.



Source: https://www.researchgate.net/publication/363604396_Acquired_Antibiotic_Resistance

Figure 3.7: Sexual reproduction in bacteria

3.17 Importance of Eubacteria

- Improve soil fertility by nitrification, nitrogen-fixing process, and ammonification.
- Useful in vitamin synthesis, Example: *Propionibacterium* and pseudomonas spp produce vitamin B12.
- Used in pharmaceutical industry e.g., Streptomyces produces antibiotics.
- Lactobacillus is primarly used in Dairy industry
- Bio-degradation of Xenobiotics and decomposes dead organism
- Useful in insect control.
- The natural flora of the human body consists of beneficial eubacteria, defending against pathogenic bacteria.

3.18 Difference between Eubacteria and Archaebacteria

Eubacteria	**Archaebacteria**
They are ubiquitous and complex organisms.	They are simpler and found in extreme conditions.
The cell wall: peptidoglycan	The cell wall: pseudopeptodoglycan
Krebs cycle or glycolysis is present	Glycolysis and Kerbs cycle are absent
RNA polymerase is simple.	RNA polymerase is complex.
Introns are absent.	Introns are present.
Contains L-glycerol phosphate in the membranes lipids.	Contains D-glycerol phosphate in the membrane lipids.
Examples: *Bacillus, Mycobacterium, Clostridium*	Examples: *Ferroplasma, Thermoproteus, Halobacterium*

3.19 Mycoplasma

- One of the genuses of Cocci shaped bacteria is Mycoplasma which is devoid of the cell wall. These are self-replicating. Another name for them is mollicutes.
- The minimal amount of organelles found in the cell includes the 70s type ribosome, the genome, which is made up of a double-stranded circular DNA naked without plasma membrane.
- Mycoplasmas divide by binary fission; however their frequent cytoplasmic division may not keep up with genome replication, causing multinucleate filaments to develop.
- They are inherently resistant to antibiotics that interfere with the formation of cell walls. It is devoid of other membrane-bound organelles and a nucleus. These species have the ability to change their form, called pleomorphism (Figure 3.8).
- The cell membranes of mycoplasmas consist of three layers. In most of their general traits, they exhibit similarities to prokaryotes.

- Mycoplasmas are human, animal, and plant commensals or parasites. Cattle with pleuropneumonia have had them discovered in their pleural cavities.
- In addition, these organisms are identified as MLO (mycoplasma-like organisms) and PPLO (pleuropneumonia-like organisms).
- Since mycoplasmas don't have a cell wall, they are resistant to beta-lactam antibiotics like Penicillin.

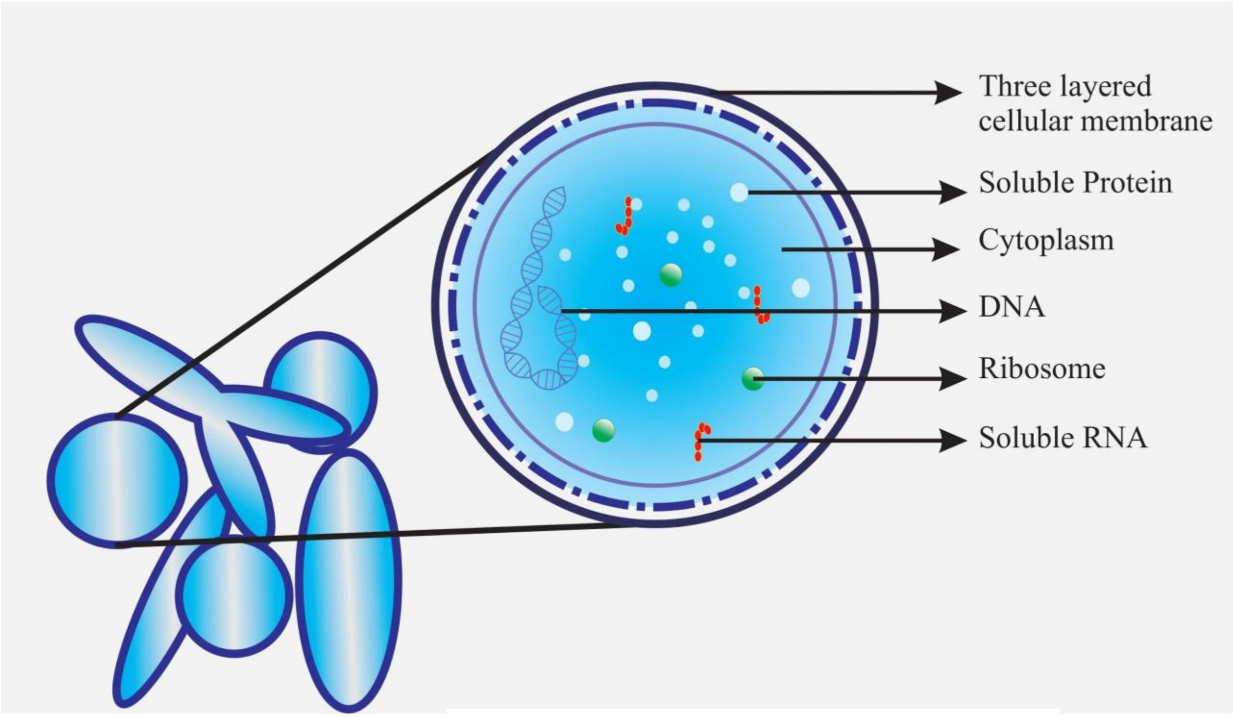


Figure 3.8: Mycoplasma cell structure

3.20 Spheroplast

A microbial cell with cell wall destroyed due to lysozyme or penicillin, is known as a spheroplast. The term "spheroplast" refers to the fact that the microbe's cell takes on a distinctive spherical shape due to membrane tension following the digestion of its cell wall. Because spheroplasts are osmotically delicate, they get disrupted in a hypotonic solution.

Antibiotic-induced spheroplasts

Spheroplasts are produced from Gram-negative bacteria by a variety of drugs. These comprise β-lactam antibiotics and peptidoglycan production inhibitors such fosfomycin, vancomycin, moenomycin, and lactivicin. Antibiotics such as fosmidomycin and phosphoenolpyruvate that block metabolic processes of peptidoglycan production resulting to spheroplasts.

In addition to the antibiotics mentioned above, Gram-negative bacteria also create spheroplasts when exposed to inhibitors of folic acid synthesis (such as trimethoprim and sulfamethoxazole) and inhibitors of protein synthesis (such as oxytetracycline, chloramphenicol, and many aminoglycosides).

Enzyme-induced spheroplasts

Gram-negative bacteria only develop spheroplasts when the enzyme lysozyme is used as membrane permeabilizer such as lactoferrin or ethylenediaminetetraacetate (EDTA) to facilitate the enzyme's passage through the outer membrane. By attaching to divalent ions like Ca^{2+} and removing them from the outer membrane, EDTA functions as a permeabilizer.

The enzymes lyticase, chitinase, and β-glucuronidase can be used to transform the yeast *Candida albicans* into spheroplasts.

3.21 CLASSIFICATION OF BACTERIA ON THE BASIS OF NUTRITION

Substances needed in biosynthesis and energy generation for any bacterial cell is known as nutritional sources. Nutrients and energy sources are required by all living cells, including bacteria, in order to produce proteins, to form membranes, and carry out biochemical activities. Bacteria require majorly C, N, P, Fe along with some other metallic ions. The carbon and energy sources can be used for defining the nutritional needs of bacteria. Certain bacteria produce their own energy from inorganic sources, others require pre-formed organic molecules.

Classification of Bacteria on the basis of nutrition

On the basis of **energy source** organisms are designated as:

Phototrophs:

- They use light as an energy source and perform photosynthesis.

Chemotrophs:

- They obtain energy from chemical compounds.

On the basis of **electron source** organisms:

Lithotrophs:

- They can be both photolithotrophic and chemolithotrophic, using reduced organic molecules as electron donors.

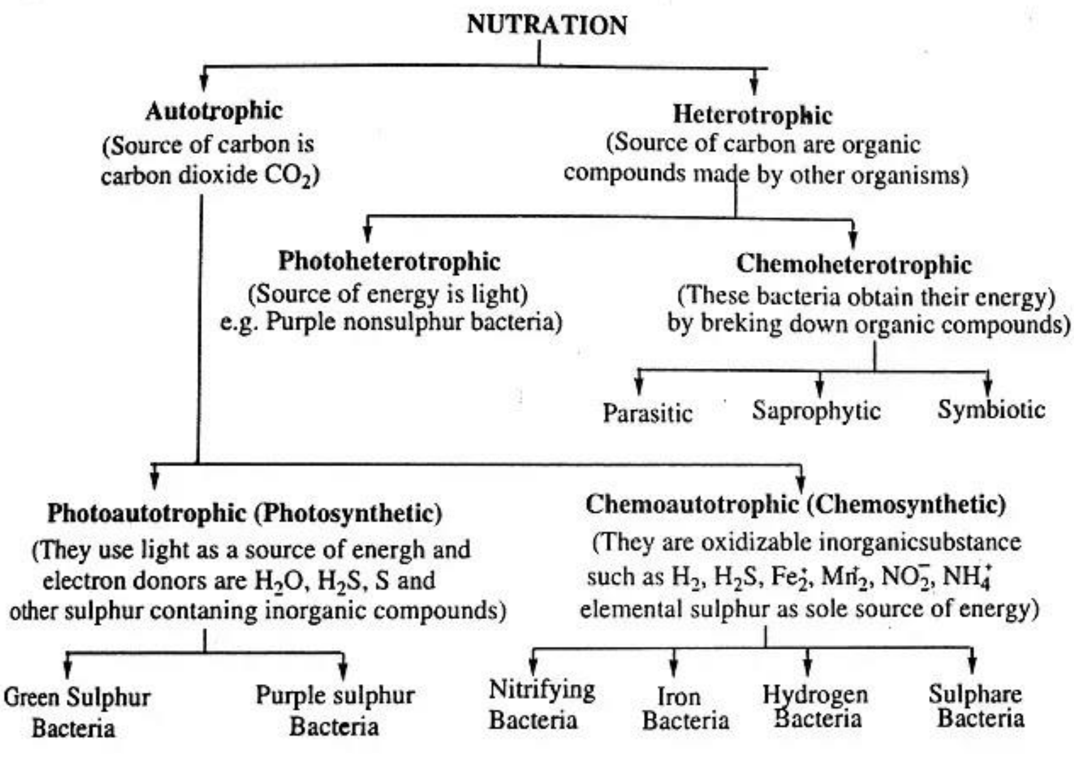


Figure 3.9: Classification of Bacteria on the basis of nutrition

Organotrophs:

- They can be photoorganotrophs or chemophotoganotrophs, using organic molecules as electron donors.

Thus, bacteria may be either:

- **Photo-lithotrops:** source of energy: light, electrons: reduced inorganic compounds (H_2S) eg: *Chromatium okeinii*.
- **Photo-organotrophs:** source of energy: light, electron: organic compounds (Succinate) eg; *Rhodospirillum*.
- **Chemo-lithotrophs:** source of energy and electron: reduced inorganic compounds (NH_3) eg; *Nitrosomonas*.
- **Chemo-organotrophs:** source of energy and electron: organic compounds (glucose and ammino acids) eg; *Pseudomonas pseudoflora*.
- Some bacteria can be chemo-lithotrophs or chemo-organotrophs like *Pseudomonas pseudoflora*

On the basis of **carbon source** bacteria may be:

Autotrophic Bacteria

These bacteria synthesize all their food from inorganic substances (H2O, CO2, H2S salts).

The autotrophic bacteria are of two types:

(i) Photoautotrophs

Chlorophyll pigment, which is present in photoautotrophs, absorbs sunlight and transforms it into chemical energy. Using water as a hydrogen donor, CO_2 is reduced to carbohydrates, producing oxygen molecules like cyanobacteria. Certain anaerobe photoautotrophic bacteria have pigments called bacteriovirdin and bacteriochlorophyll.

Purple Sulphur Bacteria:

They have bacteriochlorophyll and obtain energy from sulfur compounds e.g., *Chromatiiun. Theopedia rosea, Thiospirilium.*

Green Sulphur Bacteria:

This class utilizes H_2S as hydrogen donor; have bacteriovirdin or bacteriopheophytin or chlorobium chlorophyll e.g., *Chlorobium limicola*, *Chlorobacterium* etc.

(ii) Chemoautotrophs

They don't require light and pigment for their nutrition and oxidize inorganic substances using oxygen and releases the energy which is used to drive the synthetic processes of the cell.

Sulphomonas (Sulphur bacteria):

They oxidise sulphur or sulphide to obtain energy, e.g., *Thiobacillus*, *Beggiatoa*.

- Elemental Sulphur Oxidising Bacteria: e.g., *Thiobacillus denitrificans*
  $2S + 2H_2O + 3O_2 \rightarrow 2H_2SO_4 + 126$ kcal.
- Sulphide Oxidizing Bacteria: e.g., *Beggiatoa*.
  $2H_2S + 4O_2 \rightarrow 2H_2O + 2S + 141.8$ cal

Hydromonas (Hydrogen bacteria)

- They convert hydrogen into water, e.g., *Bacillus pantotrophus*, *Hydrogenomonas*.
  $2H_2 + O_2 \rightarrow 2H_2O + 55$ Kcal.
  $4H_2 + CO_2 \rightarrow 2H_2O + CH_4 +$ Energy

Ferromonas (Iron bacteria):

- They are found in water and oxidise ferrous compounds into ferric forms. e.g., *Thiobacillus ferroxidans*, *Ferro bacillus*, *Leptothrix*.
  $4FeCO_3 + 6H_2O + O_2 \rightarrow 4Fe(OH)_3 + 4CO_2 + 81$ kcal.

Methanomonas (Methane bacteria):

- Oxidize methane into water and carbon dioxide.

Nitrosomonas (Nitrifying bacteria):

- Oxidize ammonia and nitrogen into nitrates.
- Nitrosomonas oxidises NH_3 to nitrites. $NH_3 + ½O_2 \rightarrow H_2O + HNO_2 +$ Energy
- Nitrobacter converts nitrites to nitrates. $NO_2 + ½O_2 \rightarrow NO_2 +$ Energy

Carbon Bacteria

Oxidizes CO into CO_2 e.g., *Bacillus oligocarbophillous, Oligotrophacarboxydovorans*

$2CO + O_2 \rightarrow 2CO_2$ + Energy

Heterotrophic Bacteria

The majority of pathogenic bacteria that affect humans, other plants, and animals are heterotrophic; they get their prepared food from organic materials, whether they are living or dead. While some heterotrops have fundamental nutritional necessities like vitamins and other growth-promoting chemical demands. Fastidious heterotrophs are the name given to such organisms.

They are of three types:

a. Photoheterotrophs

They use light energy but obtain energy from organic compounds as a source of carbon and electron requirements. Bacteriochlorophyll pigment is found in these bacteria.

e.g., Purple non-sulphur bacteria (*Rhodospirillum, Rhodomicrobium, Rhodopseudomonas palustris*).

b. Chemoheterotrophs

They gain carbon and energy from organic compounds (carbohydrates, lipids and proteins).

Glucose + $O_2 \rightarrow CO_2 + H_2O$ + Energy

Chemoheterotrophs are of three type based on organic nutrients: (i) Saprophytic bacteria. (ii) Parasitic bacteria (iii) Symbiotic bacteria.

i) Saprophytic bacteria

- Survive at leaves, fruits, vegetables, meat, animal dung, leather, humus, etcTo break down and absorb this type of material they release a set of enzymes.
- The released enzymes that facilitate the digestion of complex substances like protein and carbohydrates into simpler, readily absorbed soluble molecules. Examples are *Bacillus mycoides, Bacillus ramosus*, Acetobacter etc.

ii) Parasitic bacteria

- This type of bacteria gets its nutrition from hosts sometimes harmless or causes serious diseases in certain organism those are susptible to infections.
- Disease causing bacteria are *Bacillus* typhosus, *B.* anthracis, *B.tetani. B.diplheriae, B.tuberculosis, B.* pneumoniae, *Vibrio* cholerae, *Pseudomonas* citri etc.

iii) Symbiotic bacteria

- Show close association with the host and beneficial to the organisms.
- Shows mutualism with roots of leguminous plants and fix free nitrogen into nitrogenous compounds available to plants. The bacteria receive nourishment and defense from the plant in exchange.

3.22 Summary

Bacteria have simpler cell structures than other types of species. DNA/RNA contains genetic information to control the activity of these bacteria. Some bacteria contain additional genetic material called plasmid. Frequently, the plasmid carries genes that confer a certain advantage to the bacterium for example, presence of antibiotic resistant gene. Bacteria can vary in morphology: spherical (cocci), rod (bacilli), spiral (spirilla), comma (vibrios) or corkscrew (spirochaetes). They can exist as single cells, in pairs, chains or clusters.

Bacteria live in soil, rocks, seas, and even polar snow. Nearly all animals, plants, and humans are their host. The host cells are Around 10 times bigger as bacterial cells still the association be mutual, symbiotic, and antagonistic. Due to the presence of bacteria along with fungal cells in the soil or on degrading plant waste, some bacteria play a vital role in the cycling of nutrients. While certain types can be harmful for crops and cause food to decay, others are very helpful in making fermented products such as yoghurt and soy sauce. Most bacteria are harmful and can infect plants or animals resulting into Various diseses.

3.23 Self Assessment Questions:

1. Oldest form of life on earth

   a. Virus

   b. Bacteria

   c. Human

   d. Animal

2. Who is father of microbiology?

a. Copurnicus

b. Leeuwenhoek

c. Pasture

d. None of the above

3. Which is among these is not Archaebacteria

a. Koroarchaeta

b.Thaumarchaeta

c. Euryarchaea

d. Protista

4. Among these which group is capable of performing photosynthesis

a. Koroarchaeta

b.Thaumarchaeta

c. Euryarchaea

d. Archaebacteria

5. Example of gram positive bacteria

a. Azotobacter

b. Mycobacterium

c. **both of the above**

d. None of the above

6. Among these which is rod-shaped bacteria

a. Maraxella

b. streptobacillus

c. Lactobacillus

d. all of the above

7. Which is among these is photohetrotrophs

a. Rhodopseudomonas palustris

b. Bacillus oligocarbophillous

c. Oligotropha carboxydovorans

d. None of the above

8. Which of the among is resistant to penicillin

a. Mycoplasma

b. bdellovirus

c. cynobacteria

d. spirochetes

9. What is among these is analogus to mesosomes

a. Golgi Apparatus

b. lysosomes

c. Mitochondria

d. cell wall

10. Flagella helps the bacteria

a. Reproduction

b. Locomotion

c. Nutrition

d. Predatory action

3.24 Short Questions

1. What are nitosomonas bacteria?
2. What is energy source for the methanomonas
3. What are purple sulfur bacteria?

CHAPTER - 4

Bacteria

Objectives

At the end of chapter student will be able to:

- Understand the various type of reproduction in bacteria.
- Classify bacteria those are plant and animal.
- Analyze the economic importance.

4.1 Introduction

Asexual reproduction in bacteria takes place by various mechanisms.

Bacterial asexual reproduction

- **Binary fission –** The process by which a single bacterial cell divids into two daughter cells. When the bacterial genome doubles into amount due to new complementary strands are created as a result of the bacteria circular double-stranded DNA being replicated. The two new daughter cells are divided by a transverse septum that forms in the centre of the cell after these two DNA strands are transferred to the opposing poles of the cell. Takes only a few minutes to double in number.

- **Conidia formation –** In filamentous bacteria like Streptomyces, a transverse septum forms at the terminal of the filament to produce conidia. The conidiophore, which is the part of the mother cell that contains the conidia, divides from the mother cell and germinates on the proper substrate to produce a new mycelium. Moreover, fragmentation is the term used to describe this kind of asexual reproduction.

- **Budding –** The bacterial cell undergoes constant size expansion, resulting in a small bulge on one side throughout this stage of reproduction. The nucleus breaks in two, with half remaining attached to the mother cell and the other half entering the expanding space along with some cytoplasm. The protrusion is called a bud, and it eventually forms a partition wall with the mother cell. In bacteria, this type of reproduction is also referred to as vegetative reproduction e.g., *Rhodomicrobium Vannielii.*

- **Cysts –** under unfavourable condition cysts are formed around the mother cell and cell undergoes resting state. The cell resumes on return of favourable condition e.g., Azotobacter.

- **Endospore formation –** endospores are produced under starvation or dehydration condition. They contain protoplasts, ribosomes, enzymes, t-RNA, and DNA required for creating a new cell. In a single bacterial cell, only one endospore forms, and after germination, it produces a new bacterial cell (Figure 4.1).

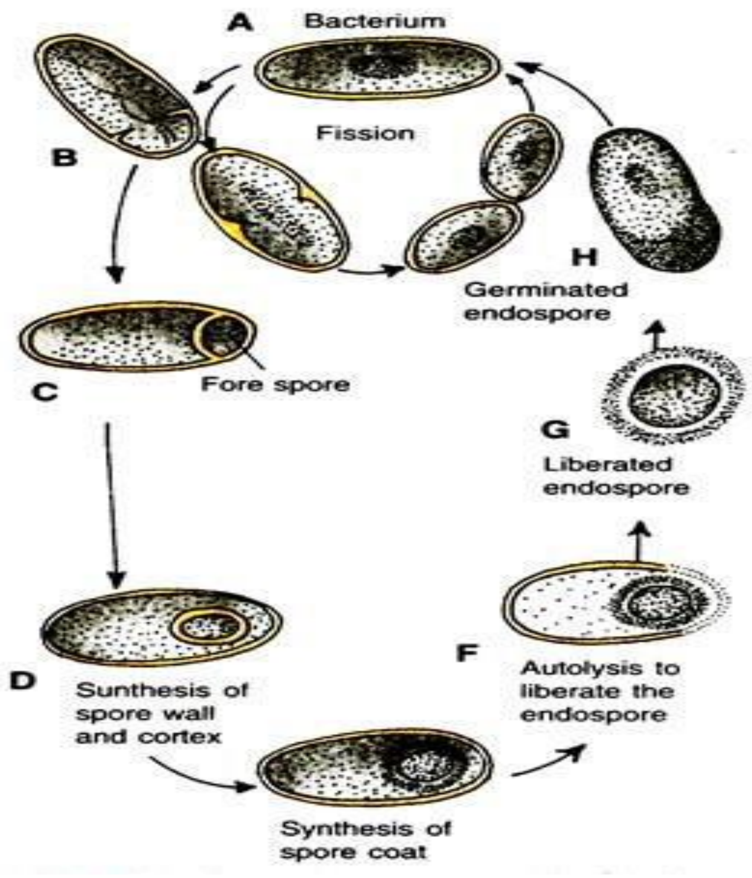


Figure 4.1: Life cycle of endospore forming bacteria

Sexual reproduction – Bacteria

Conjugation: The process by which DNA transfers from one bacterial cell surface to another. They have to transfer DNA in order to survive.

Transformation: Transfer of genetic material occurs between bacteria and surrounding environment.

Transduction: This involves the insertion of DNA with the help of virus (bacteriophage) into another bacterial cell. A non-pathogenic virus plays the role of agent to DNA transfer into host. Restricted transduction involves the transfer of similar while generalized transductions involve the transfer of a large number of genes over some time.

Bacterial Conjugation:

It involves the transfer of genetic material from one bacterium to another by the means of contact between two cells. Lederberg and Tatum proposed this strategy; they observed that the F-factor might move across *E.coli* cells, introducing the idea of conjugation (Figure 4.2).

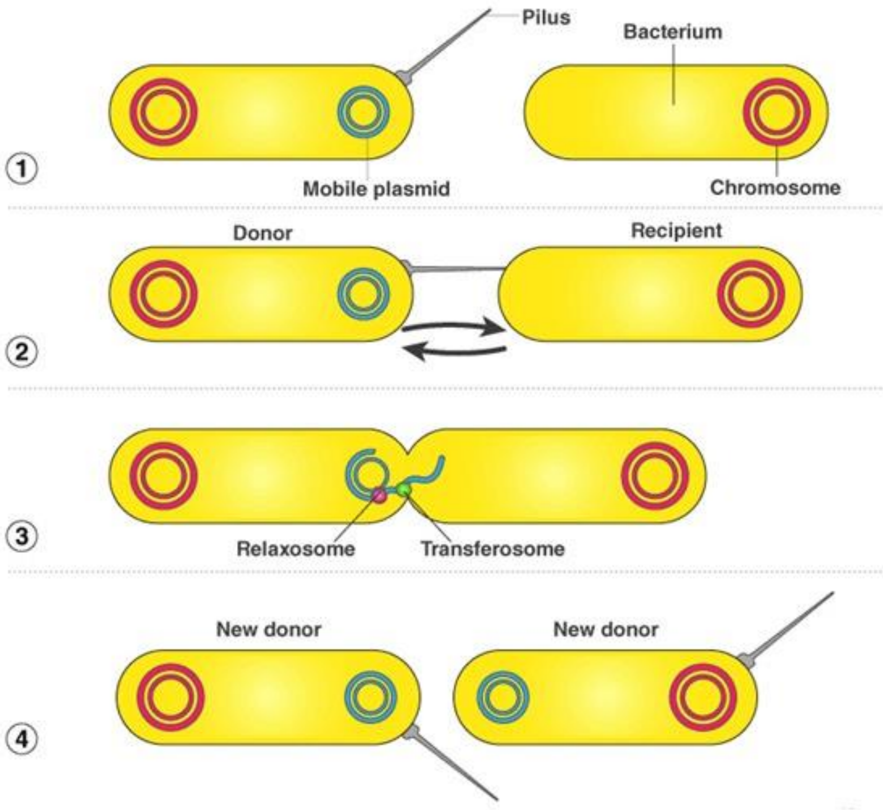


Figure 4.2: Bacterial conjugation

Bacteria contain many plasmids having gene for conjugation. Conjugation is carried out in several steps:

- Mating pair formation
- Conjugal DNA synthesis
- DNA transfer
- Maturation

Mechanism of Bacterial Conjugation:

The following steps are involved:

Formation of Pilus:

- A sex pilus is formed between the donor cells (F^+) cells and the (F^-) recipient cell.
- Physical Contact between Donor and Recipient Cell takes place.
- Then eventually resulting into Movements of the F-Plasmid.
- At the onset of replication, the (F^-) factor becomes active. At the replication breakpoint, one strand separates, and the 5' end enters the recipient cell.
- Synthesis of Complementary Strand.
- A single F-plasmid strand is present in both the donor and recipient strands. Because of this, complementary strands are produced by the donor and the recipient. The recipient cell now functions as a donor cell since it has a copy of the F plasmid.

Bacterial Transduction:

It involves transfer of genes from the recipient to the donor through bacteriophage (Fig 4.3).

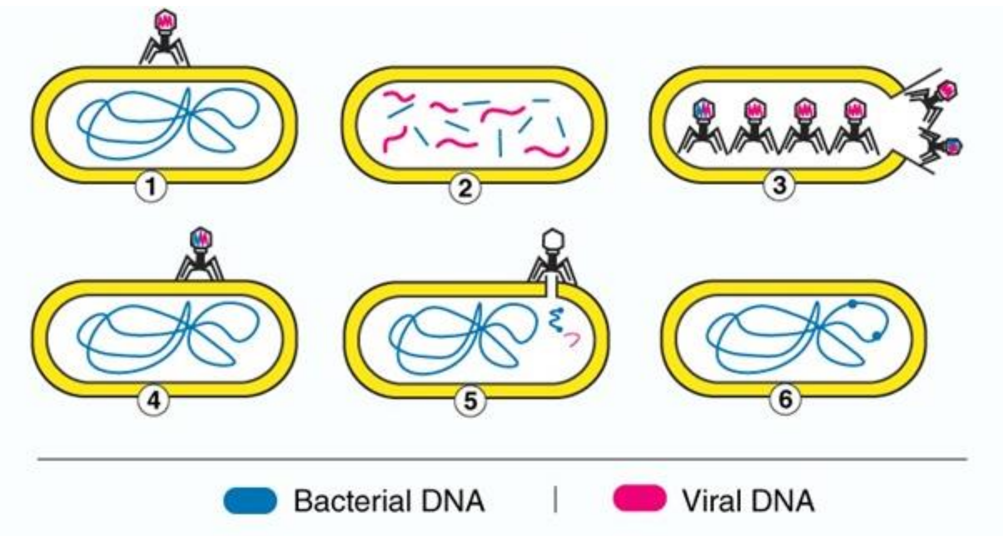


Figure 4.3: Diagram showing bacterial transduction

Forms of Transduction:

Generalized Transduction

Here the lytic phase is started by the bacteriophage when it first infects the donor cells. Their components are made by the machinery of the host cell. The DNA of the host cell is hydrolyzed by the viral enzymes, resulting in minuscule bits that are integrated into the viral genome. DNA is transferred to other bacteria by the virus.

Specialized Transduction

Few limited bacteria are transported from donor to recipient bacterium in this process. Temperate bacteriophages that go through the lysogenic cycle accomplish this.

The virus infects the bacteria and integrates its genome into the host cell's DNA and remains latent and passed to many generations. The lytic cycle begins when the lysogenic cell gets triggered.

The genome of the host cell is altered by the viral genome. As a result, occasionally the phage genome integrates the bacterial genome into the genome of the recipient cell. In this case, the recipient cells can only be penetrated by the limited genome.

Bacterial Transformation

The process by which bacteria absorb DNA from their surroundings is known as transformation. Competent cells are those that possess the capacity to absorb DNA. Griffith initially described this mechanism in Streptococcus pneumonia (Figure 4.4).

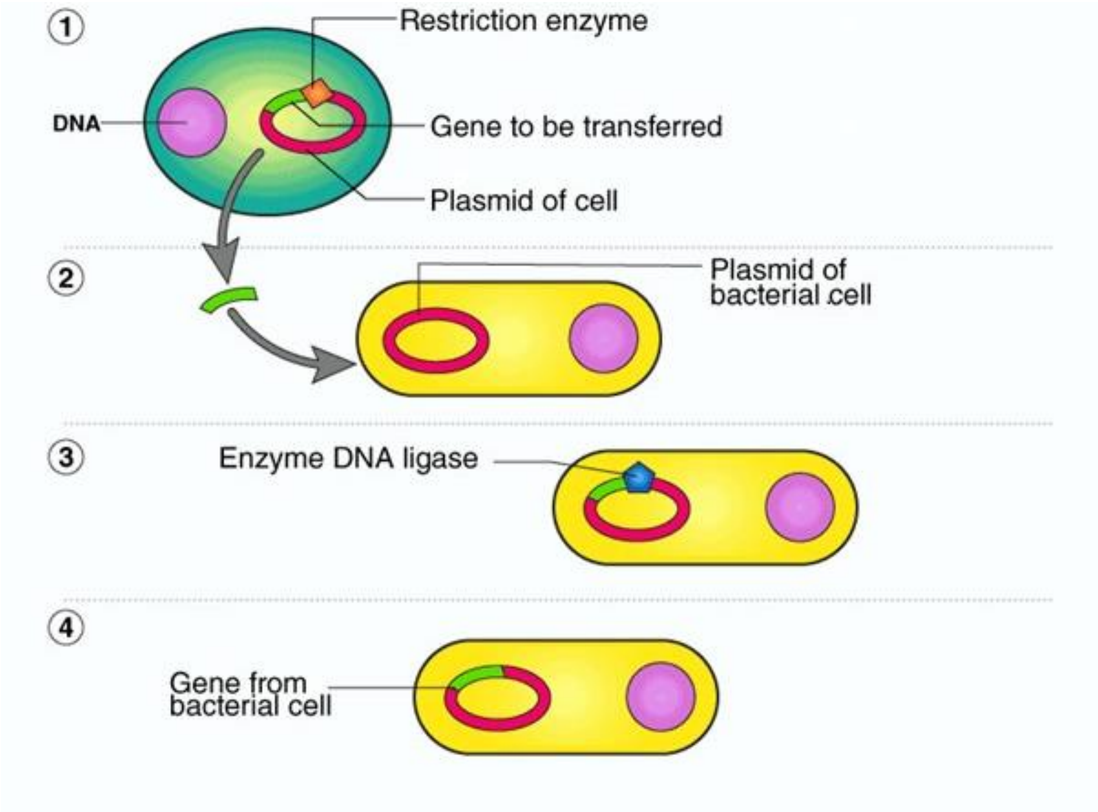


Figure 4.4: Bacterial transformation

4.2 Role of Bacteria in modern world

- The properties of bacteria have been utilised by human in a variety of industrial operations. The lactic acid bacteria's activities are what runs the cheese and butter industry.
- Another typical example of applicability in daily life is the lactic acid bacteria that cause milk to sour and form curd. First, an enzyme called lactose released by lactic acid bacteria ferments the lactose sugar in milk to produce glucose. The conversion of glucose to lactic acid occurs in the second stage. The latter creates curds and whey by coagulating the milk proteins, or casein.
- Acetic acid bacteria are responsible for converting alcohol to vinegar (acetic acid) by oxidation.
- Other examples of beneficial chemical actions of bacteria that have been tamed for the good of humanity include the curing of tea, tobacco, and the production of indigo.
- Bacteria are also used in the tanning industry for leather products and in the preparation of sponges.

- It is impossible to produce linen without bacterial activity. The tough fibers that are left behind split apart. These fibers are twisted and weaved into ropes, linen, and other materials.
- Bacterial activity is also necessary for the manufacture of chocolate and coffee. The white cocoa beans have strong bitter flavor. The distinctive color, flavor, and scent of seeds are produced by microorganisms that break down their bitter outer layer into sweet and distinctive taste.
- Production of Citric acid: It adds flavor and scent to drinks, candies, and other foods.
- Production of Vitamins: *Clostridium acetobutilicum* ferments carbohydrates and starch to produce vitamin B.
- Production of Butyl alcohol: When a particular bacterium is allowed to work on cooked corn starch, it produces butyl alcohol, acetone, and ethyl alcohol all at once through fermentation. These goods are significant industrial solvents.
- Acetone: Used in the production of photographic films as well as explosives, it is a crucial component.

Application of enzymes isolated from bacteria

Product	**Bacterium**	**Application**
Amylases	*Thermophilic Bacillus* Species	Used in brewing to convert maltoses from amyloses.
Cellulases	*Clostridium Thermocellus*	Sugars are released from cellulose in papermaking and agricultural waste.
Proteases (thermolysin, subtilisin, aqualysin)	*Thermus Aquaticus, Bacillus Species*	Used in cheese processing, brewing, baking, hair removal from skins in the leather industry, and laundry
Glucose isomerase	*Bacillus Coagulans*	Fructose production from glucose used as a sweetener in food
Beta-galactosidase	*Thermus Aquaticus*	Lactose in milk whey is hydrolyzed to produce glucose and galactose.
Cobalamin (cyanocobalamin)	*Pseudomonas Stutzeri*	Treat vitamin deficiency
Vinegar	*Acetobacter Species*	Alcohol industry

Monosodium glutamate	*Micrococcus Species*	Sugar
Dextran	*Leuconostoc Mesenteroides*	Sucrose

Role in Agriculture:

(i) Decay and decomposition:

A key factor in the breakdown of organic matter is brought about by soil microorganisms. They first take on the role as scavengers, cleaning the environment. Replenish the soil with nutrients.The saprophytic bacteria break down the remains and waste products of living things, including plants and animals.

As a result, many of the constituent of minerals—such as C, O, H, S, and P- are broken down into simpler molecules like carbon monoxide, water, nitrates, sulfates, and phosphates.

While some return to the earth, others are released into the atmosphere. They can be taken up by plants as micro and macro-nutrients. Cities take advantage of this bacterial activity in their sewage disposal systems. Degradation is aided by the bacterial activity on the city's sewage. As a result, water is ultimately cleaned and transformed from a costly and hazardous substance into an odorless and beneficial fertilizer.

ii) Soil fertility:

Certain bacteria are crucial for preserving soil fertility, while others contribute to its enhancement. The amount of nitrogen in the soil determines its fertility. A necessary component of protoplasm is nitrogen. Therefore, it is necessary for the metabolism of all developing plants.

Although the atmosphere is probably composed of 80% nitrogen, green plants are typically incapable to utilize it. They take it in largely the form of nitrates and, to a lesser extent, ammonia from the soil.

When these salts are continuously absorbed, the soil becomes depleted of them. In order to promote plant development, a significant amount of these soluble nitrogen compounds should be present in fertilizers. Certain microorganisms provide a consistent supply of these salts in the natural world. There are three types of bacteria that serve as Nature's farmers: ammonifying, nitrifying, and nitrogen-fixing bacteria (Figure 4.6).

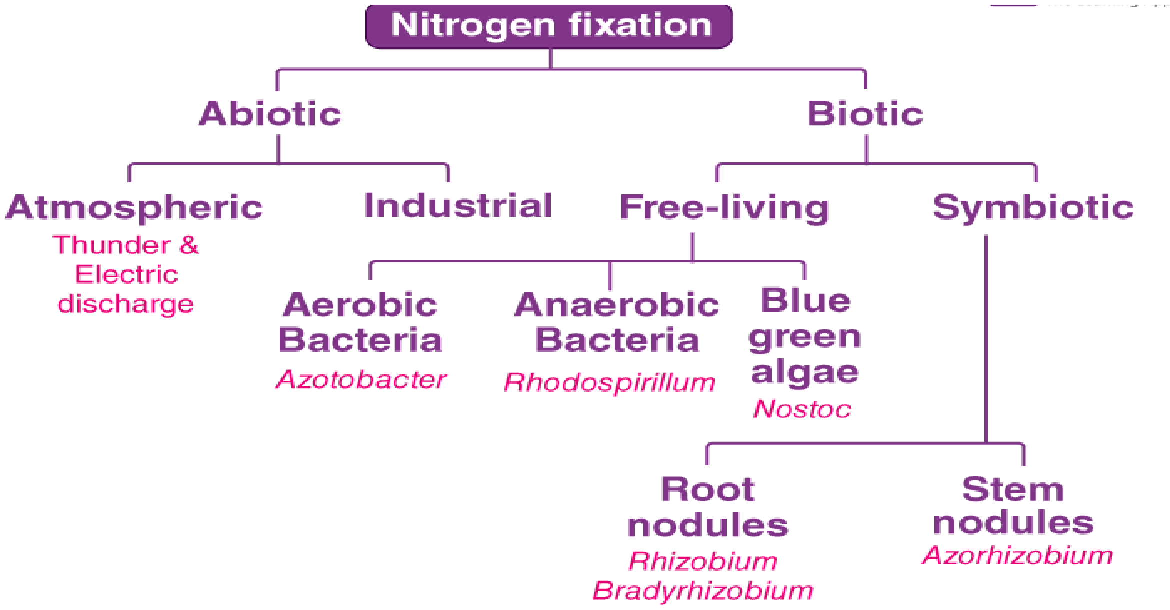


Figure 4.6: Nitrogen fixation

They are responsible for ensuring that nitrogen is constantly moving through the soil, the atmosphere, and the plant kingdom. The nitrogen cycle is the set of modifications that organisms' actions cause nitrogen into nitrate and other.

(a) Ammonifying Bacteria:

By secreting enzymes, the saprophytic bacteria convert the proteins and other nitrogen-containing residues of plant and animal origin found in the soil to amino acids.

Then ammonifying bacteria transforms the amino acids into ammonia. Ammonium carbonate can be created by the released ammonia combining with water and carbon dioxide in the soil.

Certain plants, including grains, may use ammonium compounds as a nitrogen source. However, ammonium compounds are not absorbed by most plants as a form of nitrogen.

(b) Nitrifying Bacteria:

Ammonia has a high solubility. It penetrates quickly through the soil and gets acted upon by chemoautotrophic bacteria. These are the nitrifying bacteria, which include Nitrobacter and Nitrosomonas. They use ammonium compounds to create nitrates.

The following two stages are involved in the reaction:

Nitrosomonas	$NH_4^+ + 2O_2 \longrightarrow 2H_2O + NO_2 \; \overset{energy}{\uparrow}$
Nitrobacter	$NO_2^- + \frac{1}{2}O_2 \longrightarrow NO_3^- \; \overset{energy}{\uparrow}$

Ammonium carbonate is oxidized by Nitrosomonas to nitrous acid, which releases energy. Potassium nitrite is created when the nitrous acid reacts with the bases in the soil. Nitrobacter releases energy by oxidizing nitrites to nitrates.

The overall amount of combined nitrogen in the soil is not increased by either the nitrifying or ammonifying bacteria alone.

Nitrogen is transformed into nitrates by the nitrifying bacteria from the inaccessible form of ammonium salts. Nitrification is the process that turns unavailable ammonium salts into nitrates that may be used.

(c) Nitrogen-fixing Bacteria:

Denitrification contributes significantly to the loss of nitrogen. If soil fertility is to be preserved, any reduction must be countered by equivalent improvements.

Rainwater carries away the nitrogen compounds that are formed as a result of electric discharges into the atmosphere to the soil. Originated from a biological fixation process that is made possible by the actions of two different bacteria that fix nitrogen.

While some of them are free-living in the soil, others are found in the nodules found in the roots of leguminous plants. These have the capacity to transform atmospheric nitrogen into nitrogenous chemicals. As a result, bacteria that fix nitrogen are unique because they can access a nitrogen supply that most other plants cannot. We refer to this nitrogen transformation process as nitrogen fixing.

(i) Azotobacter, beijerinckia (aerobic forms) and Clostridium (anaerobic) live free in the soil:

After the death of bacteria these nitrogenous substances are decomposed by other bacteria, and ammonia is prodeuced. This ammonia is converted by the nitrifying bacteria into nitrites and then nitrates which are used by green plants as a source of nitrogen.

(ii) *Rhizobium leguminosarum* (syn. *Bacillus radicicola*) is another nitrogen-fixing bacterium:

It is found in roots of several plants, including beans, mesquite, peas and others. These are all members of the Leguminosae family. Small nodular appearance present in the roots. Bacterial nodules grow on the leaves also for example *Pavetta indica*.

Millions of these bacteria reside in these tubercles or nodules. They are able to absorb free nitrogen from the atmosphere and transform it into nitrogen molecules. In exchange for the nitrogen substances they supply, the host plant produces carbohydrates for them. This relationship explains why the legumes are rich in nitrogen.

The legume family of plants includes some of our greatest plant-based protein sources. When other plants have stripped the nitrogen from the soil, legume plants can thrive. Sometimes the farmer grows them to a height of about a foot and then ploughs them under.

The decomposition of these legume plants improves the soil fertility by enriching the soil with abundant amount of nitrogen. We refer to this as green manuring. The soil that is used to cultivate cereal crops repeatedly gets depleted. It may be re-enriched by cultivating a crop of some pea family plants on it. Crop rotation is the process of switching from cereals to leguminous crops. Nitrogen is found in higher concentrations in leguminous plants than in soil salts. Rhizobium extracts nitrogen from the atmosphere. Nitrogen cannot be fixed by Rhizobium or legume roots on their own.

Rhizobium is a soil-dwelling organism that resembles a rod-shaped structure with flagella. Legume roots release certain chemicals onto their surface that attract microorganisms. The root hairs curl as a result of the bacteria secreting a growth hormone in response.

They develop into a continuous mass that resembles threads in the root hair, eventually reaching the root cortex. In this manner, a thick mass of these bacteroids fills many of the cortical cells.

Their cortical cell existence acts as a trigger those results in irregular growth. A nodule is formed when the cortical cells near the inflammation proliferate, redivide, and enlarge. A nodule is made up of a core mass of bacteroids-filled cells.

Layers of bacterial-free cortical zone surround this infection zone. The meristematic area and a vascular strand are located at the apex and base, respectively, of the nodule.

The rod shape within the host cells as a result of feeding on carbohydrates. They take on a V, T, or Y form. Because of the production of the red respiratory pigment leg-hemoglobin, the nodule's center is red.

4.3 Summary

In this chapter, we discussed about the bacterial reproduction and elucidating the various mechanisms of bacterial reproduction. In binary fission, bacteria divide into two identical daughter cells. Conjugation involves the transfer of genetic material between bacterial cells through direct contact, leading to genetic diversity and the acquisition of advantageous traits. Transformation allows bacteria to uptake free DNA from their environment, while transduction involves the transfer of genetic material via bacteriophages, further contributing to bacterial diversity and evolution.

When it comes to biotechnological applications, such as the synthesis of enzymes, antibiotics, and biofuels, bacteria are the essentials. Bacteria produce enzymes that catalyze a variety of biological processes, allowing for the effective synthesis of a large number of commercial goods. Furthermore, microbes have been modified to create important substances like ethanol. Bacteria play pivotal roles in soil fertility and plant health through processes such as nitrogen fixation and disease suppression. Nitrogen-fixing bacteria, such as Rhizobium and Azotobacter, convert atmospheric nitrogen into a form that plants can utilize, enhancing soil fertility and reducing the need for synthetic fertilizers.

4.4 Fill in the blanks

1. ....is example of saprophytic bacteria

   ....and .... type of autotrophic nutrition present only in monera not in protista

2. ....disease cause by mycoplasma in cattle
3. All prokaryotes have circular DNA except..............
4. ....and.................. are surface structures on monera
5. ....type of bacteria have ....type of plasmid which decrease pollution
6. ....type of plasmid is useful in recombinant DNA technology
7. ....cyanobacteria fix N2 in rice field as free living
8. ....is known as biofertilizer and is Pteridophyte
9. ....pigment of cyanobacteria is similar to all plants
10. . ...is storage in cyanobacteria
11. .... is type of reproduction which is sexual in which DNA enter from medium
12. Virus mediated gene transfer in bacteria is known as................
13. When virus DNA get integrated into genomic DNA it is known as................
14. ....type of plasmid give ....phenotype and help in sexual reproduction
15. ....and ....genera form endospore

4.5 Short Answer Question

1. Define Binary fission in Bacteria.
2. What is Conjugation?
3. Difference between Transduction and Transformation.

CHAPTER - 5

Algae

Objectives

At the end of chapter student will be able to:

- Differentiate the range of thallus organization, reproduction, life cycles and importance of various algal groups.
- Categorize the diversity of various algal groups, their modes of nutrition and reproduction, benefits and importance.
- Classify the algae according to Fritsch.
- Explain the algal cell structure and its components.

5.1 Algae

Algae (Singular Alga) are a large and diverse group of photosynthetic & aquatic organisms. These are shapless and with various shapes and sizes, from single celled organisms like diatoms, member of euglenophyta and dinoflagellates to multicellular organisms like giant kelps and brown algae.

Unicellular or multi-cellular organisms

Lack well-defined body

Cell wall rich in carbohydrates

Mode of reproduction is both Sexual and Asexual.

Algae are ubiquitous in nature and within water bodies because they prefer a damp or wet environment.

GENERAL CHARACTERSTICS OF ALGAE

1. Algae are eukaryotic, unicellular or multicellular plants eg. Chlamydomona, diatoms and brown algae.
2. Plant body is known as Thallus, unlike plants, algae lack complex structure like roots stems and leaves. They may have simple structure like filaments or thalli (flattened, blade like structures), but they do not have specialized vascular tissues which are found in plants.

3. **Habitat:** Algae are primarily aquatic organisms, either freshwater or marine and some are terrestrial also.
4. Algae are eukaryotic thallophytes
5. Algae are autographs
6. Algae store food in the form of starch.
7. **Reproduction:** Algae reproduce by different method:
    - Vegetative: it includes fragmentation and hormogonia
    - Asexual by zoospores, aplanospores, hypnospores, akinetes, azygospore
    - Sexual by isogamous, anisogamous, and oogamous gametic fusion.

5.2 CLASSIFICATION OF ALGAE

Algae is classified into three main classes on the basis of the pigment present in them.

ALGAE

Chlorophyceae (green algae) | Phaeophyceae (brown algae) | Rhodophyceae (red algae).

1. Chlorophyceae (Green algae)

Characteristics of Chlorophyceae

- They are most common type of algae.
- They are green because they contain high amount of chlorophyll a, chlorophyll b and a small amount of β-carotenoids
- The shapes of the chloroplasts vary, for example. Shapes include spiral in Spirogyra, cup in *Chlamydomonas,* star *in Zygnema*, and girdle in *Ulothrix*.
- **Habitat:** Mostly freshwater (*Spirogyra*, *Oedogonium, Chlamydomonas*, *Volvox*, etc), some are marine (*Sargassum*, *Laminaria*, etc) and some are parasitic (*Polysiphonia, Harvevella, Cephaleuros*)
- **Distribution:** Chlorophyceae members are cosmopolitan in distribution.
- They have both unicellular and multicellular characteristics.
- **Thallus**
- Examples: *Chlamydomonas:* unicellular free living
- *Volvox*: colonial form
- *Spirogyra:* multicellular, unbranched filamentous form
- *Ulva*: multicellular, parenchymatous form

- **Storage form of food:** They store their food in the form of **Starch.**
- **Pyrenoids** stores starch
- **Cell wall:** is rich in cellulose.
- **Reproduction:** Chlorophyceae exhibit various methods of reproduction vegetative (fragmentation), asexual (akinete, aplanospore, azygospore) and sexual (isogamous, anisogamous, oogamous type gametic fusion method.

2. Phaeophyceae (Brown algae)

- Photosynthetic pigments: They contain chlorophyll a and c as well as the brown-colored pigments fucoxanthin and β-carotenoids.
- Their habitat is primarily marine, with relatively few occurring in freshwater environments.
- Thallus: Brown algae are multicellular in nature. Unicellular forms are uncommon or colonial brown algae that are motile or non-motile.
- Food is stored by brown algae in the form of complex carbohydrates such laminarin starch, manitol (alcohol), and in certain cases, iodine**.**
- Reproduction: By various types of method they can reproduce**:** vegetative (fragmentation), asexual (motile zoospores) and sexual methods (isogamous or oogamous type gametic fusion).

3. Rhodophyceae (Red algae)

- They possess red-colored pigments known as phycocyanin and phycoerythrin, in addition to chlorophyll a, d, xanthophyll, and β-carotenoid.
- Their primary habitat is located in sea water. Some, like *Batrachospermum*, are freshwater species.
- Thallus: A variety of living forms may be seen in red algae.
- Examples: Unicellular- *Porphyridium*,
- Multicellular- *Goniotrichum*,
- Parenchymatous- *Porphyra*,
- Unicellular colonies-*Chroothece*,
- **Storage form of food:** Red algae store their food in the form of Floridean starch and floridoside sugar.

- **Reproduction:** The two basic methods of reproduction are asexual and sexual. Only unicellular forms of the thallus undergo vegetative proliferation.
- Vegetative reproduction by fragmentation, asexual reproduction by non- motile spores (aplanospore) and sexual reproduction is oogamous type.
- Certain organisms exhibit alternation of generation throughout their life cycle.

5.3 Range of Thallus Organization

Alage exhibit a very diverse vegetative structure, ranging from simple unicellular thalli to intricate multicellular thalli. There are following groups into which algae are classified (Figure 5.1).

Unicellular Algae- Unicellular algae divide into-

Unicellular motile algae

Unicellular non-motile algae

Multicellular Algae- Multicellular algae divide into following forms-

- Colonial
- Filamentous
- Siphonaceous
- Parenchymatous

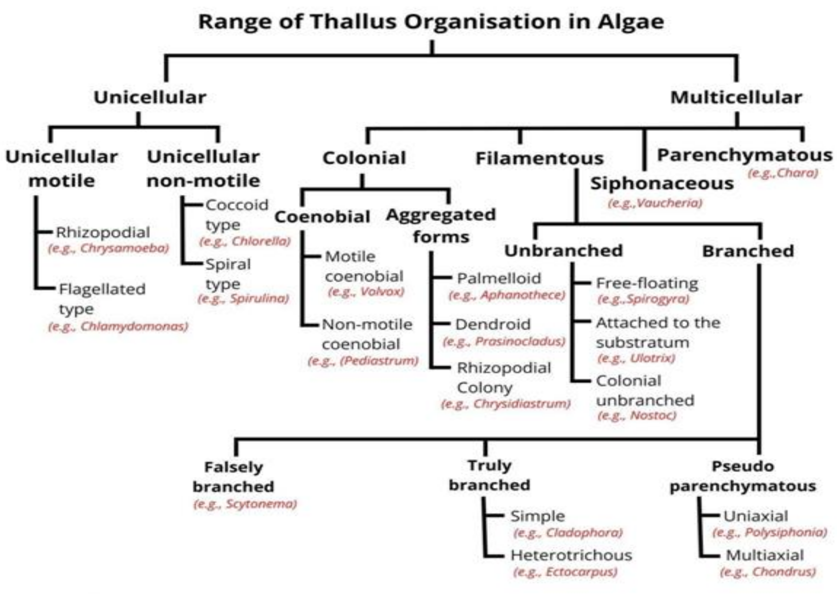


Figure 5.1: Range of Thallus Organisation in Algae

1. Unicelluar algae: Found in all groups of algae, with the exception of Phaeophyceae and Charophyceae. They belong to the following categories.

a. Rhizopodial algae: They lack rigid cell wall. They have cytoplasmic projections that facilitate their amoeboid mobility. e.g., *Rhizochrysis, Chrysamoeba.*

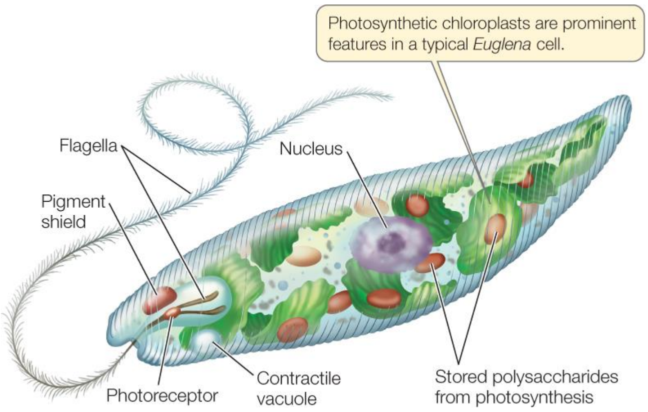


Figure 5.2: A Photosynthetic Euglenid form

b. Flagellated Forms - All groups of algae contain this type of cell, with the exception of the Phaeophyceae, Rhodophyceae, and Cyanophyceae. There are two equal flagella in the Chlorophyceae family. There are two unequal flagella in the Dinophyceae and Xanthophyceae families. The Euglenophyceae family has single flagella (Figure 5.2).

i. **Spiral filamentous -** Certain unicelluar algae, like spirulina, produce coiled or spiral structures.
ii. **Non-motile -** These are non-moving coccoidal algae that lack eye spots and flagella, which are necessary for movement. e.g*; Chroococcus, chlorella (*Figure 5.3).

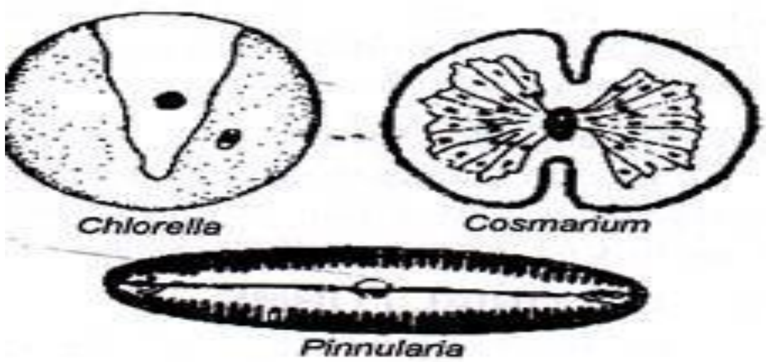


Figure 5.3: Thallus organization Non-motile Unicellular forms of algae

2. Colonial algae: The result of cell divisions aggregate within a mucilaginous mass to form the colonial habit. Four types of colonial organizations may be distinguished:

a. **Coenobial colony**- A colony with specific shape, size and arrangement of cells is known as coenobium (Figure 5.4). The coenobium colony may be motile e.g; *Volvox, Eudorina* or non-motile e.g; *Hydrodictyon*

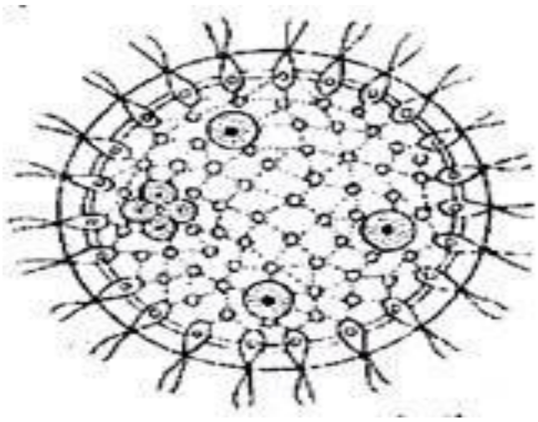


Figure 5.4: Thallus organization motile colonies

b. **Palmelliod colony**. There is no set number, shape, or size of cells in a palmelliod colony.Despite their shared mucilagenous matrix, the cells continue to be erratically grouped, but they are autonomous and separate functions. Certain palmelloid species, like Chlamydomonas, are in a transient phase, whereas others are in a permanent phase Tetraspora (Figure 5.5).

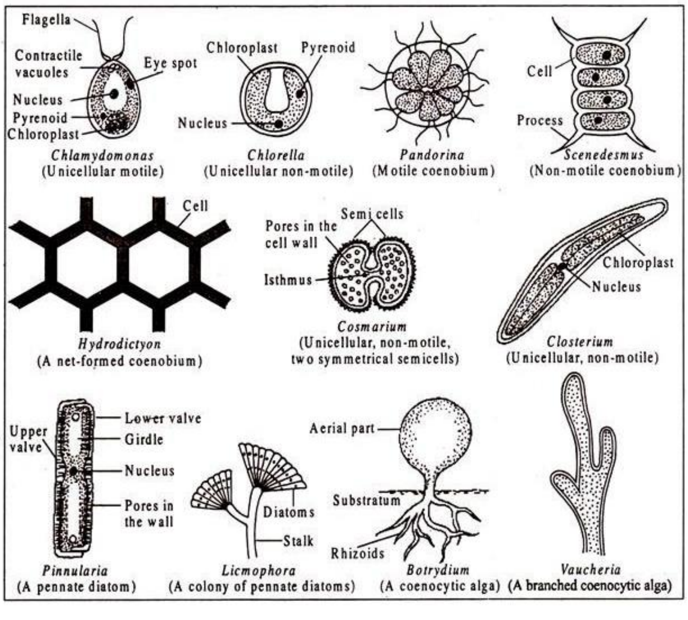


Figure 5.5: Thallus organization Palmelloid forms

Dendroid- The colony resembles a little tree. A mucilagenous thread is found at the base of every cell, and when multiple cell threads are combined, the colony as a whole takes on the appearance of a tree. e.g; *Chrysodendron.*

c. **Rhizopodial-** Rhizopodia connects the cells in a rhizopodial colony. e.g; *Chrysidiastrum.*

3. **Filamentous forms:** Cells repeatedly divide transversely to generate filamentous forms.The cells of a filament may be organized in one row (uniaxial) or multiple rows (multiaxial), and the filaments can be branched or unbranched (Figure 5.6).

Unbranched filaments- There are very few algae which possess simple unbranched filaments.Spirogyra, for example, may be free floating or adhered to a substrate.
e.g; *Zygnema,Ulothrix, Oedogonium* or form colony e.g**;** *Nostoc, Oscillatoria*

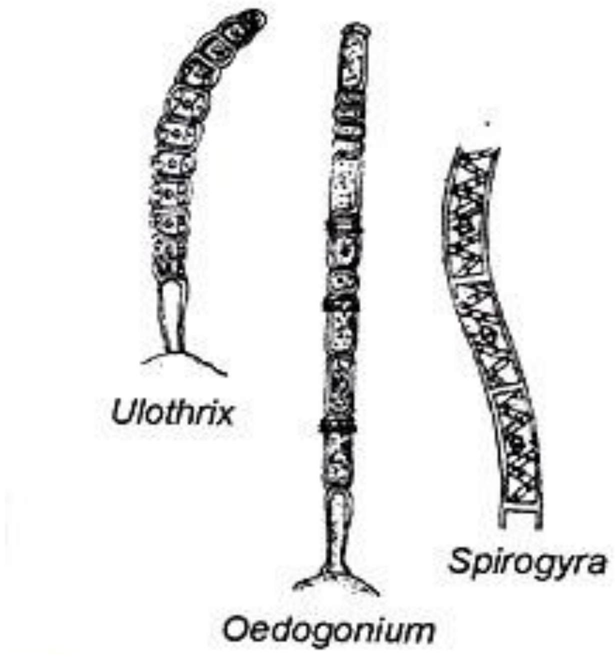


Figure 5.6: Thallus organization. Unbranched filament

Branched filaments- Repeated transverse divisions of lateral cell outgrowths result in the formation of branched filaments. There are two categories for them.

False branching: The trichome may break, but the false branch does not form as a lateral growth. e.g-*Scytonema*

True branching: Three types of lateral outgrowths give rise to true branches.

a. **Simple filaments.** A basal cell keeps the simple branching filaments connected to the substratum. e.g; *Cladophora* (Figure 5.7).

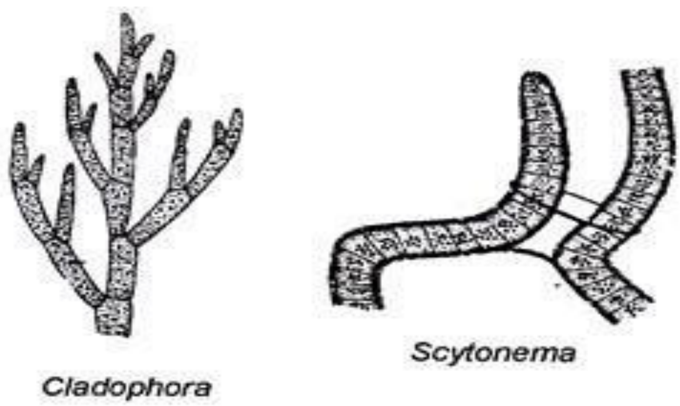


Figure 5.7: Thallus organization. Branched filentous form

Heterotrichous - This type of thallus has significantly evolved to differentiate between an upright and prostrate system. e.g; *Ectocarpus, Coleochaete, Stigeoclonium* (Figure 5.8).

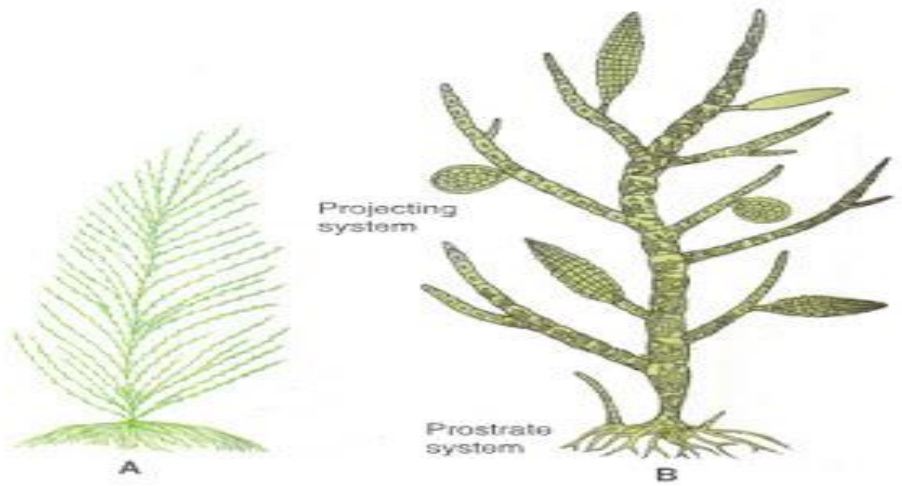


Figure 5.8: Thallus showing Habit

a. **Pseudoparenchymatous-** A parenchymatous structure is formed by one or more core filaments and their branches in numerous filamentous shapes.A pseudoparenchymatous thallus is referred to as uniaxial (Batrachospermum, for example) if it is created by branches of a single filament, and multiaxial (Polysiphonia) if branches of multiple filaments are involved (Figure 5.9).

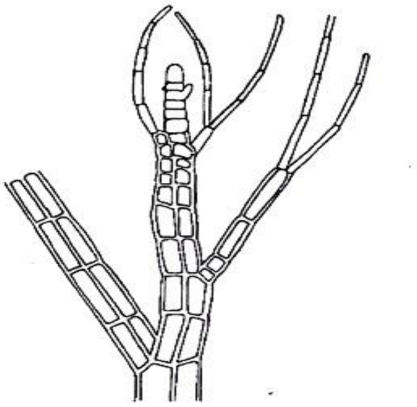


Figure 5.9: Thallus organization Pseudoparenchymatous forms. *Polysiphonia*

4. **Siphonaceous forms:** The branched, aseptate, coenocytic, tubular filaments that make up the siphonaceous thallus are the result of nuclear division without consequent wall development eg-Botrydium and Vaucheria (Figure 5.10).

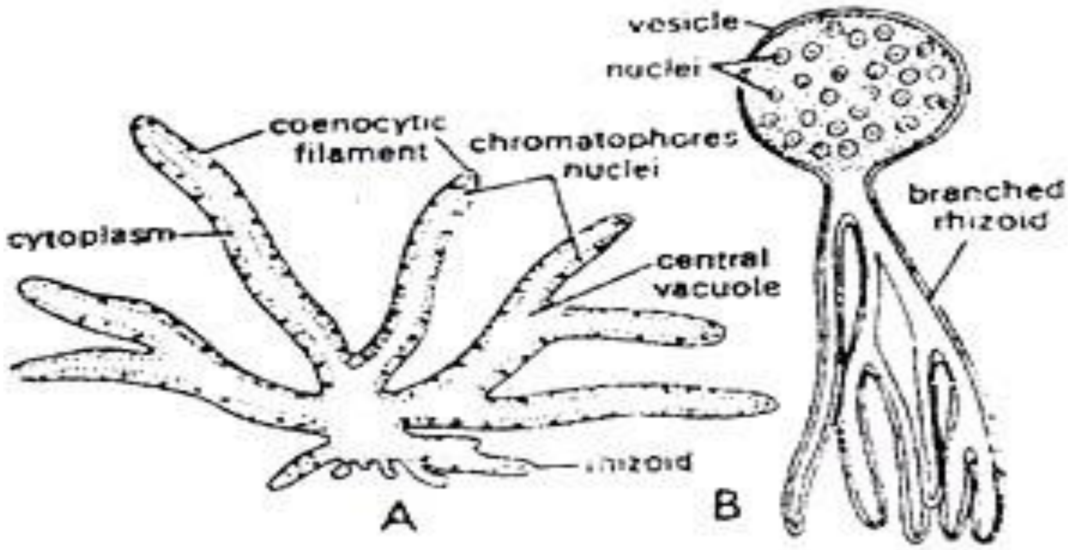


Figure 5.10: Thallus organization Siphonaceous form (A) *Vaucheria* (B) *Botrydium*

5. **Parenchymatous forms**: Cell divisions in two or more planes give rise to the foliose tubular thalli of this kind. Eg-*Ulva, Sargassu , Fucus* (Figure 5.11).

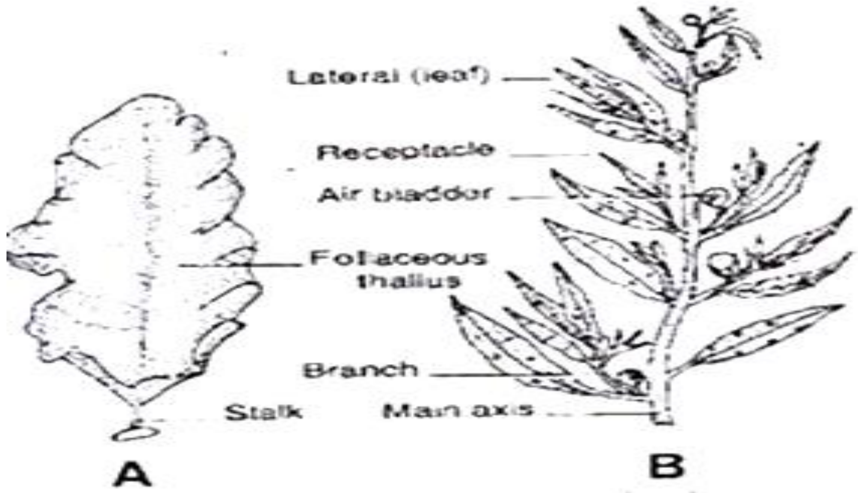


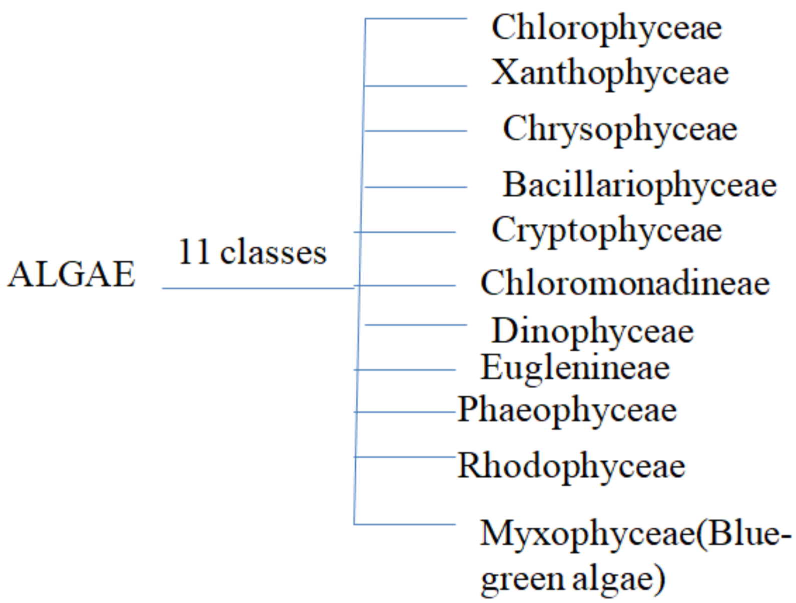
Figure 5.11: Thallus organization parenchymatous forms

5.4: Classification of Algae by Fritsch

The classification of algae was given by F.E. Fritsch (1935) in his book 'The Structure and Reproduction of the Algae' based on criteria like pigmentation, types of flagella, assimilatory products, thallus structure and methods of reproduction.

F.E. Fritsch (1935, 1948) divided algae into 11 classes on following basis: - Thallus structure, Method of reproduction, Variation in the life cycles, Number and attachment of flagella, Chemical nature of pigments, Reserve food materials.

FRITCH'S SYSTEM OF CLASSIFICATION



Fritsch's Classification of Algae and Their Characteristics

Myxophyceae (Cyanophyceae)

Simple algae without a nucleus or chromatophore. The presence of phycocyanin is the reason for their blue-green hue. Phycobilisomes are an additional type of pigment. Chlorophyll is present in thylakoids. Their reserve diet consists of myxophycean starch and protein granules. There is no sexual reproduction in these algae.

Fritsch recognised 5 orders under Myxophyceae.

- Chroococcales (*Gleocapsa, Microcystis*)
- Chamaesiphonales (*Chamesiphon, Dermocarpa*)
- Pleurocapsales (*Pleurocapsa*)
- Nostocales (*Nostoc, Oscillatoria, Anabaena*)
- Stigonematales (*Nostochopsis, Stigonema*

Euglenophyceae

Presence of unicellular flagellates with single cell others are colonial. Possess an eyespot, a vacuole, chloroplasts, and a nucleus. Their reproductive organs, which are ciliated and naked, imitate miniature animal structures e.g. *Euglena, Heteronema*, etc.

Chlorophyceae

The number of flagella and structure of plants differ. Possess thallus chlorophyllous in freshwater mostly. Starch serves as the reserve resource, while cellulose makes up the cell wall. Algae in this group are characterized by motile cells with cilia. Anisogamous, isogamous, and oogamous sexual reproduction are all possible.

Fritsch's categorization of algae divides the Chlorophyceae in nine orders.

- Volvocales (*Volvox*)
- Chlorococcales (*Chlorella*)
- Ulothrichales (*Ulothrix*)
- Cladophorales (*Cladophora*)
- Chaetophorales (*Fritschiella*)
- Oedogoniales (*Oedogonium*)
- Conjugales (*Zygnema*)
- Siphonales (*Vaucheria*)
- Charales (*Chara*)

Chloromonadineae

This group of algae exhibits vivid or olive-green colors. They contain a lot of xanthophyll. There are many discoid chloroplasts. They divide longitudinally to reproduce. There is only one order in Chloromonadinae: Chloromonadales (Vacuolaria, Trentonia).

Xanthophyceae (Heterokontae)

These algae appear yellow or green-yellow due to the presence of xanthophylls. They have no pyrenoids, and fat serves as their reserve food source. Cell walls with varying lengths and uneven flagella overlap.

Fritsch divided the Xanthophyceae class into four orders.

- Heterochloridales (*Heterochloris, Chloramoeba*)
- Heterococcales (*Myxochloris*)
- Heterotrichales(*Tribonema*)
- Heterosiphonales (*Botrydium*)

Chrysophyceae

This class of algae includes phycocyanin, phycochrysin, and yellow-green pigments. The pigment responsible for the distinctive yellow or orangish hue is called phycochrysin. The plants are found in unicellular or multicellular algae in colonial forms. Cell walls may or may not be present. It appears as a halved overlap when present. Algae have one to three flagella and silicified cysts. Leuosin serves as the reserve food source. According to Fritsch's classification, there are three orders in the Chrysophyceae family of algae:

- *Chrysomonadales (Chrysodendron)*
- Chrysosphaerales (*Chrysosphaera*)
- Chrysotrichales (*Chrysoclonium*)

Bacillariophyceae (Diatoms)

The algae have an olive or yellow-green color. Diatomin is found in chloroplasts. Pyrenoids are frequently observed. The behaviors are non-motile and unicellular. Pectose and a silicified cell wall are present. They have subtle patterns and a symmetrical appearance. The family Bacillariophyceae includes only two orders:

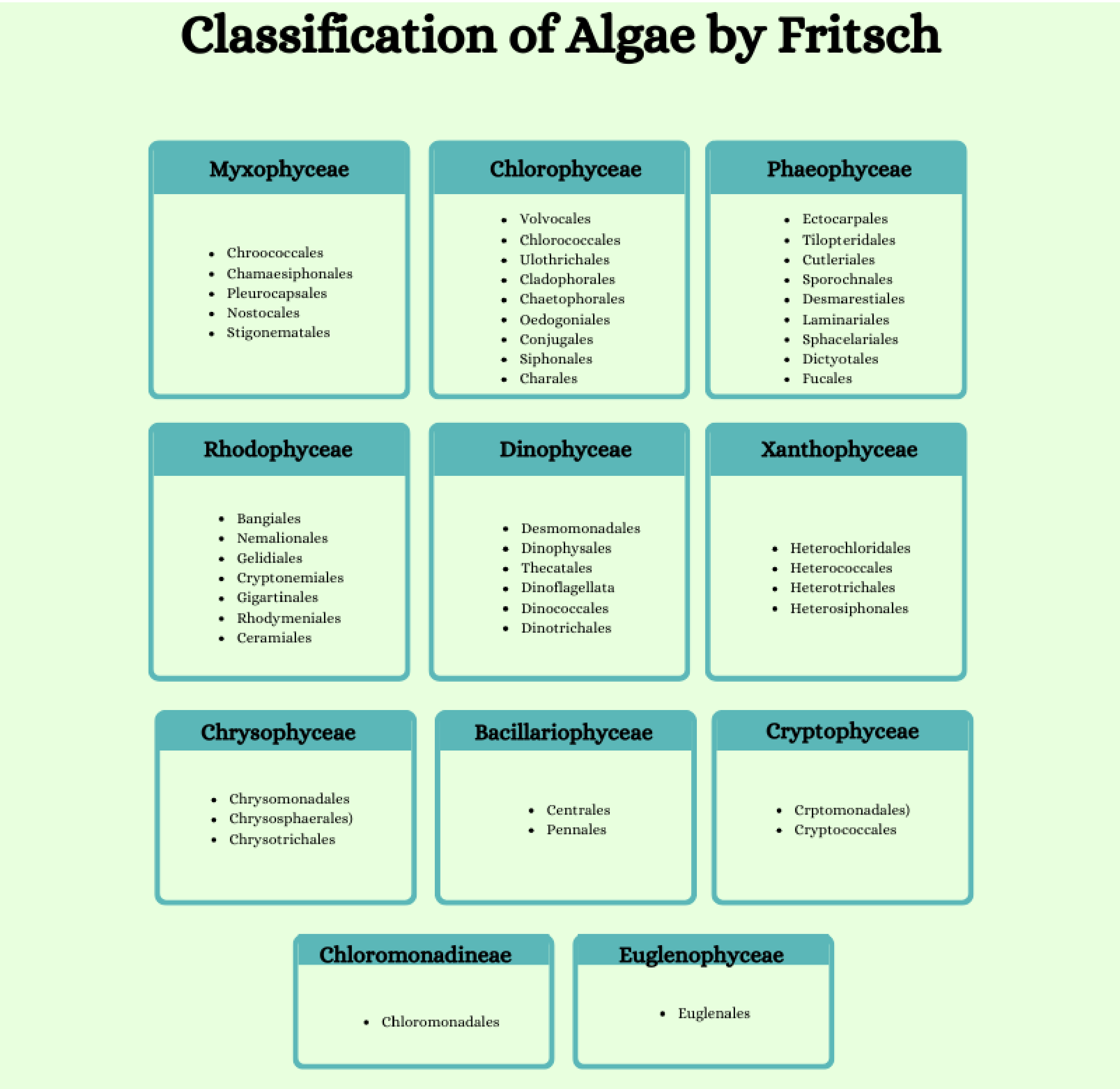
- Centrales (*Cyclotella*, *Chaetoceras*)
- Pennales (*Grammatophora* , *Navicula*)

Cryptophyceae

Algae may appear green, red, olive-green, or greenish-blue in appearance. They may be found in both freshwater and marine environments. Two huge parietal chloroplasts, two uneven flagella, and endogenous cysts are present in every cell.

Cryptophyceae divided into only two orders.

- Crptomonadales (*Cryptomonas*, *Chilomonas*)
- Cryptococcales (*Tetragonidium*)



Dinophyceae (Peridineae)

Algae show up as dark yellow, brown, or red. Unicellular, motile, filamentous, with biflagellate cell walls, a big nucleus, discoid chromatophores, and longitudinal and transverse furrows. Starch or oil serves as the reserve material. For instance, Peridinium, Ceratium, and Heterocapsa. Dinophyceae has 6 orders recognised by Fritsch:

- Desmomonadales (*Desmocapsa*)
- Dinophysales (*Dinophysis*)
- Thecatales (*Exuviaella*)
- Dinoflagellata (*Ceratium*)
- Dinococcales (*Cystodinium*)
- Dinotrichales (*Dinothrix*)

Phaeophyceae

Plants exhibit a brown or yellow hue. Fucoxanthin is the primary colored pigment. They possess laminarin, lipids, or mannitol as reserve food. Seaweeds that are filamentous or arranged and possess two flagella—one for forward motion and the other for backward motion—produce uni- or plurilocular sporangia. Biciliated zoospores possess uneven ones. There is no resting period for the zygote. According to Fritsch's categorization of algae, Phaeophyceae belongs to nine orders:

- Ectocarpales (*Ectocarpus*)
- Tilopteridales (*Tilopteris*)
- Cutleriales (*Cutleria*)
- Sporochnales (*Sporochnus*)
- Desmarestiales (*Desmarestia*)
- Laminariales (*Laminaria, Macrocystis*)
- Sphacelariales (*Sphacelaria, Haploteris*)
- Dictyotales (*Dictyota*)
- Fucales (*Fucus, Sargassum*)

Rhodophyceae

The algae which belongs to Rodophyceae, are known as red algae,contain phycoerythrin pigment. The reserve food material floridean starch. Polysyphonia exhibit a filamentous or highly ordered body, protoplasmic connections between cells, and carpospores, which sprout into tetrasporic diploid plants. According to Fritsch, Rodophyceae has seven orders which are as follows:

- Bangiales (*Bangia, Porphyra, Porphyridium*)
- Nemalionales (*Batrachospermum, Nemalion*)
- Gelidiales (*Gelidium*)
- Cryptonemiales (*Corallina*)
- Gigartinales (*Gigartina, Gracilaria*)
- Rhodymeniales (*Champia, Rhodymenia*)
- Ceramiales (*Ceramium, Polysiphonia*)

5.4 Cell Structures in Algae

I. Cell Wall:

The Cell wall is composed of cellulose. It also contains hemicellulose, mucilage, pectin that are present in different kinds of algae, including silica, calcium carbonate, fucoidin, alginic acid, and fucin. The cellulosic wall is made up of cellulose microfibrils with different thicknesses that are orientated differently inside a granular matrix, according to research using electron microscopy.

The silicified diatom cell wall exhibits distinctive secondary features. Mucopeptide, which is mostly a peptide of a few amino acids covalently bound to amino-sugars, glucosamine, and muramic acid makes up the cell wall of Cyanophyceae.

Bacteria cell wall also contains this muco-complex. Certain algae, like Gymnodinium and Pyramimonas, lack a proper cell wall. Rather, they have a pellicle, which is a border membrane (Figure 5.12).

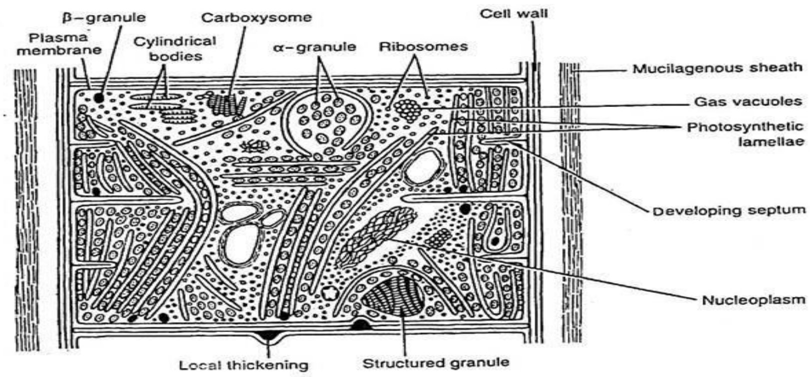


Figure 5.12: structure of blue green algae

II. The Protoplast:

A protoplast is a cell's protoplasmic material. The protoplast of eukaryotic algae, consist of one or more spherical or ellipsoidal nuclei and cytoplasm, surrounded by the lipoproteinaceous exterior border called the cell membrane. Like all other biological membrane systems, the cell membrane is composed of lipid and protein and is a fluid mosaic in nature. It is highly elastic, extremely thin, and selectively permeable. It regulates the flow of substances into and out of the cells.

A well-organized spherical or elliptical body is the nucleus found in all eukaryotic algae (Chlorophyceae, etc.). It is still encircled by a unique nuclear membrane. A chromatin reticulum contained in a matrix known as karyolymph occupies the inner side. There are two layers in the nuclear membrane. The endoplasmic reticulum and the outer membrane are continuous. There are one or more nucleoli or endosomes in each nucleus. Varying types of algae have different numbers of nucleoli, may be one, two, or more of them. The centromere of the chromosomes can be distributed or localized. Some species have as few as two chromosomes (*Porphyra linearis*), while others have as many as 592 chromosomes (*Netrium digitali*).

In an eukaryotic algal cell, membrane-bound cell organelles, such as chloroplasts, mitochondria, golgi apparatus, endoplasmic reticulum, and, in certain situations, eye spots or stigma etc. are present.

The nucleus of prokaryotic algal cell, or members of the Cyanophycean class, is not surrounded by any membrane. Rather, the protoplast differentiates into an inner, colorless centroplasm and an outer, peripheral chromoplasm that contains pigments involved in photosynthetic reactions. The latter contains the genetic material, which is not present in the membrane-bound nucleus and DNA strands do not unite with histones to create chromosomes.

In Cyanophyceae, the centroplasm thus symbolizes the developing nucleus. Even while the nucleus of Dinophyceae is membrane-bound, it lacks chromosomes and the mitotic apparatus, making it less completely eukaryotic. Cell organelles and cytosol make up an algal cell's cytoplasm (Figure 5.13).

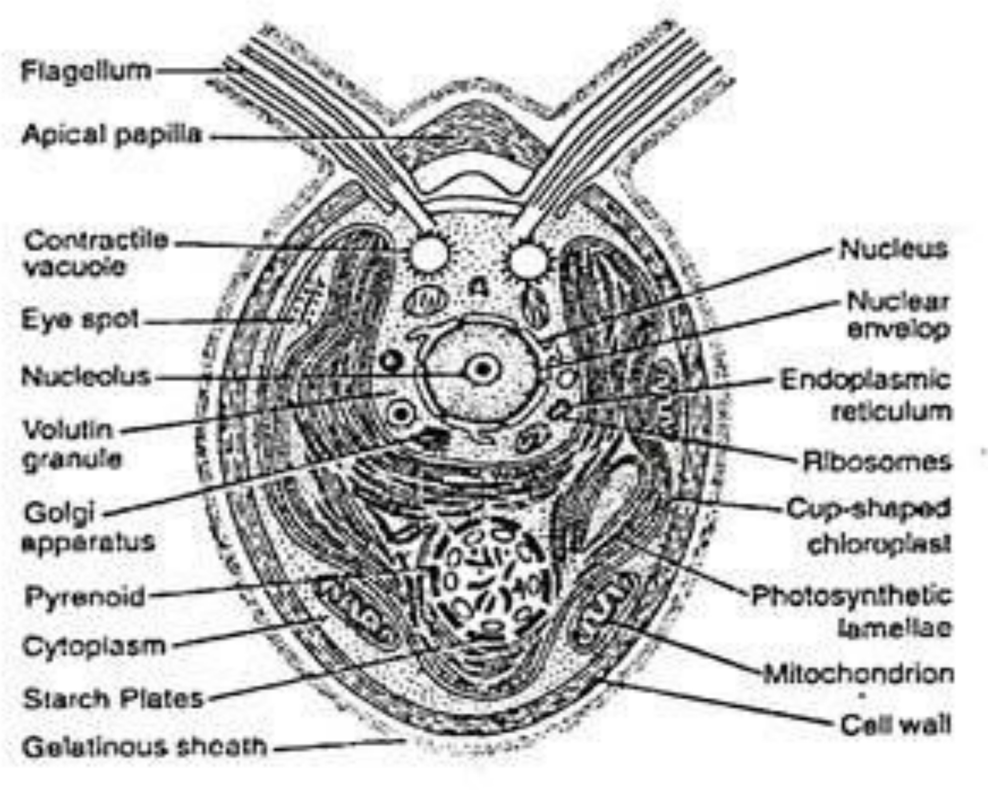


Figure 5.13: Structure of *Chlamydomonas*

1. The Chloroplast:

Algal cells are primarily known for their chloroplasts. Their pigments are photosynthetic. It has two membranes.

There are eight main types of chloroplasts that are known to occur in different types of algae. These include cup-shaped algae (like *Chlamydomonas* and *Volvox*), discoid algae (like *Chara*, *Vaucheria,* and centric diatoms), parietal algae (like Chaetophorales, Phaeophyceae, Rhodo-phyceae, many Chrysophyceae, and pinnate diatoms), spiral algae (like *Spirogyra*), reticulate algae (like *Oedogonium*, *Hydrodictyon*, and *Cladophora*), stellate algae (like *Zygnema*), and ribbed algae (like Volvocales). Almost all members of the plant kingdom share a similar fundamental chloroplast structure.

There are three major structural regions in the chloroplast:

1. An envelope with two membranes and a confined area.
2. The mobile stroma that contains the digestible enzymes for protein synthesis, starch storage, and metabolism

3. The finely arranged interior lamellar membranes that are pigment-containing and function in energy transduction and capture.

Grana are made up of discs that are stacked one atop the other like coin piles by the internal lamellar mechanism. Each disc is referred to as a thylakoid and is a sac or vesicle. An interthylakoid space is enclosed by each thylakoid.

The thylakoid membrane divides the stroma from the single, complicated cavity that makes up the thylakoid system.

The thylakoids of Cyanophyceae are not enclosed in membrane-bound groups to form chloroplasts; rather, they are free to float freely inside the cytoplasm. Chlorophyll is found in the thylakoids, and the accessory pigments are found on their surface as phycobilisomes, which are tiny vesicles.

a. Pigmentation:

The pigments provide various colors to the thallus of various types of algae:

i. Chlorophylls:

Algae include five different forms of chlorophylls: Chi a, b, c, d, and e. Of them, all types of algae include chlorophyll a. Only Chlorophyceae include chlorophyll b; Phaeophyceae, Cryptophyceae, Bacillariophyceae, and Chrysophyceae contain chlorophyll c; certain red algae contain chlorophyll d; and certain Xanthophyceae contain chlorophylle.

ii. Caroteinoids:

The carotenoids are made up of xanthophylls and carotenes. These pigments are add-on photosynthetic components.

In algae, carotenes come in five different varieties: Chlorophyceae, Rhodophyceae, Bacillariophyceae, Cryptophyceae, e-carotene, c-carotene, and flavone in members of Cyanophyceae are the algae groupings that contain α-carotene, β-carotene, and c-carotene, respectively.

iii. Xanthophylls:

Fucoxanthin is the primary xanthophyll pigment in Phaeophyceae and Bacillariophyceae, while myxoxanthophyll, myxoxanthin, and oscilloxan- thin are exclusive to Cyanophyceae. Several types of xanthophylls are found in algae. These include lutein, violaxanthin, and neoxanthin, which are found in members of the Chlorophyceae and Phaeophyceae.

iv. Phycobilins:

Water-soluble linear tetrachlorolethanes are known as phytobilins. These are biliproteins that are either blue (phycocyanin) or red (phycoerythrin) in hue. Only the Rhodophyceae and Cyanophyceae include them. By absorbing and delivering the light energy to the reaction center, they serve as accessory pigments.

b. Pyrenoids:

Proteinaceous structures called pyrenoids are found in chromatophores, which are the specific type of chloroplasts seen in algae. Usually, they are connected to the production and preservation of starch. Within the Bacillariophyceae family, they store fat. Pyrenoid may be one (for example, *Chlamydomonas)* or many (like *Oedogonium*).

2. Mitochondria:

With the exception of Cyanophyceae, all algal cells include mitochondria. Every mitochondrion has an envelope made of two membranes. An aqueous matrix including solutes, soluble enzymes, and mitochondrial glucose is enclosed by the inner membrane of plant mitochondria.

The inner membrane, which is bigger than the outer membrane, invaginates to produce sac-like cristae that vary in number and shape and often have a narrow neck. An outer membrane that is in close proximity to the inner membrane encircles the entire mitochondrion once more, creating an intermembrane space that is uninterrupted by the intercristal space.

The matrix has a coarse granular texture and is highly proteinaceous. The organelle is semiautonomous since it possesses its own ribosomes and circular DNA, which enable it to synthesis some of its own proteins. While Micromonas (Chlorophyceae) cells often have several mitochondria, each cell in this species only has one mitochondrion. Blue green algal cells are devoid of mitochondria. In eukaryotic cells, the cytoplasmic membrane is the site of biochemical processes typically connected to distinct membranous organelles. Similar to bacteria, the cell membrane invaginates to create the meso-some, a structure that houses the respiratory enzymes.

3. Endoplasmic Reticulum (ER):

The endoplasmic reticulum, a large membrane network of interconnecting tubules and cisternae (flattened sacs), is found within the algal cells, according to research conducted using electron microscopy. The whole cytoplasm is traversed by the ER membranes. The reticulum, which is affixed to the cytoplasmic face of the membrane, is made up of interconnecting parallel cisternae linked to the ribosome. Rough endoplasmic reticulum (RER) is the name given to this type of ER, which is an important location for protein production. In contrast, smooth endoplasmic reticulum (SER) refers to ER membranes devoid of ribosomes.

4. Dictyosomes or Golgi apparatus:

All algal cells, with the exception of blue-green algae, contain dictyosomes, also known as Golgi bodies, which are visible under an electron microscope. A part of the cell's endomembrane system, the Golgi apparatus seems to act as a bridge between the plasma membrane and the endoplasmic reticulum.

Golgi bodies may be found anywhere in the cell, in the vicinity of plastids (such as diatoms and *Bulbochaetes*), or in the vicinity of the nucleus (such as in *Chlamydomonas*). Stacks of two to twenty flat vesicles make up the Golgi bodies.

Researchers refer to each stack as a dictyosome. Together, all dictyosomes make up the Golgi apparatus. Its purpose is to package materials for export to the outside of the cell. In order to sustain growth or replace the destroyed plasma membrane, it is also in charge of the production of new ones.

5. Eye-Spot or Stigma:

Algal eye-spots, also called stigmas, are pigmented patches found in the front, middle, or posterior regions of the motile vegetative and reproductive cells (Fig. 5.14). It affects how light is perceived, either directly or indirectly. Typically, the stigma is located within the thylakoids and runs longitudinally between two rows of granules in the eye-spot.

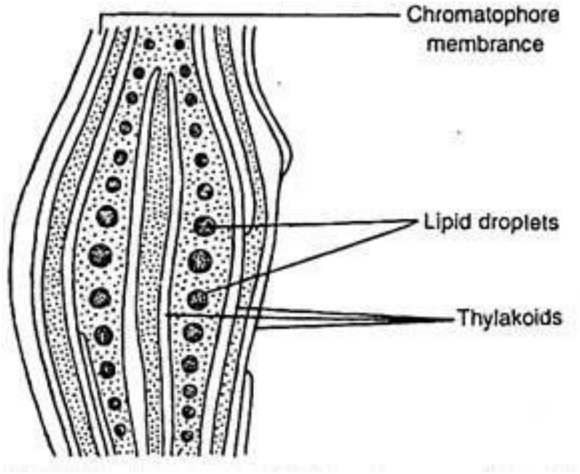


Figure 5.14: A spot of *Chlamydomonas reinhardtii*

6. Vacuoles:

Except of Cyanophycean members, almost all algal cells have one or more vacuoles. The tonoplast, a unique membrane, encloses each vacuole.

Three types of vacuoles are found in motile forms:

(i) Simple vacuole:

They exhibit cyclical contraction and expansion and are minuscule in size, Also referred to as contractile vacuoles. They discard the cell wastes produced by metabolism. Additionally, they control the water content of the cell by periodically releasing any excess water. Thus, their function is secretive.

(ii) Complex Vacuole:

These are the characteristics shared by Euglenophyceae and Dinophyceae. It is made up of a big reservoir, a collection of vacuoles with different diameters, and a cytopharynx that resembles a tube. Inside the cell, the vacuoles carry out the osmoregulation function. Additionally, reserve food materials like laminarin and chrysolaminarin are occasionally stored in the vacuoles.

(iii) Gas Vacuoles:

Gas-containing cavities exist in the cells of Cyanophyceae members as stacks of tiny, uniformly-diameter transparent cylinders. Gases may flow easily through their barriers. In addition to provide buoyancy to the planktonic forms, the gas vacuoles act as barriers against intense light.

7. Flagella:

Except of Cyanophyceae and Rhodophyceae, all groups of algae have motile vegetative or reproductive cells. The tiny protoplasmic appendages known as flagella, which resemble filiform or threads, beat to produce movement. The number, length, position, and presence or absence of hairs is all variable. The range of numbers is one, four, or more.

They are mainly of two types:

1. Whiplash or Acronematic:

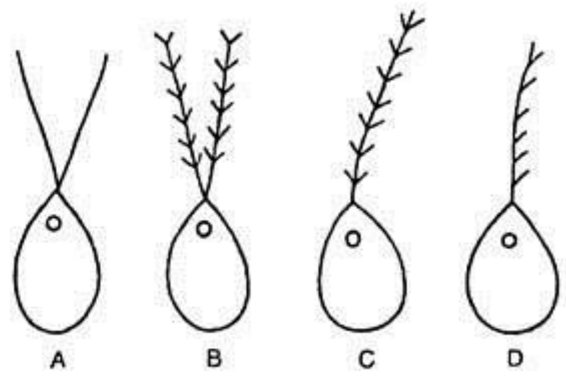
Hairless smooth surface flagella.

2. Tinsel or Pleuronematic:

They have one or more rows of mastigonemes, also referred to as flimmers, which are lateral tiny filamentous hairs.

They are further categorised into:

a. Pantonematic. when two rows of opposing mastigonemes are present
b. The pantoacronematic - The word pantoacronematic refers to a pantonematic flagellum that has a terminal fibril .
c. The schematic- it contains monomorphic mastigonemes (Figure 5.15).



Different types of flagella in algal cells : A. Cell with acronematic flagella, B. Cell with two pantonematic flagella, C. Cell with pantocronematic flagellum, and D. Cell with stichonematic flagellum

Figure 5.15: Different types flagella in algal cell

Isokont refers to more than one identical flagella per cell; heterokont refers to more than one different flagella per cell.

Flagellar Roots in Algae:

The extremely thin hyaline protrusion of cytoplasm is known as a flagellum. Typically, each flagellum has a single granule known as the blepharoplast or basal body at its base. When an algal cell has a solid wall, a pore allows the flagellum to emerge.

The axoneme, a core or axial thin filament, is present in every flagellum. A cytoplasmic membrane or sheath, created by an expansion of the cell or plasma membrane, envelops the axoneme. The sheath terminates immediately below the flagella's apex. The term "end-piece" refers to the apical bare section of the axoneme.

The transverse segment of the flagellum (Fig. 5.16, 17) shows nine peripheral doublet fibrils surrounding two central singlet fibrils. Every fibril is enveloped in a membrane, with an extra membrane covering the two central fibrils.

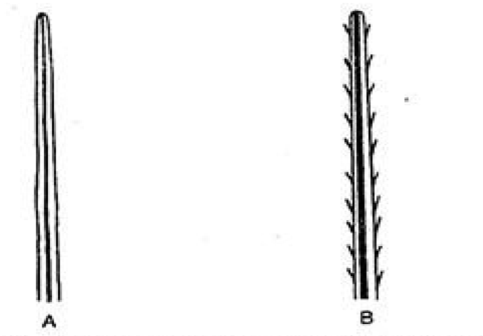


Figure 5.16: Flagella: A. Single wiplash flagellum, and B. Single tinsel flagellum

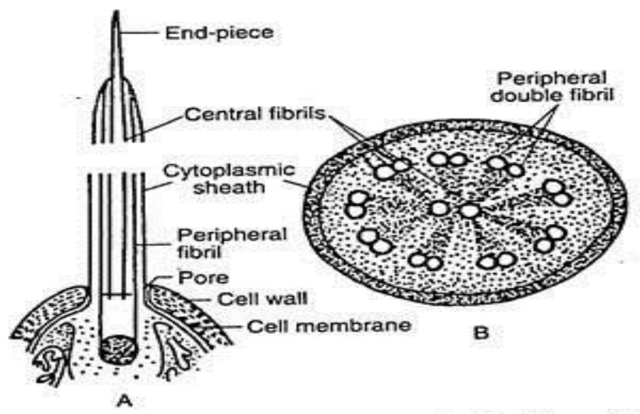


Figure 5.17: Flagella : A.Structure of a flagellum with basal structure, B. T.S. of single flagellum

5.5 Summary

- Diversity of environments, such as lakes, rivers, and seas, ponds, brackish water, and even snow, are home to algae. Algae are often green in color; however, they can be red, brown, and orange with different hues of colour. For example, snow algae have carotenoid pigments in addition to chlorophyll, which is what gives the surrounding snow its distinctive red hue.
- Algae are simple, thalloid, autotrophic, aquatic plants that contain chlorophyll.
- In contrast to the presence of fungi and animals, they can be found in damp wood, stones, and soils.
- They are frequently found next to or inside bodies of water. They are structurally similar to a major category of photosynthetic creatures called terrestrial plants.
- Economically algae are very important for us they may be useful in medicines, agriculture-based industries, food and fodder.

- They also lack vascular tissues, which are necessary for the proper circulation of water and nutrients throughout their body.

5.6 Self-Assessment Questions

1. Mark the incorrect –

   (1) All photoautotroph have pigments (2) All autotroph require energy

   (3) All bacteria have 70s ribosome **(4) All Monera is Eubacteria**

2. Both fresh water and marine habitat is of:

   (1) Protozoans (2) Euglenoids

   (3) Diatoms **(4) Both 1 and 3**

3. "Golden Algae" is the common name of Algae:

   (1) Chrysophytes **(2) Desmids**

   (3) Euglenoids (4) Cyanophyceae

4. In how many Group of Protista Heterotopic nutrition is present:

   (1) Two **(2) Three**

   (3) Four (4) All five

5. Example having two flagella:

   (1) Dinoflagellates (2) Euglenoids

   (3) Brown algae **(4) All**

6. The diatoms do not easily decay like most of the other Algae because:

   (1) Silica is metal (2) No enzyme degrade silica in wall

   (3) Silica is biological material **(4) both 2 and 3**

7. Marine habitat can be for:

   (1) Diatom (2) Dinoflagellates

   (3) Amoeboid **(4) All**

8. Chl a and Chl b present in:

   (1) Euglenoids (2) Green Algae

   (3) Higher plants **(4) All**

9. Which one of the following is uncommon between Nostoc and Diatom?

(1) Non-motile (2) Unicellular

(3) PS II **(4) Nucleus**

10. Which can be characteristic feature of diatoms is:

(1) Chl b (2) Pellicle (3) Flagella **(4) Oxygenic photosynthesis**

11. Membrane bound organelle absent in:

(1) Dinoflagellates (2) Diatoms

(3) Euglenoids **(4) Mycobacterium**

5.7 Short Question Answer

1. Give examples of Unicellular Algae.
2. Give classification of Algae.
3. Draw a well labelled diagram of the Algae.

CHAPTER - 6

Algae

Objectives

At the end of chapter student will be able to:

- Understand the morphology and life cycle of algae members.
- Explore the role of algae in the agriculture and industry.

6.1 Nostoc

Blue-green algae, often known as cyanobacteria, belong to the genus Nostoc. They carry out photosynthesis and are prokaryotic. Primarily prevalent in freshwater environments, they can be found as free-living, colonies, adhering to rocks, or at the bottom of lakes or Tree trunks. They can also be found in some bryophytes (Anthoceros) as an algal component of lichens. They are able to carry out photosynthesis and nitrogen fixation. They coexist with fungi as endosymbionts (Figure 6.1).

6.2 Classification

These are prokaryotic, found in groupa, lack membrane-bound organelles and genetic material is dispersed in the cytoplasm and shows photosynthesis.

Domain	Bacteria
Phylum	Cyanobacteria
Class	Cyanophyceae
Order	Nostocales
Family	Nostocaceae
Genus	*Nostoc*

Some of the commonly found Nostoc species are:

- *Nostoc commune* is eaten as a salad
- *Nostoc azollae* forms symbiotic association with water fern
- *Nostoc punctiforme* form symbiotic relationship with Anthceros and other higher plants
- *Nostoc flagelliforme* is known as Fat choy. It is used as a vegetable in China
- *Nostoc pruniforme* forms very big colonies (diameter as large as ~25 cm)

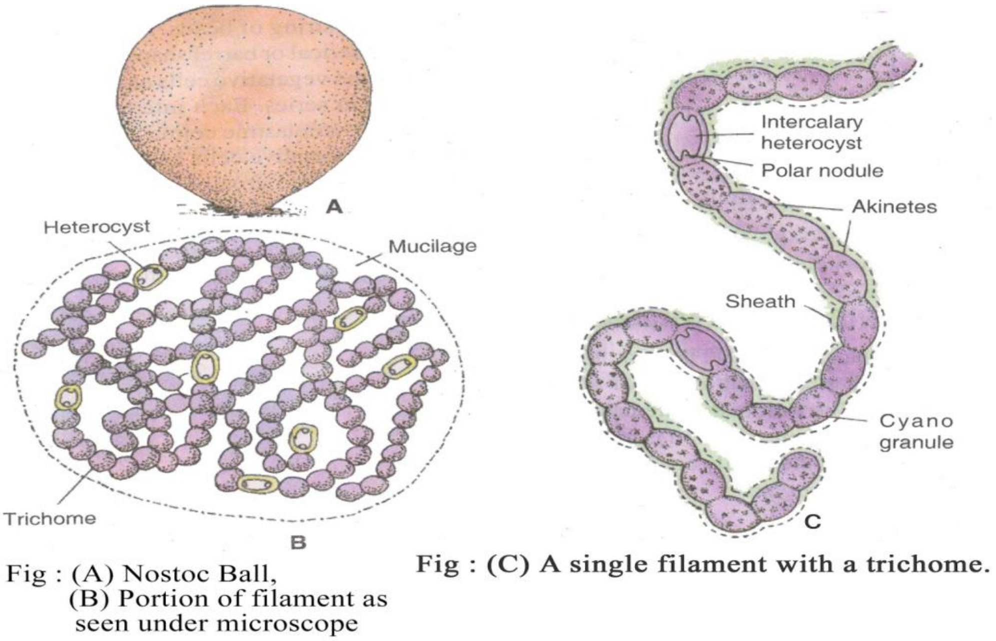


Figure 6.1: structure of Nostoc

Nostoc Structure

- Nostoc are unbranched and filamentous. A colony is a gelatinous mass containing many filaments. The colonies might have the size of an egg. The filament is made up of a chain of cells that resemble beads. We refer to them as trichomes.
- Cells might be cylindrical, spherical, or oval.
- The filament contains some differentiated cells known as heterocysts. They serve as nitrogen fixation sites. The enzyme nitrogenase fixes nitrogen.
- A protective covering known as a mucilaginous sheath surrounds every filament. It takes in and holds onto water. The gelatinous sheath is composed of proteins and carbohydrates.
- There are a variety of sizes, shapes, and colors for colonies. They are mostly greenish or bluish-green in hue, in addition to being reddish-brown or yellow-green.
- Other extrinsic pigments include nostocine and scytonemin. These pigments protect the cells from UV radiation, in conjunction with a few amino acids.
- Chromoplasts are arranged outward, a cell's cytoplasm can be divided into two distinct colors: inner cytoplasm and outer colored cytoplasm. Pigments differ across cells. Peptidoglycan makes up the thick cell wall of every single cell.

- Chlorophyll is a green pigment found in cells. Additionally, there is phycocyanin (blue) and phycoerythrin (red). The inner cytoplasm has an immature nuclear body or nucleus, and the DNA lacks histones.

6.3 Nostoc Reproduction

- Nostoc reproduces vegetatively or asexually by spore formation.
- By fragmentation, vegetative reproduction occurs. Little colonies may develop alongside larger colonies and then split off to create their own colonies.
- Short, free filaments are known as hormogonia. When a filament breaks, they are created. The gelatinous sheath is still present. Within the colony, new trichomes grow (Figure 6.2).
- Asexual reproduction occurs through the development of akinetes, which are dormant spores. Food deposition causes certain cells to develop thick walls. They may endure unfavorable circumstances for a long time. They germinate to create a new filament when the right circumstances are met. Nostoc reproduces through heterocysts as well. The filament splits up into heterocysts. They split off and start a new filament.

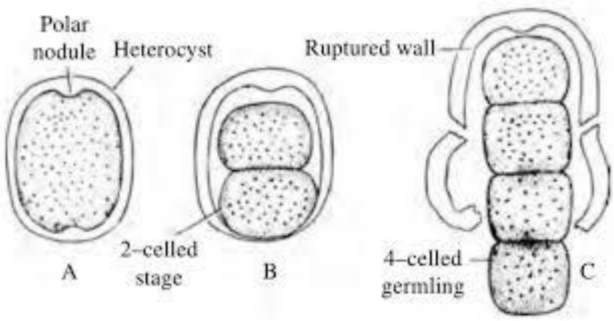


Figure 6.2: life cycle of Nostoc

6.4 Ecological Importance:

- The capacity of nostoc to fix nitrogen makes them significant. They are rich in proteins and vitamin C and are consumed as a delicacy in several Asian nations, such as *N. commune* and *N. flagelliforme*. They are also utilized in rice fields to boost the nutrient value of the soil.
- It has been demonstrated that *N. muscorum* accumulates polyhydroxy butyrate, a precursor to plastic.

- Cyanobacteria have the ability to convert CO_2 into biofuels, which may have practical use in industry. Research indicates that nostoc produces hydrogen.
- They may be applied to bioremediate wastewater and break down contaminants in the environment.
- Various species, e.g., *N. muscorum, N. commune, N. insulare, etc.* show antibacterial or antiviral activity having application in drug designing.

6.5 Chlamydomonas

A green-algae called Chlamydomonas may be found in both fresh and sea water. There are about 150 species in the genus those are biflagellated and unicellular. There are moments when it gets so much of it that the entire body of water turns green. It serves as a model organism for molecular biology research.

Classification of *Chlamydomonas*

Kingdom	Plantae
Division	Chlorophyta
Class	Chlorophyceae
Order	Chlamydomonadales
Family	Chlamydomonadaceae
Genus	*Chlamydomonas*

6.6 Morphology of Chlamydomonas

- These are motile and unicellular green algae.
- Their shapes might include oblong, spherical, oval, pyriform, and ellipsoidal.
- Chlamydomonas frequently has pyriform, or pear-shaped, thallus, which has a large posterior portion and a narrow anterior part.
- Cellulose makes up the thin cell wall.
- The endoplasmic reticulum, dictyosomes, ribosomes, mitochondria, and nucleus are all found in the cytoplasm.
- The nucleus is located in the cytoplasm of the chloroplast, which resembles a hollow.
- There are two vacuoles, which carry out excretory and osmoregulatory tasks.
- Two whiplash flagella located at the organism's front end.
- The organism may be recognized by its cup-shaped chloroplasts. Instead, it can be stellate in *C. arachne*, reticulate in *C. reticulata*, and 'H' shaped in *C. bicilliata*.

- The tiny microcompartments in the chloroplast called pyrenoids are in responsible for starch production. In Chlamydomonas, pyrenoids can range from one to several.There is an eyespot on the front part of the chloroplast. It is a small, photoreceptive area with an orange or red color. It is focused on the flagella's motion (Figure 6.3).

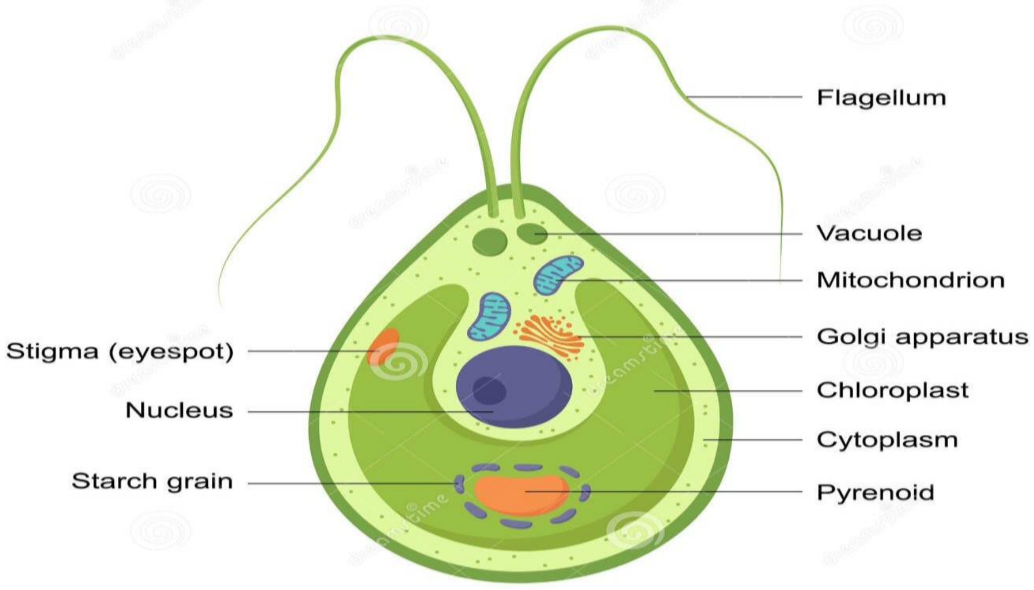


Figure 6.3: Structure of Chlamydomonas

Reproduction and Life Cycle of *Chlamydomonas:*

Both sexual and asexual reprodction has been observed.

Asexual Reproduction in *Chlamydomonas*

1. **Zoospores**

   Favorable circumstances lead to the formation of zoospores. The protoplast separate from the cell wall as the organism's flagella contract. Initially, the protoplast splits into two daughter cells along its longitudinal axis. It then divides into four daughter cells at a right angle to the preceding longitudinal division. Similar to this, Chlamydomonas divides into 2–16 daughter cells by basic mitosis. The offspring cells develop flagella and a cell wall of their own. The term "zoospores" refers to these offspring cells. The daughter cells that develop into distinct individual cells are released when the parent cell, or zoosporangium, ruptures (Figure 6.4).

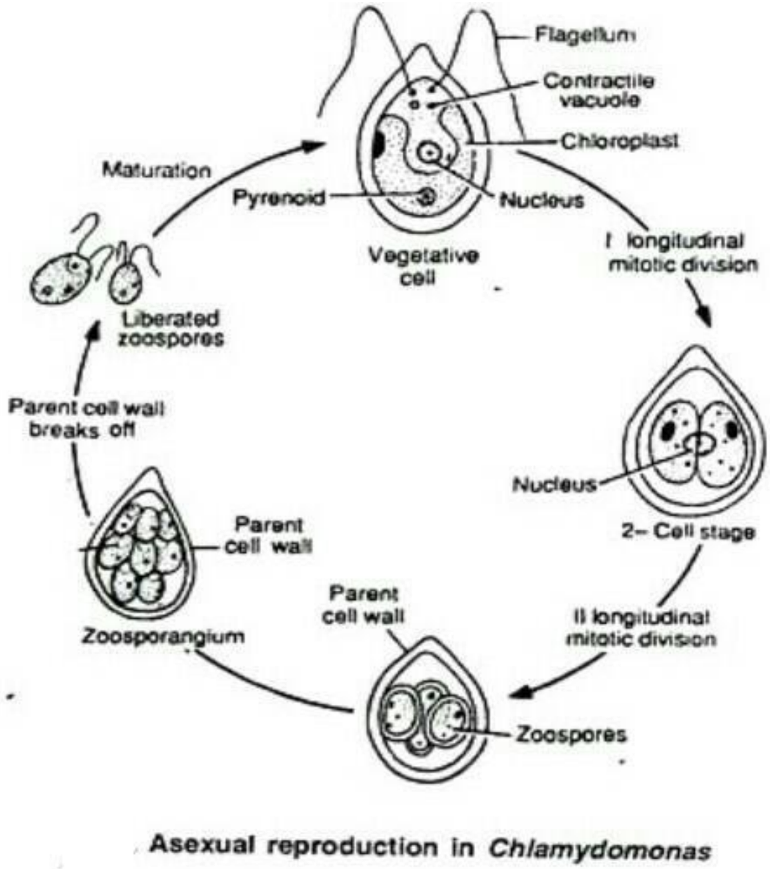


Figure 6.4: Asexual Reproduction in Chlamydomonas

2. **Aplanospores**

   In unfavorable circumstances, Chlamydomonas forms aplanospores. The protoplast breaks out from the cell wall and the parent cell loses its flagella. Two to sixteen daughter protoplasts without flagella are produced when the protoplast splits. They are referred to as aplanospores and exude a thin layer around the protoplast. When favorable circumstances arise, the aplanospore has the potential to either germinate or transform into zoospores.

3. **Hypnospores**

   In unfavorable circumstances, the protoplast secretes thick walls, which create hypnospores. When favorable circumstances present themselves, the spores begin to sprout into distinct individuals.

4. **Palmella Stage**

   Under unfavorable circumstances, Chlamydomonas exhibits this stage. The protoplast does not produce zoospores when it splits into daughter cells. Although they do not form flagella, each daughter protoplast releases a viscous coating around itself. The term "palmello spore" refers to these daughter protoplasts. The palmella stage, which produces an infinite number of spores, is formed when the protoplast progressively splits. The gel-like coating breaks down when favorable circumstances return, allowing each spore to develop into a new thallus.

6.7 Sexual Reproduction in Chlamydomonas

1. **Isogamy**

   Chlamydomonas creates gametes that are physiologically distinct but physically identical. The protoplast separates from the cell wall and the organism's vegetative thallus, known as the gametangium, loses its flagella. 32 daughter protoplasts are produced from the split protoplast. Every daughter protoplast develops into a gamete by growing flagella. The gametangium releases the gametes. Agglutinins, which coat each gamete, emit a hormone known as gamone. This hormone aids in the identification of the opposing strain's gametes. Strains (+) and (-) in heterothallic species are attracted to one another. When the gametes of the opposing strains come into contact, their nuclei and cytoplasm fuse together. A zygospore is a quadriflagellate zygote that eventually loses its additional flagella and secretes a thick wall (Figure 6.5).

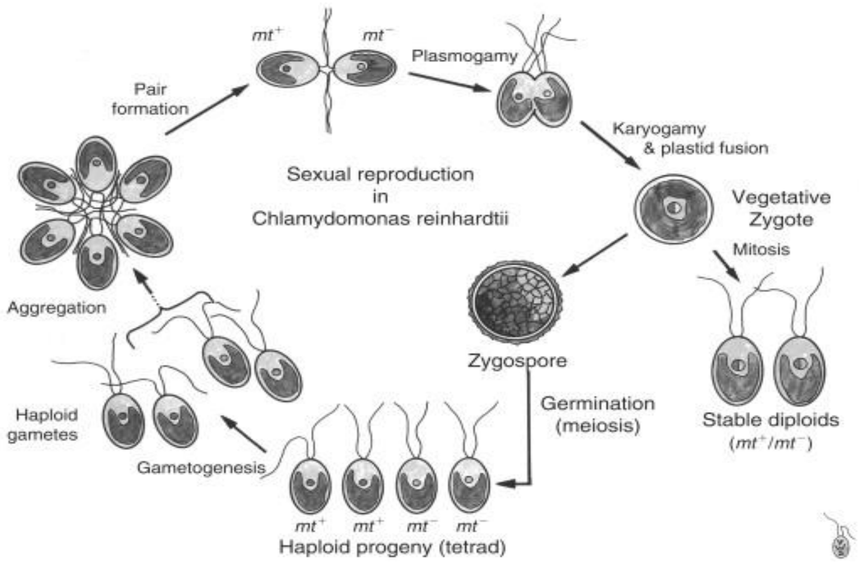


Figure 6.5: Sexual Reproduction in Chlamydomonas

2. **Anisogamy**

   Anisogamy results in the production of gametes with two distinct sizes. The male gametangium produces the tiny male gametes, also referred to as microgametes. The female gametangium produces the bigger female gametes, also referred to as macrogametes. Together, the two gametes create a diploid zygote that develops into zygospores.

3. **Oogamy**

   During oogamy, the Chlamydomonas vegetative thallus stops being able to move and takes on the characteristics of a female gamete, macrogamete, or egg. Microgametes, or male gametes, are created by the division of protoplasts. A zygote is created when the microgamete and macrogamete combine.

Zygote or Zygospores

The zygote is a diploid spore in a state of rest that surrounds itself with thick, wrapped walls. It gathers a significant amount of oils and carbohydrates. When favorable circumstances are again present, the zygospores begin to germinate, withstanding a prolonged period of unfavorable conditions. Meiosis causes it to split into four haploid nuclei, each of which develops into a distinct individuals.

6.8 Oedogonium

Odogonium (Green algae) are free-living and were initially found in Poland's waters by W. Hilse in 1860. This kind of algae lives in freshwater environments and is both plankton and bottom dweller. It reproduces both sexually and asexually.

Classification

Kingdom: Plantae

Division: Chlorophyta

Class: Chlorophyceae

Order: Oedogoniales

Family: *Oedogoniaceae*

Genus: *Oedogonium*

6.9 Cell Structure

- Under a microscope, Oedogonium cells have a thin, cylindrical form.
- All filament cells are the same, except for the cells at the top (apical) and bottom (holdfast).
- The holdfast cell's extensive development on both of its disconnected sides helps the fiber adhere firmly to the substrate.
- The apical cell is wide and has a dome-shaped tip curvature.
- The single colorless cell in the filament is the holdfast. The number of caps on the cells in a filament indicates how many times a cell has split.
- The three layers that give filament its stiffness and protection are chitin on the outside, pectose in the center, and cellulose on the inside.
- Protoplasm have nucleus, reticulate, chloroplasts, a central vacuole and cytoplasm.
- The central vacuole contains a cell sap that is made up of inorganic substances, secretions, and excretions.
- The Oedogonium's cells also have the endoplasmic reticulum, mitochondria, and the usual Golgi apparatus. The nucleus is a big, oval-shaped structure that lies in the center of the cell (Figure 6.6).

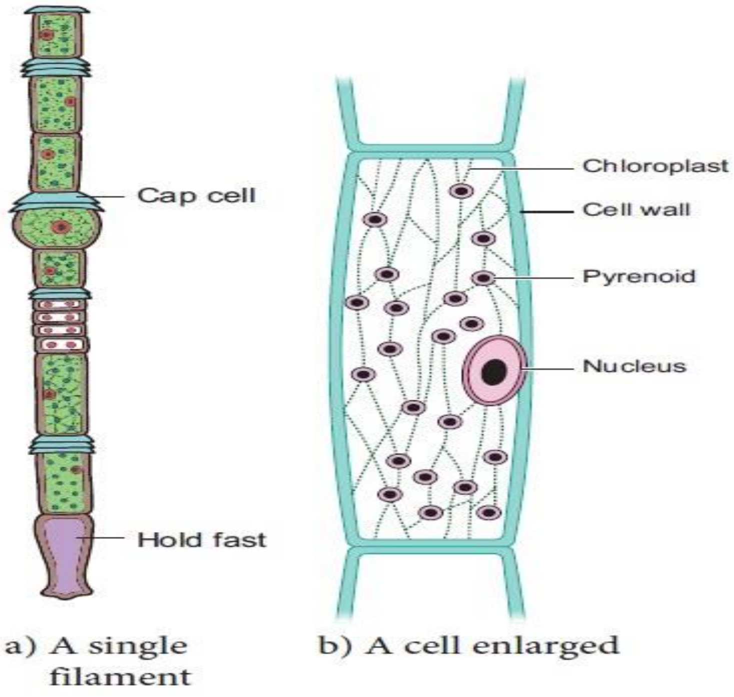


Figure 6.6: Structure of Oedogonium

6.10 Thallus Structure

The thallus, or green body of the algal, is made up of multicellular, unbranched filaments that are aligned end-to-end. The filament's cells are either free floating or have a holdfast holding them to the substratum. Two variants of the Oedogonium species are recognized:

A. **Macrandrous species**:

   The antheridia and oogonia, the normal-sized male and female sex organs, are carried by the filaments. Macrandrous monoecious organisms have their sex organs on the same filament. In macrandrous dioecious species, the sex organs of the male and female are developed in distinct filaments.

B. **Nannandrous species**: The oogonia and antheridia vary morphologically. This kind is consistently dioecious. The antheridia, often referred to as dwarf men, are quite tiny in comparison to oogonia. In the vicinity of the oogonium, the tiny male filaments attach to the female filaments.

6.11 Ecology of *Oedogonium*

- Found in both freshwater and marine water.
- They grow at pH range of 7.3 to 9.6 and it is very adaptable to different nutrient types and water levels in the body of water.
- The free-floating species create static habitats in the form of polyalgal patches or mat-like structures i.e. algal bloom. The secretions of various algal filaments form polyalgal mats. The majority of the benthic dwellers are juvenile. As they become older, they float to the top and create polyalgal carpets.
- Cladophora, Spirogyra, and Rhizoclonium are the many algal species that are present in the polyalgal mats. Oedogonium filaments often flourish in warmer conditions, such as those experienced in July and August. Holdfasts allow these species to cling to one another while they synthesise.

6.12 Reproduction in *Oedogonium*

Asexual Reproduction

- **Fragmentation:** When filaments rupture, each piece separates to form a new thallus. Because a single filament location can divide many times, some cells contain multiple caps.

- **Zoospores:** Zoospores aid in asexual reproduction in vegetative cell. The zoosporangium are forms on the vegetative cells that contain zoospores. Around the base of the zoospores a ring of flagella is present. The zoospores are released from the vesicle and drift freely for some time until they find a substratum, at which point they start to split into filaments.
- **Akinetes and aplanospores:** Large, immobile spores with thick walls that are joined to the parent cell's wall are known as akinetes. There is plenty of food behind the strong walls. Aplanospores are thick-walled, non-motile spores that have a wall that is distinct from the parent cell. In unfavorable circumstances, both of these spores remain dormant; when favorable circumstances return, they begin to germinate.

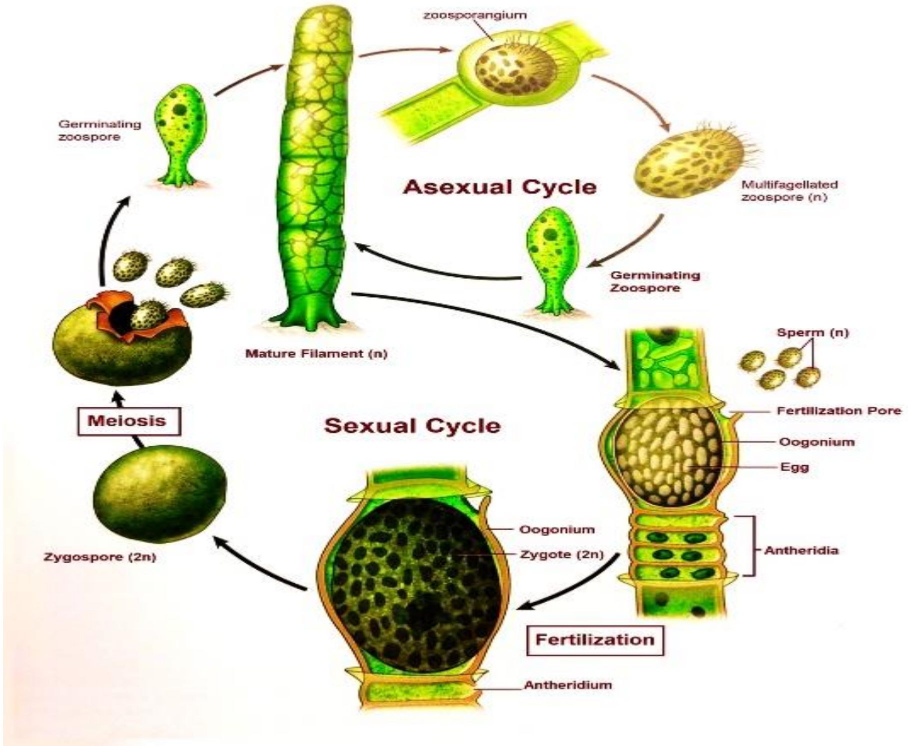


Figure 6.7: Life cycle of Oedogonium

6.13 Sexual Reproduction

Oedogonium reproduces sexually by oogamy. Both macrandrous and nannandrous species exist. In contrast to the antheridium, which may contain one or two multiflagellated sperm cells, each oogonium is composed of a single egg. The oogonia is chemotactically attracted to the motile gametes that are expelled from the antheridia. Through a hole in the oogonia, a single sperm cell enters, and fertilization occurs. Through meiosis, the zygote splits into four multiflagellated cells. These cells divide to create new filaments when each finds a substratum on its own. An Oedogonium has a haplontic life cycle.

6.14 *Vaucheria*

This alga is yellow-green in color and a member of the Xanthophyceae class. Most people refer to it as the "water felt." This species is widespread, with freshwater and marine habitats hosting the majority of its members. There are also some terrestrial species. They are frequently observed in ponds, salt marshes, estuaries, and moist farmlands. Nine of the genus's estimated 54 species are located in India.

Classification of *Vaucheria*

Kingdom	Chromista
Division	Xanthophyta
Class	Xanthophyceae
Order	Vaucheriales
Family	Vauchericeae
Genus	Vaucheria

6.15 Structure of *Vaucheria*

- The filamentous, branching, coenocytic, and siphonaceous thallus constitutes the plant body of Vaucheria (Figure 6.8).
- Although they have an aseptate shape for the most part, septa can emerge as a result of trauma or sex organ development.
- Rhizoids are responsible for attaching the terrestrial species of Vaucheria to the soil substrate. The species that float, however, lack or have poorly formed rhizoids.
- The outer wall of Vaucheria's filamentous body is thin and not as flexible.
- It is composed of two layers: cellulose for the inner layer and pectin for the outside.
- A central vacuole containing cell sap at the apices is found inside the filament.
- Chromatopores and a nucleus are present in protoplasts. Chromatophores are pigment-containing but pyrenoids-free elliptical or disc-shaped chloroplasts. It contains carotenoids, xanthophylls, chlorophyll a, and chlorophyll e. In the cytoplasm, food is seen as colorless droplets and is stored as oil.

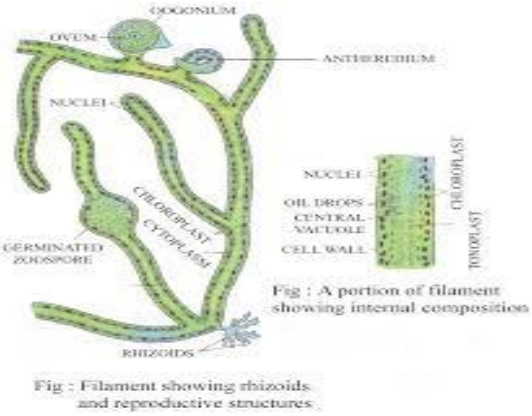


Figure 6.8: Structure of Vaucheria

6.16 Reproduction in *Vaucheria*

1. Vegetative Reproduction in *Vaucheria*

In Vaucheria, vegetative reproduction occurs through fragmentation. The genus's filaments may fracture as a result of mechanical harm from insect bites. At the place of damage, septa form, and the fractured fragments grow into a new thallus.

2. Asexual Reproduction in *Vaucheria*

1. **Aplanospores:** Non-motile spores known as aplanospores develop individually inside structures known as aplanosporangium. They develop at the apex of aerial hyphae under unfavorable circumstances. A transverse septum divides the club-shaped, non-flagellated aplanosporangium from the remainder of the thallus. The aplanospores split up the aplanosporangium's cell wall to form new filaments.
2. **Zoospores:** An individual zoosporangium contains single flagellated asexual spores called zoospores. At theapex of filaments, green, club-shaped structures called zoosporangia grow when a cross-wall separates the filament from the remainder of it.

   The zoosporangium's protoplast contracts at the moment of spore liberation, creating a small opening through which the spores are discharged. Once released, the zoospores are flagellated. The zoospores are ovoid, multiflagellate, multinucleate, yellowish-green structures with a tiny central vacuole.

3. **Kinetes:** Under unfavorable conditions, akinete formation occurs when filaments split into little segments by a thick gelatinous wall. The akinetes, which are often referred to as cysts or hypnospores, are tiny, multinucleate, thick-walled segments. This stage

is sometimes referred to as the Gongrosira stage because of the segmented filament's resemblance to the genus of Gongrosira algae (Figure 6.9).

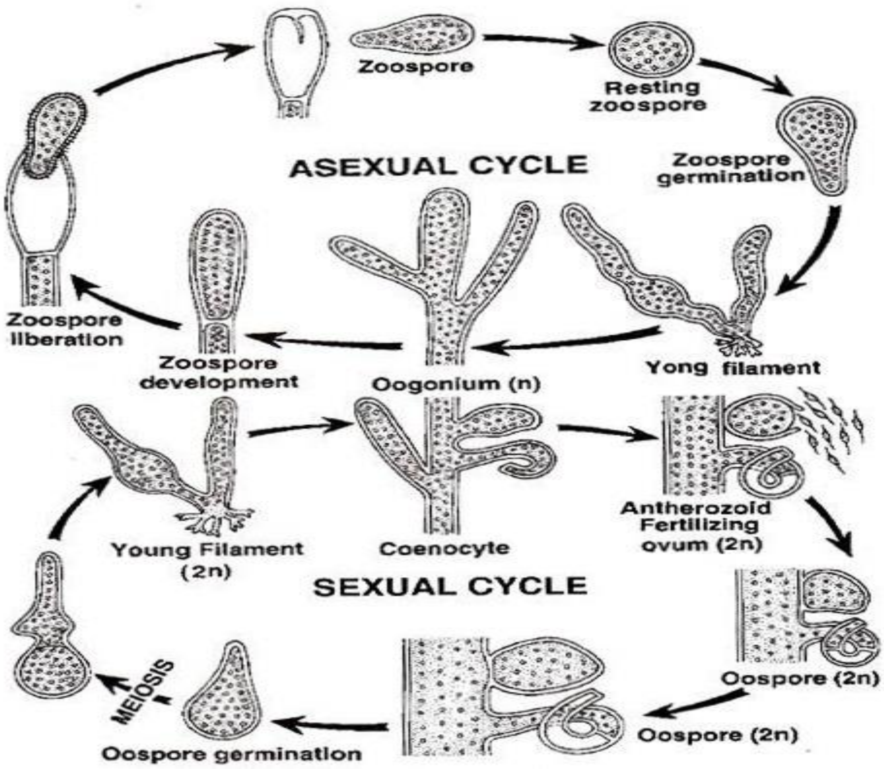


Figure 6.9: Life cycle of Vaucheria

Sexual Reproduction In *Vaucheria*

Vaucheria reproduce sexually by oogamous methods. The term "oogonium" refers to the female sex organ, whereas "antheridium" refers to the male sex organ. Vaucheria's plant body can be either heterothallic, in which case the male and female sex organs exist on separate plants, or homothallic, in which case both the male and female sex organs are produced near to one another on the same filament.

Development of Antheridium

A little lateral branch emerges from the Vaucheria filament to facilitate the growth of the antheridium. In the apex, the branch is aggregated with chromatophores and nuclei. A septum is then generated when the branch's of apex bends into the shape of a trumpet which separate The antheridium from rest of filament. The nuclei within the antheridium divide mitotically to produce biflagellated, spindle-shaped antherozoids. There are differences between the flagella; one is whiplash and the other is tinsel. At the apex, the antheridium opens, releasing antherozoids.

Development of Oogonium

Cytoplasm builds up and causes the base of the antheridial branch to protrude. This multinucleated mass of cytoplasm is called wanderplasm because it is colorless, contains a large number of nuclei, and lacks chromatophores. Numerous chromatophores travel in the wanderplasm, where the wall bulges out to produce an oogonial initial that ultimately enlarges.

The oogonial beginning continues to grow, eventually becoming an ovoid or spherical structure with a beak at the tip. Transverse septa are formed to keep them apart. All but one of the oogonium's nuclei degenerates throughout development. The ovum or egg is formed by this single nucleus.

Fertilisation

An opening forms in the antheridium when the oogonium ruptures during fertilization. A little quantity of cytoplasm is released by the damaged beak of the oogonium, causing several antherozoids to become entangled in the liquid and just one to enter the oogonium. When the antherozoids come into touch with the ovum, they shed their flagella and combine to create a diploid zygote.

Germination

After emerging from the oogonium, the zygote that developed inside it dormantly survive for a while. The zygote splits meiosally and mitotically to create a coenocytic structure when favorable circumstances arise. At some time, the zygote wall breaks, and the protoplasm stretches out to form rhizoidal aerial and first hyphae.

6.17 Red Algae

The first endosymbiotic event that gave rise to the first chloroplast is the ancestor of the red and green algae. Two membranes make up their plastids: an outside membrane from the creature that initially ingested it and an inside membrane that served as the cyanobacterial cell wall. The evolutionary history of all plants is reflected in the tale of several types of algae.

A unique type of algae, red algae have developed a variety of morphologies and techniques. *Asterocolax gardneri* is a red alga that parasitizes other red algae. Keep in mind that it lacks the Rhodophyta's distinctive hue. It doesn't need photosynthetic pigments since it feeds on other algae, negating the requirement for photosynthesis to produce its own food.

Morphology

There is a wide variety of morphologies in red algae. They could have one or many cells. Unicellular organisms can exist in colonies or in isolation. Multicellular organisms might resemble sheets, coralloids, filamentous, leafy, or even crusts. This group's red chloroplasts are caused by an excess of the red pigment phycoerythrin (Figure 6.10).

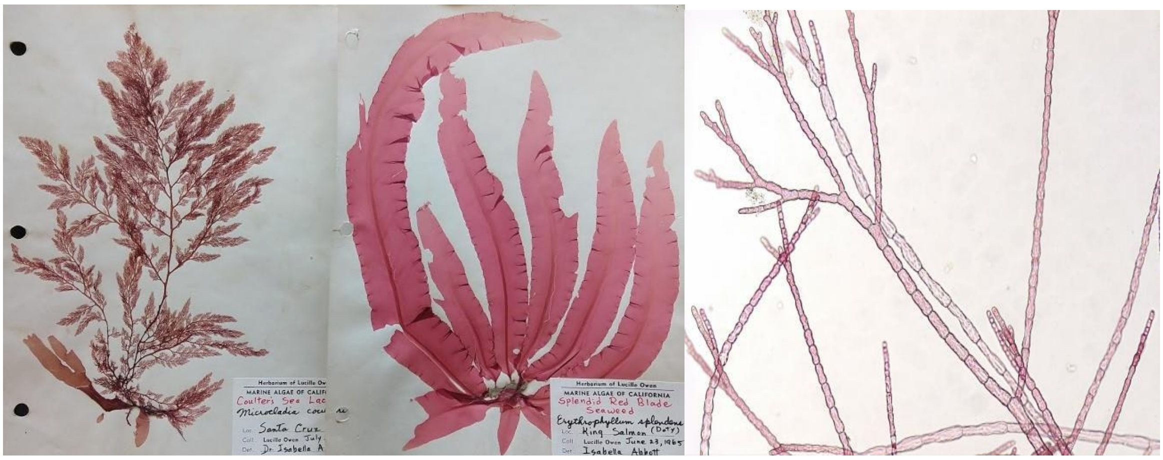


Figure 6.10: multicellular red algae.

6.18 Polysiphonia Life Cycle

The life cycle of red algae is characterized by generational alternations and the presence of a carposporophyte, an extra diploid stage. Polysiphonia is the model organism for Rhodophyta. Polysiphonia gametophytes share the same fundamental morphology since they are isomorphic (iso- meaning identical, morph- meaning shape) (Figure 6.11).

Figure 6.11: Polysiphonia structure

The Polysiphonia life cycle has a uniform fundamental shape across all phases. A little red thallus with delicate branches would be how they would all appear if you were not magnifying them. The reproductive structures—does it have tetrasporangia, cystocarps, or spermatangia—are utilized to distinguish between different life stages. Staining is the cause of any variations in color you may see in the photos in this section. All of them would show up on an unstained slide as this rich red tone.

Male Gametophyte

The tips of the thallus branches give rise to elongated structures on the male gametophyte. These are spermatangia, in which mitosis produces spermatia. gametophyte male Polysiphonia. The male gametophyte's branches in the picture on the left each terminate in a few elongated structures that resemble corn ears. These formations are all spermatangiums. A spermatangium is shown by itself, separated from the gametophyte, in the figure on the right. In order to create haploid, non-motile, unicellular gametes known as spermatia, cells in the spermatangum go through mitosis. The clarity of the photograph is inadequate to see individual spermatia (Figure 6.12).

Figure 6.12: Polysiphonia male gametophyte

Female Gametophyte and Carposporophyte

The carpogonium is a structure that houses the egg that the female gametophyte generates. A long, thin outgrowth on this structure is known as a trichogyne (trich- meaning hair, -gyne meaning female). A spermatium joins forces with a trichogyne during fertilization, and the spermatium's nucleus descends the tube to the egg. A zygote is created when the spermatium's nucleus joins forces with the egg's nucleus. The female gametophyte keeps this zygote and feeds it as it develops (Figure 6.13).

Figure 6.13: Female gametophyte

A gametophyte girl on a ready-made slide. The gametophyte fractured into several pieces during the slide-making process and had a vivid blue-green stain. The thallus would often be crimson in color (see the tetrasporophyte thallus). Numerous sizable, cup-shaped formations are affixed to the branches, suggesting that a cystocarp formed after fertilization of the eggs in these areas.

Cystocarps are the globose structures that protrude from the female gametophyte thallus. Both female gametophyte tissue (n) and carposporophyte tissue (2n) make up a cystocarp. The haploid pericarp, which derives from the female gametophyte, is the outermost layer of the cystocarp. The word peri- means surrounding. The diploid carposporophyte, which creates structures known as carposporangia, is what makes up the inside of the cystocarp, inside of which it produces **carpospores** by mitosis. All of these-carposporophyte, carposporangia, and carpospores--are diploid.

The haploid pericarp that makes up the structure's exterior is what makes up the cystocarp. The pericarp's cells have a blocky, almost scale-like appearance. The tissues that make up the pericarp are diploid and are associated with the carposporophyte. Numerous elongated carposporangia make up the carposporophyte (Figure 6.14).

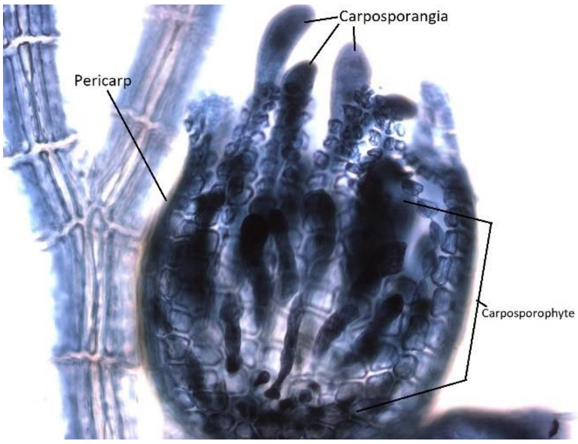


Figure 6.14: The image shows branches of the female gametophyte thallus.

6.19 Tetrasporophyte

Being released into the ocean, the diploid carpospores will go to a different place due to water currents. A carpospore will undergo mitosis to become a tetrasporophyte (2n) if it finds the right habitat. With the exception of the round, darker areas inside the branches, it resembles both the male and female gametophytes in appearance. Here, meiosis will take place to create haploid tetraspores, or tetrasporangia. The same thallus is enlarged and the tetrasporangia inside the branches (Figure 6.15, 16).

Figure 6.15: Unstained thallus of a tetrasporophyte.

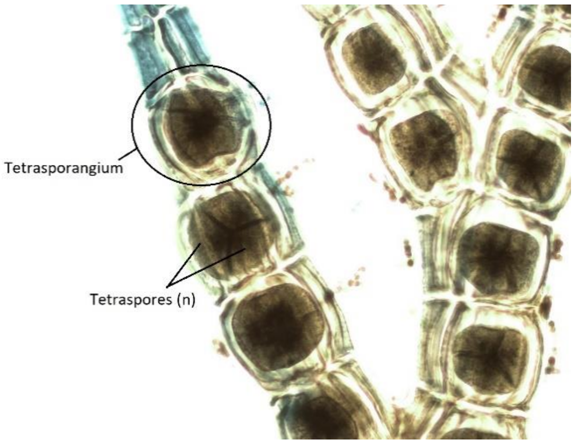


Figure 6.16 The image shows branches of the tetrasporophyte.

A massive tetrasporangium fills each compartment found inside the branches. In the majority of them, the meiotic division of the tetrasporangium into four separate cells is well delineated. These are tetraspores, haploid cells. Within the thallus' branches, the tetrasporophyte generates tetrasporangia (2n). By means of meiosis, every tetrasporangium generates four distinct haploid tetraspores. After being discharged, tetraspores (n) undergo mitosis to develop into gametophytes, which can be either male or female, which finishes the life cycle.

6.20 Life Cycle

Four haploid tetraspores are present. These tetraspores develop into either "male" or "female" haploid gametophytes during mitosis. At the terminals of its branches, the male gametophyte generates spermatangia, which undergo mitosis to become haploid spermatia. The female gametophyte produces the carpogonial branches, which have an egg at the base and a long filament called a trichogyne that extends from the egg chamber. When a spermatium and a trichogyne unite, the spermatium's nucleus descends the trichogyne and fertilizes the egg, creating a diploid zygote. The zygote develops inside a structure known as the cystocarp while it is still joined to the gametophyte. The pericarp, or outer layer of the cystocarp, is formed by the haploid tissue of the female gametophyte. Through mitosis, the zygote has grown into a carposporophyte inside the pericarp, generating elongated carposporangia. Within each carposporangium, mitosis creates diploid carpospores. After being discharged, carpospores develop into tetrasporophytes by mitosis. Tetrasporangia are generated within the tetrasporophyte's branches, where they go through meiosis to yield four haploid tetraspores (Figure 6.17).

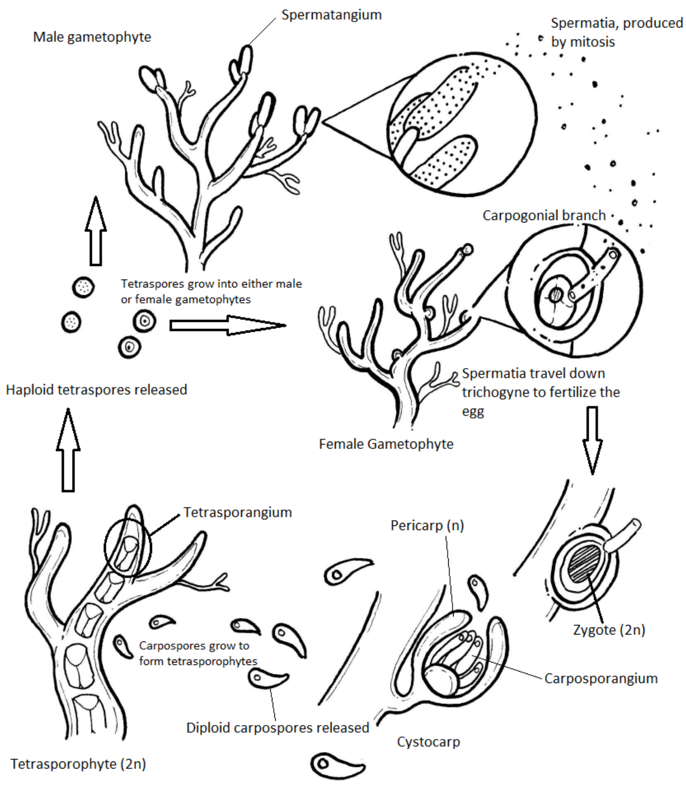


Figure 6.17: The alternation of generations life cycle of *Polysiphonia*

6.21 Role of algae in the environment, agriculture, biotechnology and industry.

All around the planet, algae are diverse in terms of size, shape, and color. While some algae may survive on their own, others must grow on soil, rocks, or other living things. These animals are vital because they generate a large amount of oxygen, which is necessary for human and animal respiration. Certain algae resemble plants, such as seaweed.

Algae may exist in a wide variety of environments and range in size. Phytoplankton is the term for the microscopic algae that swims or floats in lakes and seas. They lack branches, roots, leaves, and flowers, much like the majority of plants. Algae may range in size from single cells to enormous kelp. Algae are valuable because they may be used as fertilizer, feed, and a source of food for fish aquaculture. They may also be utilized for binding soil, aid in maintaining the pH balance of water, and be found in an extensive variety of items.

1. Algae as a Foundation of Food Chains

In both fresh and saltwater habitats, algae play a crucial role in several food cycles. Like plants on land, they feed on organic nourishment. Fish and other aquatic species depend on them for diet, either directly or indirectly.

Different freshwater and brackish water fish frequently utilizes variety of algae in their digestive tracts, including diatoms, filamentous algae, planktonic green algae, and blue-green algae, indicating that these algae are directly used as fish food. These algae are rich in nutrients that fish need, such as lipids, carbohydrates, sugars, glycogen, and polysaccharides.

2. Algae Useful in Fish Farming

Fish aquaculture depends heavily on algae. For instance, filamentous algae provides a food source for the Siamese fish *Tilapia mossambica*. Scenedesmus cultures are frequently eaten as a daily fish meal in India, where this fish has been effectively introduced.

3. Use of Algae in Recreational Purposes

In streams and lakes, where they live with fish and increase the area's overall visual appeal and recreational value, certain algae are purposefully planted.

4. Algae Usage in Sewage Treatment

Algae, including Chlamydomonas, Scenedesmus, Chlorella, and Euglena, are used in sewage treatment. These algae produce the oxygen needed for microorganisms to break down sewage quickly through photosynthesis.

5. Algae and Water Quality

Water blooms can result from an increase in algae, particularly phytoplankton, in lakes, ponds, and reservoirs throughout the summer. Excessive development of algae can cause scum to appear on the surface of the water with hazy, green or yellowish color. In addition to being unsightly, water blooms pose a risk to public water sources and leisure pursuits like fishing and swimming.

Toxins that are detrimental to fish and livestock can be released by certain algae, namely blue-green algae. Moreover, because of their organic matter composition, algae can make filtering procedures more difficult and raise the chlorine need needed to control bacteria in reservoirs.

6. Algae Useful for Petroleum, Gas, and Oil Formation

Scientists believe that, like coal, oil and gas are products of the photosynthesis of extinct plants. Oil and gas originate from decaying plants and animals in the sea, as opposed to coal, which originates in marshes. Plankton, which are microscopic marine plants, are vital. They migrate to animals that devour them after using sunlight to produce energy. In shallow water locations, the organic substance of the dead plankton accumulates in mud.

Because of the pressure and oxygen deficiency, this biological stuff eventually transforms into gas and oil. Certain bacteria may also produce natural gas, mostly methane (CH_4). Gas is frequently produced when methane-producing microorganisms interact with organic materials.

7. Algae's Role in Making Limestone

Certain algae absorb calcium from freshwater and seawater and store it as calcium carbonate within their cell walls. Together with some green algae and flagellates, blue-green and red algae are significant. Freshwater environments are vital for blue-green algae, which produce limestone close to glaciers and hot springs.

In the ocean, red algae are essential, particularly for coral reefs. The red algae that produce lime are almost as vital as the tiny creatures that build coral. They form limestone along beaches and are widespread in both warm and cold waters.

8. Algae Useful in Space and Science

Chlorella makes space travel easier by preserving clean air throughout lengthy flights. A container containing water, nutrients, and chlorella is filled with stale air that has too much carbon dioxide in it. Sunlight is used by the algae to convert carbon dioxide to oxygen. In fundamental scientific research, Chlorella, Chlamydomonas, and Acetabularia are also used.

9. Algae Usage as Food

For a very long time, people have consumed algae. Seaweeds were used as medicinal thousands of years ago, according to Chinese sources. Seaweed was consumed by the Japanese with rice. Made from a particular kind of seaweed, kombu is a dish from Japan. Hawaiians and Polynesians consumed a wide variety of seaweeds. In Europe, Irish moss was a common ingredient in blancmanges and other cuisines. Algae provide vitamins (particularly A and E, and to a lesser extent C and D), carbs, and iodine. They have a moderate laxative effect as well.

Green tea and chlorella are combined in Japan. The usage of mass-produced chlorella as animal and human food in Germany and the US has been investigated by researchers.

10. Algae Used as Livestock Feed

Livestock such as goats, cows, and sheep have been fed algae, especially marine algae. Certain regions, such as Iceland, Scandinavia, and the British Isles, let animals to nibble on seaweed during low tide. Animals fed algae exhibit improved digestion, and seaweeds were played with as feed for horses and cows throughout World War I, when food was in short supply in Europe.

11. Algae Used as Fertilizer

Seaweed is a useful soil fertilizer. Seaweeds were collected for manure in places like Britain and France. Their gradual disintegration and formation of humus, which is beneficial to plants, improves the quality of the soil. It has been discovered that adding specific kinds of blue-green algae to rice fields increases rice production.

12. The Use of Algae in Medicine

Traditional medicine has employed algae for a variety of purposes. For example, specific forms of algae were employed in Chinese medicine to treat stomach illnesses and glandular problems. Agar, which is derived from certain algae, has been used as a laxative and to treat gastrointestinal issues. In labs doing medical research, it has also proven crucial for the culture of germs.

13. Algae's Industrial Uses

Algae are also utilized in industry. In the past, Europe utilized "kelp" to extract soda for glassmaking. These days, alginates—chemicals with a variety of commercial applications-are extracted from algae. Agar, which is made by red algae, is widely used in medical labs.

6.21 Summary:

Algae exhibit a wide range of morphological diversity having various unicellular forms colonial Forms,filamentous forms, thalloid Forms, multicellular complex Forms. Algae exhibit diverse reproductive strategies i.e. Asexual Reproduction: Commonly include binary fission, fragmentation, and spore formation. This allows rapid population growth. Sexual Reproduction: Involves the fusion of gametes. Algae can have complex life cycles, often with alternation of generations, where they switch between haploid (gametophyte) and diploid (sporophyte) stages. Algae play important role in environment, agriculture, biotechnology, and industry and used to produce biofertilizes, oxygen production, improve soil structure and water retention, bioremediation, biofuel production, rich source of protein, aquaculture and in food industry

6.22 Self-Assessment Question

1. Spore with true cell wall present in life cycle of:

   (1) Sporozoans **(2) Slime moulds**

   (3) Both 1 and 2 (4) Amoeba

2. Dinoflagellates Can have colour:

   (1) Green (2) Red

   (3) Blue **(4) All**

3. Uncommon between Dinoflagellats and Diatom is:

   (1) Well defined nucleus (2) Chl a

   (3) Producers **(4) Presence of flagella**

4. Cell present in all Except:

   (1) Spore of Slime mould (2) Diatom

   (3) Plasmodium of slime mould (4) Nostoc

5. Chlamydomonas and Euglena differ in:

   (1) Chl a **(2) Motile**

   (3) Presence of Chloroplast (4) Under Protista

6. Structure which make body of euglenoids flexible is:

   (1) Flagella (2) Cell wall

   (3) Pellicle (4) All

7. Primitive relatives of Animals are

   (1) Protozoa (2) Euglenoids

   (3) Diatom (4) None

8. Amoeboid protozoans found in

   (1) Fresh water (2) Marine

   (3) Moist soil **(4) All**

9. Cell wall of Dinoflagellates made up of

(1) Soft cellulose plates **(2) Stiff cellulose plates**

(3) Stiff cellulose and silica plates (4) It is composed of calcium carbonate

10. Being.......... diatoms are use in Polishing and filtration:

(1) Digestible (2) Stiff

(3) Gritty (4) Flexible

11. In Diatoms the cell walls form two .... overlapping shells:

(1) Hard **(2) Thin**

(3) Thick (4) Stiff

12. Member of protista is primarily

(1) Decomposers **(2) Aquatic**

(3) Terrestrial (4) Parasitic

CHAPTER – 7

Fungi

Objectives

At the end of chapter student will be able to:

- Understand the general characterstics features of fungi.
- Differentiate the range of thallus organization, reproduction, life cycles and importance of various fungal groups.
- Categorize the diversity of various fungal groups, their modes of nutrition and reproduction benefits and importance

7.1 Introduction

Fungi constitute a large and diverse group of plant kingdom. The Latin word '**fungus**' means **mushroom**. Thallophytes that are both heterotrophic and achlorophyllous are fungi. They belong to the category Thallophyta since they share several characteristics with algae. Mycology (mykes = mushroom; logos = study) is the study of fungi, and the scientists who research fungi are called mycologists. There are between 50,000-1, 00,000 recognized species of fungi in the world (Figure 7.1). Approximately 5100 genera and 50,000 species of fungus exist today. The worldwide research that is being conducted is the reason behind this number's continuous rise

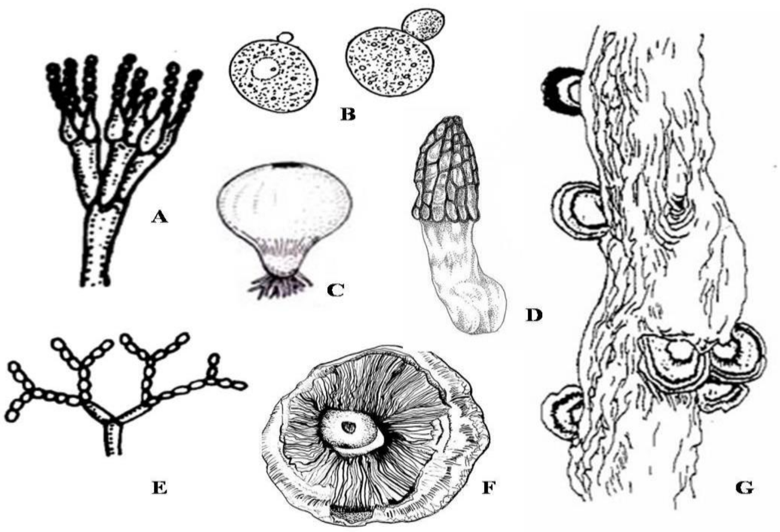
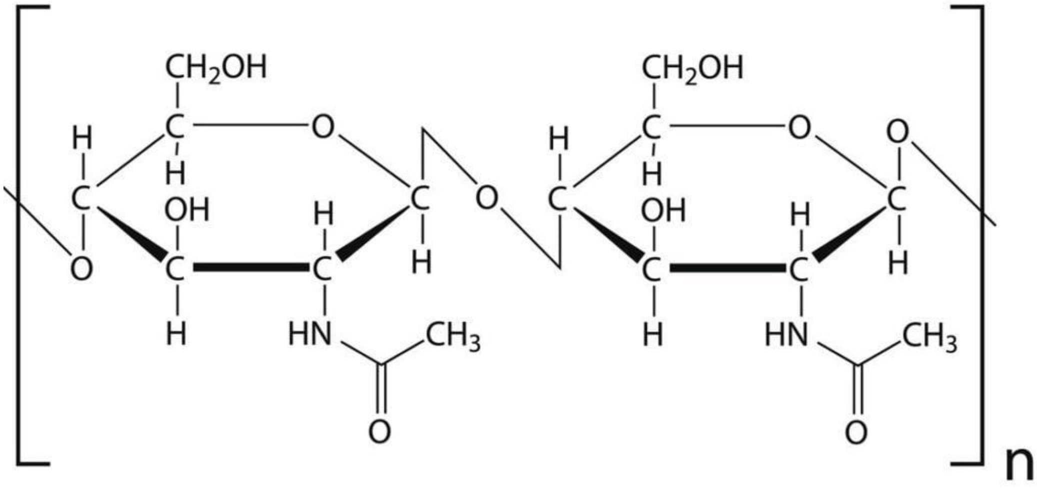


Figure: 7.1 Various fungi and their fruiting bodies. A: *Penicillium*, B: *Saccharomyces cerevisiae* (Yeast), C: *Lycoperdon* (Puff ball), D: *Morchella* (Morel), E: *Neurospora*, F: *Agaricus* (Mushroom), G: Bracket fungi on tree trunk

They exhibit great diversity in terms of form, plant body structure, physiological functions, and methods of reproduction, and they grow in a range of settings. Except in a few instances when mycelium is either entirely absent (*Synchytrium*) or the plant body is unicellular (*Saccharomyces* species), hyphae make up the majority of the plant body. True cellulose does not make up their cell wall. Either chitin or fungal cellulose makes up this substance. The three modes of nutrition that fungus uses to survive are saprophytic, parasitic, and symbiotic since they are unable to synthesis food from carbon dioxide and water when exposed to sunlight. As a saprobe, they promote the decomposition of organic matter; as a parasite, they assault live protoplasm and infect humans, animals, and plants. Glycogen and lipids are the main foods used as reserves. They don't produce starch since they don't have chlorophyll. Three methods of reproduction are used: vegetative, asexual, and sexual.

7.2 Characteristics of Fungi:

- Fungi are eukaryotic creatures; fungal body is unicellular with cell wall and have microscopic threads called hyphae
- They are non-vascular due to the absence of any specialized transport tissue
- They are heterotrophic and feed on preformed organic material
- They use spores to reproduce. Asexual spores -sporangiospores, Aplanospores, Zoospores, Conidia, and sexual spores include Oospores, Zygospores, Ascospores, and Basidiospores, among others.
- Mostly immobile.
- Both haploid and diploid stages exist in them.
- Fungi are achlorophyllous, they lack the pigments called chlorophyll that are found in plant cells' chloroplasts and are essential for photosynthesis.
- The fungus's vegetative body might consist of tiny threads known as hyphae or it can be unicellular.
- Hyphae are able to proliferate and create myceliums, which are networks.
- Unicellular fungi without hyphae are called yeasts.
- Although the fungi's cell wall structure is similar to that of plants, it is chemically made up of chitin $(C_8H_{13}O_5N)_n$.



7.3 Structure of Chitin

- A unique kind of sterol and ergosterol can be found in the cell membrane of fungus.
- Heterotrophic creatures are fungi. They eat organic materials, including plant and animal remains, to acquire food and energy.
- An acidic atmosphere is ideal for fungal growth (tolerate acidic pH).
- Fungi manufacture various enzymes that help them digest food before ingesting it.
- Food is stored as starch by fungi.
- Fungi are the source of chitin biosynthesis.
- A lot of fungus have tiny nuclei that contain DNA.
- The nuclear envelope does not disintegrate during mitosis.
- Fungi are classified as saprophytes, which derive their energy from decomposing and dead materials, parasites, which dwell inside their hosts and assault and kill them, and symbionts, which benefit each other mutually.
- Optimum temperature for saprophytic fungi is 20–30°C, and parasitic fungi is 30-37°C.
- There are two modes of reproduction: asexual (Anamorph) and sexual (Teliomorph): Asexual techniques: asexual spore production, fission, somatic budding, and fragmentation. Sexual procedures include spermatization, gametic

copulation, somatic copulation, gamate-gametangium copulation, and gametangium copulation.

- Fungi create a molecule called a pheromone, which facilitates sexual reproduction between male and female fungal cells.
- Some fungi are macroscopic and visible to the naked eye. Among the macroscopic fungi are mushrooms and mold.
- A study published in 1991 calculated that there are 1.5 million species of fungus on Earth.
- There are only around 300 fungal species that may infect humans.

Examples: *Candida albicans, Aspergillus, Blastomyces, Coccidioides, Cryptococcus neoformans, Histoplasma, Pneumocystis jirovecii,* etc.

7.4 Ecological significance

Since fungi lack chlorophyll, they are unable to produce food through photosynthesis like plants can. Rather, they resemble mammals and are heterotrophs. However, they lack a mouth and teeth. Thus, what does fungus "eat"? They take in organic chemicals from other living things and use them as food. Depending on the type of fungus, the other creatures might be living or dead.

Fungi as Decomposers

Organic chemicals are obtained by most fungus from deceased organisms. They are saprotrophs, which are decomposers. After other decomposers have finished their job, a saprotroph feeds on whatever organic matter that is still there. Enzymes are used by fungi to break down organic materials, which they then absorb the resultant organic molecules. Fungi are essential to ecosystem health since they are decomposers. They liberate the nutrients from nonliving organic materials and discharge them into the soil. After being used by plants, the nutrients can be transferred to herbivores and other consumers.

Although they can only develop and feed on the exposed surfaces of organic materials, bacteria are also important decomposers. On the other hand, fungus can delve deeply into organic stuff thanks to their hyphae. Additionally, only fungi are capable of decomposing strong plant materials like cellulose found in plant cell walls and lignin found in wood.

Special enzymes enable them to carry out this task. The tips of the hyphae release the enzymes. Due of these properties, fungus are the main forest decomposers (Figure 7.2).

Figure:7.2 Forest Decomposers "fungi"

These wild mushrooms appear delicate, yet they are rather effective. Dead wood and other difficult plant material are broken down by them.

Symbiotic Relationships of Fungi

Not every type of fungus consumes dead things. Numerous symbiotic relationships—including mutualism and parasitism—are present.

Fungi as Parasites

The parasite benefits and the host suffer when two organisms coexist. In order to thrive, parasitic fungi must consume the remains of other living beings. Owing to special features, fungi can infiltrate a host. They also produce the enzymes that cause the host's tissues broken down easily. Parasitic fungi can kill their host and are often the cause of diseases. In agricultural plants, they are the primary cause of diseases.

Fungi as mutualistic partner

Numerous mutualistic connections exist between fungi and other living organisms. In mutualism, the partnership is advantageous to both species. Two typical examples of mutualistic connections between fungus are lichen and mycorrhiza.

A mycorrhiza is a mutualism between a plant and a fungus. The fungus grows in the roots of the plants. Food is easily accessible from the plant, which is advantageous to the fungus. The fungus creates mycelia, which help the plant absorb water and nutrients.

A mutualistic partnership between a photosynthetic organism and a fungus is known as a lichen (Figure 7.4). Green algae or cyanobacteria often make up the other organism. Around the bacterial or algal cells, the fungus proliferates. The photosynthesizer's continuous production of food provides the fungus with an advantage. The water and nutrients that the fungus absorbs are beneficial to the photosynthesizer. Lichen lacks roots, unlike plants, so it may grow on exposed rocks. Lichens are hence frequently referred as pioneer species in the initial ecological succession.

Figure:7.4 Lichen Growing on Rock.

Certain fungus and insects have mutualistic connections. For instance, in their nests, leafcutter ants cultivate fungus on leaf beds. The fungus are given a safe haven to live in. The fungus are fed to the ants' larvae.

Ambrosia beetles "plant" fungal spores in the holes they pierce in tree bark. The fungus has a perfect growing environment in the pores in the bark. From their "garden," the beetles gather fungus for food.

Fungi for Food

For thousands of years, people have planted and harvested mushrooms for nourishment. Yeasts are used to make alcoholic drinks and to bake bread. Other fungi are employed in the fermentation process of a broad range of foods, such as cheeses, tempeh, and soy sauce. Blue cheese gets its unique flavor and look from the fungus that grows through it.

Fungi for Pest Control

Harmful bacterial and insect infestations on crops can be controlled with fungi that are safe to use. Insects that eat plants are parasitized by fungi, which also compete with bacteria for resources and available space. Fungi reduce the need for pesticides and other dangerous substances.

Other Uses of Fungi

- They are a significant supplier of vitamin C, or citric acid.
- They create medicines like penicillin, which have prevented countless deaths.

7.5 Thallus Found in Fungi

The following points highlight the two main types of thallus found in fungi with their diagrams.

The types are: 1. Unicellular Thallus 2. Filamentous Thallus.

Unicellular Thallus:

A thallus is essentially a spherical, single-celled structure found in certain minor fungus, such as chytrids (A). When it reproduces, it changes into a reproductive entity. It is these that produce the asexual or sexual cells. They are known as holocarpic mushrooms. The reproductive and vegetative phases do not coexist on the same thallus in them (Figure:7.5).

The vegetative phase of Plasmodiophora is characterized by a naked, multinucleate amoeboid mass of protoplasm (D). We call it Plasmodium. The diploid Plasmodium protoplast splits to create the resting spores. A unicellular thallus is also present in the yeasts, which are connected to the filamentous forms (B). The mycelium is missing in the unicellular holocarpic forms.

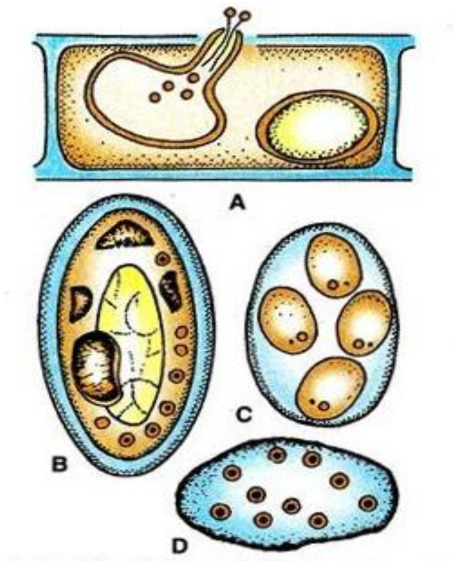


Figure:7.5 (A-D) Fungi.Unicellular Holocarpic Thalli.A, *Olipidium endogenum* (holocarpic chytrid),two organism within the algal host;B,),two organism within the algal host;B, Yeast, unicellular thallus;C, Reproduction phase of B:D

2. Filamentous Thallus:

The filamentous thallus is present in the great majority of fungus. The process begins with spore germination. As soon as the spore touches down on an appropriate substratum with favorable environmental conditions, it begins to germinate. In certain species, the spore merely develops into a brief, tubular form with restricted development during germination.

It is referred to as a hypha in technical terms and makes up the thallus. Nonetheless, the majority of fungi produce fluffy thallus from their spores, which are composed of a cottony mass of fine, branching filaments. The term "hyphae" refers to these long, delicate filaments (sing, hypha). When they reach a particular maturation level, some of these hyphae extend into the air and carry the reproductive bodies.We refer to these fungi as eucarpic. All of the hyphae come together to form the mycelium, or vegetative body (thallus) of a fungus. Thus, one of the mycelium's structural components is the hypha. It is made up of a thin, translucent wall that is lined or filled with cytoplasm.

Substratum is the term for the medium in which the mycelium grows. In the life cycle, the structure that obtains nourishment is the mycelium. It continues to perform the normal functions of a plant cell, excluding photosynthesis, including growth, respiration, digestion, excretion, and absorption. A loose, ramifying network is formed when the hyphae that make up the mycelium branch spread out in all directions either within or above the substratum.

In general, hyphae are colorless, especially when they are enmeshed in the substratum. In certain mushrooms, the aerial hyphae take on color. The typical tints include orange, yellow, red, blue, and brown. Typically, the color is limited to the hyphal wall.

The colors are not an essential component of the living being, even if they exist in the protoplasmic contents. The fungus's physiology is unaffected by the pigments. Apical refers to the lengthening that occurs at the ends of the hyphae.

Hypha: The microscopic structures known as fungal hypha are confined by a strong cell wall, contain protoplasm, and can be both dark and pigmented in shades of brown and yellow or hyaline, or colorless. Its diameter remains relatively constant, ranging from 2 to 20 μm, and it develops indefinitely only at its tip. Neighboring hyphae in the thallus produce short branches during this phase that touch at the tip and may eventually develop contact with one another. The hyphae's wall dissolves at the site of contact over time, connect of the two to form a continuous tube. This mechanism facilitates the production of a robust mycelial network, effective cytoplasmic development, nucleus exchange, and coordinated tissue growth.

The lengthy, multinucleate hyphae of lower fungus belonging to the Zygomycetes and Oomycetes families are made up of continuous cells known as coenocytes (Figure7.6). It is either non-septate or aseptate hyphae. Even in these situations, where reproductive structures are forming, septa are generated to delimit aged hyphae. The hyphal protoplasm of Ascomycetes, Deuteromycetes, and Basidiomycetes, or higher fungi, is periodically disrupted by cross walls or septa (sing. septum). In this instance, hypha is referred to as septate hypha. But because of the cross wall perforations, the protoplasm is still continuous throughout the fungal hypha

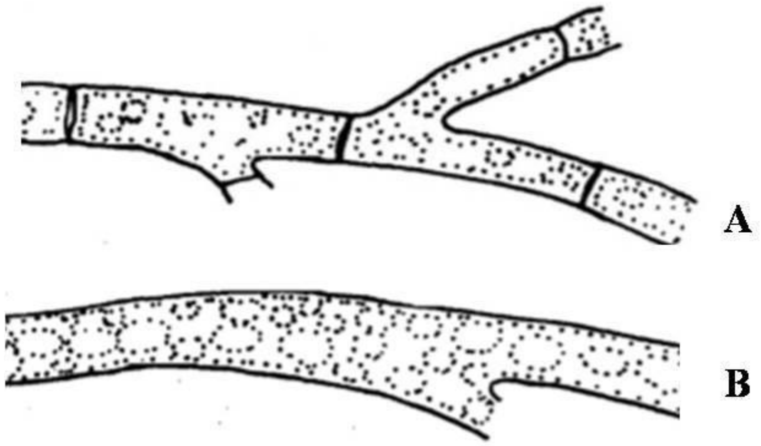


Figure:7.6 Fungal hypha A: Septate B: Non-Septate or aseptate

Primary and adventitious septa are the two different types. Centripetal division of the cells from the hyphal wall inward forms of septa. Nuclear division between daughter nuclei forms primary septa, but changes in cytoplasm concentration as the material travels from one area of the hyphae to another causes adventitious septa to form independently of nuclear division.

Ascomycetes have a small, simple pore in the middle of their septa that keeps the cytoplasmic continuity intact. Basidiomycetes (apart from rusts and smuts) also have perforated septa, but they are slightly different in that they have a barrel-shaped inflation with a hemispherical perforated membrane on either side of the aperture known as dolipore septum. When each cell of the septate hyphae has genetically identical nuclei, the fungal mycelium is referred to as homokaryotic. Conversely, some fungal mycelium has nuclei of a distinct genotype that develop from hyphae that have undergone anastomosis or mutation; these hyphae are referred to as heterokaryotic (Figure: 7.7).

Individuals belonging to the Basidiomycetes phylum may contain two nuclei that differ in genetic makeup (dikaryotic) or one haploid nucleus that is genetically similar in every segment (monokaryotic).

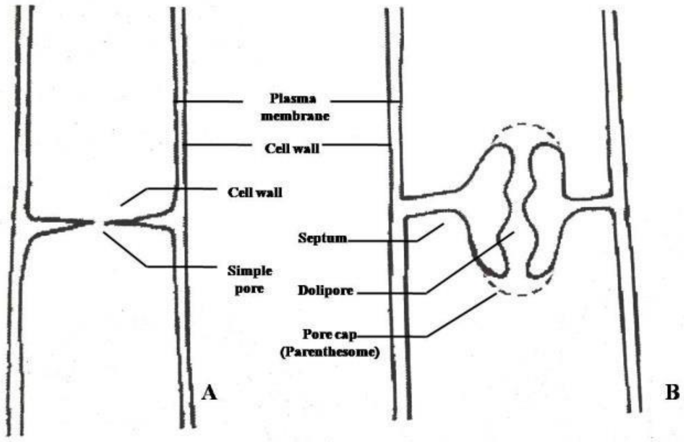


Figure: 7.7 Types of primary septa. A: Simple septa, B: Dolipore septum with a parenthesome

Fungal hyphal aggregations: Throughout their life cycle, all fungi exhibit varying degrees of hyphal aggregation, from loosely to tightly connected tissues. Plectenchyma is the term used to describe all such structured fungal tissues. There are three main categories of plectenchyma
(Figure 7.8):

(i) **Prosenchyma** – It is a loosely twisted tissue with hyphae that are roughly parallel to one another and elongated cells that can usually be distinguished from one another.

(ii) **Pseudoparenchyma –** It is made up of thin-walled, isodiametric, or oval cells that are closely packed together. It resembles the parenchyma of vascular plants.

(iii) **Pseudosclerenchyma** It is made up of black, densely packed cells with thick walls.

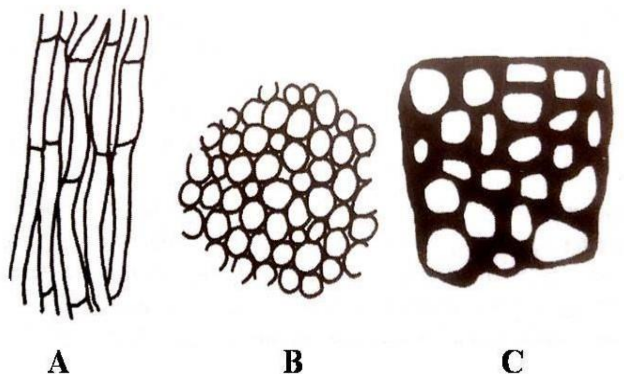


Figure: 7.8 Types of plectenchyma. A: Prosenchyma, B: Pseudoparenchyma, C: Pseudosclerenchyma

Different vegetative and reproductive structures, including mycelial strands, mycorrhiza, rhizomorph, stroma, sclerotia, and sporophore, are formed by plectenchyma.

(i) **Mycelial strands:** Many Deuteromycetes members and Basidiomycetes exhibit mycelial strands. These are the collections of rather homogeneous, parallel hyphae. One or more leader hyphae, which emerge from the thallus margin and are encircled by their own interweaving and anastomosing branches to form a cord (1-2 mm thick and a few centimeters long), are the center of a mycelial strand. Mycelial strands play a role in material translocation and are the mechanism by which fungi can spread to a new substrate from an established food source.

(ii) **Mycorrhiza:** The symbiotic relationship between plant roots and fungal hyphae, primarily Agaricales, is known as mycorrhiza. Coniferous and deciduous plants' root tips frequently consist of many layers of fungal cells. To build the "Hartig network," fungal mycelium grows into the soil layer and then inside the root's cortical cells. By taking the place of the roots, the expanded fungal mycelium aids in the improved absorption of minerals from the soil. Mycorrhizal-associated roots perform better than non-mycorrhizal roots.

(iii) **Rhizomorph:** Rhizomorphs, which are highly differentiated root-like hyphal aggregations, are named from the Greek words rhiza, which means root, and morphe, which means shape. They have an elongated, thin-walled central core, smaller, highly colored cells, and a rind. The parasite of trees and shrubs Armillaria mellea is the source of these. Rhizomorphs facilitate the fungus's ability to move between root systems.

(iv) **Stroma:** The stroma is a compact hyphal aggregation that forms fructifications, like a cushion or mattress. These observed in members of the Deuteromycetes, Basidiomycetes, and Ascomycetes taxa as different kinds of sporodochia, acervuli, pycnidia, ascocarp, and basidiocarp.

(v) **Sclerotium:** A hard resting body called a sclerotium (plural: sclerotia) is created when somatic hyphae group together. They may consist of flattened, elongated, or spherical masses that are distinctive to a given species in terms of size, form, and color. The majority of sclerotia do not grow larger than 2 cm in diameter, while microsclerotia (*Macrophomina phaseoli*) can have a diameter of less than 100 micrometers. Sclerolithia in *Polyporus myllittae* have a diameter of more than 25 cm and a weight of several kg. These are used for storage and serve as a propagule, assisting the fungus in surviving under unfavorable environmental conditions.

(vi) **Sporophore**s: Usually upright and aerial, sporophores may be branched (Peronospora) or unbranched (Albugo), and they may possess sporangia (Albugo) or conidia (Peronospora) on them. Sporangiophores are sporophores that bear sporangia, and conidiophores are sporophores that bear conidia. Pycnia, hymenia, sporodochia, and acervuli are formed by sporophores, which are frequently found in groups.

7.5 Nutrition

Fungi cannot produce their own food since they are non-chlorophyllous, in contrast to green plants. They are unable to even directly consume inorganic food from the soil due to their extremely basic structure. Moreover, all fungi are entirely heterotrophic and lack plastids, which is another characteristic that unites them. They must therefore get their nourishment from the surrounding environment or from living, dead, or dying organisms. Based on this, the types of fungus are listed below.

Biotrophs: These are the group of fungi which obtain their food directly from living host tissues only. Biotrophs secrete chemicals which increases the permeability of membranes to sugars and amino acids. The host cell starts leaking sugars and amino acids which is absorbed by the fungi. During this type of interaction, fungal cells remain confined to the intercellular spaces and obtain nourishment through **haustoria** (pl. **haustorium**). Haustoria are the outgrowth of vegetative hyphae which increase the absorptive surface area of the parasitic fungus. They penetrate the host cell and with a miniature pore and come in contact with the plasma membrane of the host cell. Haustoria can be knob like (*Albugo*), elongated or branched (*Peronospora*) and highly branched (*Erysiphe*). A special group of fungi are biotrophic mycoparasites which have the ability to parasitize mycelia of other fungi, but do not cause any damage to the host cell, as they are not able to grow on dead organic substratum. Some of the common examples are *Piptocephalis virginiana* (Zygomycetes) that can parasitize *Mucor* hypha.

Types of haustoria

A: Knob-like in *Albugo*

B: Highly branched in *Erysiphe*

C: Elongated capitate in *Peronospora*

D: Elongated digitate in *Peronospora*

The fact that one partner (fungi) gains while the other suffers makes this interaction also known as a parasitic one. Obligate parasites, such as *Melampsora, Peronospora,* and *Puccinia,* are parasites that can only thrive on their living host.

Develops on dead organic culture media are not suitable for these. However, facultative saprophytes—such as *Taphrina deformans* and other smuts—are parasites that normally live on living things but can briefly switch to a saprophytic way of existence when necessary.

Certain fungal species, such as *Fusarium* and *Pythium*, are known as facultative parasites because they parasitize compatible hosts under specific environmental conditions, despite the fact that they typically pass through the saprophytic mode of life cycle.

Different parasites use different methods to absorb food from their host. Fungi classified as ectoparasites (Erysiphe) have their mycelium outside of the substratum or host, whereas endoparasites have their mycelium lodged in the host tissue. To improve nutrient absorption, both of these types of fungi produce haustoria.

Hemibiotrophs are a unique class of plant pathogenic organisms. These are the fungi that initially need living cells, but as their hyphae spread, they kill the host. A few well-studied instances of hemibiotrophs are the peanut leaf spot disease *Cercosporidium personatum* and the anthracnose fungus *Colletotrichum lindemuthianum*.

Necrotrophs or Perthotrops: These are the fungi that assault living cells with such virulence that, in the early stages of their parasitic life, they kill the host cells and feed on the dead tissue. Additionally, they might release poisons that harm the host cell's plasma membrane, allowing nutrients to seep out and make themselves readily available to the fungus. Mycoparasites that feed on dead fungi can parasitize and destroy other fungi. For instance, *Trichoderma viride* can encircle and destroy the living hypha of a variety of different fungus, including *Rhizoctonia solani* (Figure:7.9).

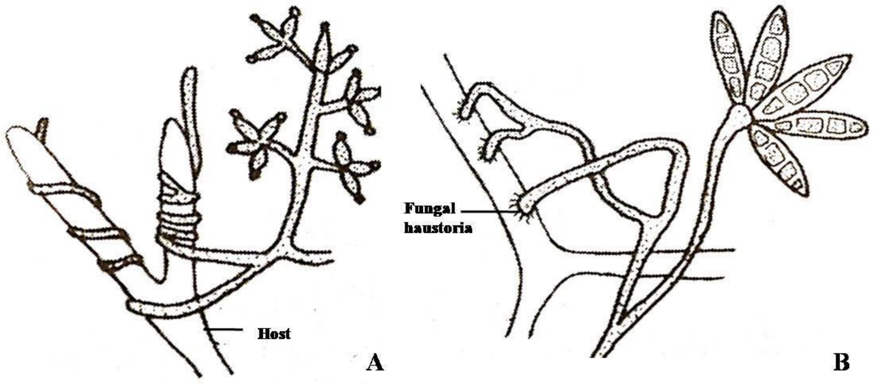


Figure:7.9 Necrotrophs feeding on other fungi. A: *Trichoderma viridae* coiled around hyphae of *Rhizoctonia solani*, B: Biotrophic mycoparasite has formed haustoria on hyphae of *Mucor*.

There are specific fungal groups that utilize protozoa, rotifers, or eelworms and have evolved unique techniques to catch these creatures. A ring that quickly constricts around a nematode is one of the most intriguing methods. This ring confines the worm until the hypha develops haustoria within the nematode's body. The victim's haustorium takes up food from their body, which causes them to eventually pass away. This technique is used by fungi belonging to the genus *Arthrobotrys, Dactylella*, and *Dactylaria.*

Saprotrophs: Through their wall, these fungi release extracellular and digestive enzymes onto the decomposing organic matter. These enzymes break down the substrate polymers into monomers (sugars, monosaccharides, and amino acids), which are then easily absorbed by the Saprotrophs' vegetative hyphae through deep substratum penetration. *Aspergillus, Agaricus, Morchella, Penicillium, Rhizopus*, and *Saprolegina* are a few exemplary saprophytes. When it comes to saprophytic fungi, the mycelium can be either endophytic—where the rhizoid is embedded in the substratum—or ectophytic, where the rhizoid is on the substratum (Rhizopus).

Mutualistic symbionts: Positive interaction and mutual benefit are found in mutualistic symbiosis. Certain fungal species, including lichen and mycorrhiza, engage in mutualistic partnerships with other organisms and gain nutritional advantages from these relationships. Algae and fungi work together symbiotically to create lichen. The fungal partner aids in the absorption of water and inorganic nutrients, while the algal partner synthesizes organic food. Mycorrhiza development takes place and certain fungal species develop in the roots of higher plants. A fungus facilitates improved soil nutrient absorption. Mycorrhiza can be found inside or outside. Ectophytic mycorrhiza, also known as external mycorrhiza, is limited to the outside layer of roots. On the other hand, the mycelium of internal mycorrhiza is firmly lodged in the root cells.

7.6 Classification of Fungi

Taxonomy: The study of the naming and classification of living things is known as taxonomy. A binomial is a name for a species that has two parts. The genus (plural: genera) is the first component, while the specific epithet is the second. Homo sapien, for instance, is the species designation for humans. When writing, the binomial is underlined or italicized to highlight the species name. After a species has been identified by science, it is assigned a specific species name. Put another way, a species has only one legitimate scientific name that applies to it, independent of its geographic location.

All organisms are classified into three domains:

A very recent addition to the classification hierarchy is the Domain level. There are five Kingdoms within the Domain Eukarya: Plants, Animals, Fungi, Stramenopila, and Protista. Different from the other kingdoms, fungi are highly unique. Organisms that do not belong in the first three kingdoms are deposited in the Kingdom Protista. The kingdom Stramenopila contains a variety of algae, including brown algae and various other varieties, as well as extant fungi like Oomycota.

Fungi are classified on the basis of:

i. Reproductive structures
ii. Types of spores
iii. Features of life cycle
iv. Morphology
v. Habit and Habitat

As a kingdom apart from plants, animals, and bacteria, fungi are categorized. One significant distinction is that, in contrast to plant cell walls, which include cellulose, fungal cells have cell walls made of chitin. These and other variations demonstrate that the fungus are a single, related group of organisms known as the Eumycota (real fungi), who are a monophyletic group that shared a common ancestor. This fungus is not to be confused with the structurally related water molds (oomycetes) and slime molds (myxomycetes).

Fungi were divided into two kingdoms (according to Ainsworth):

(a) Myxomycota, or slime molds
(b) Eumycota, or real fungi.

Five subdivisions were identified within the Eumycota group, namely:

i. Mastigomycotina (lower fungi)
ii. Zygomycotina (lower fungi)
iii. Ascomycotina (higher fungi)
iv. Deuteromycotina (higher fungi) and
v. Basidiomycotina (higher fungi)

Sub- Division: Mastigomycotina was categorized into four classes:

(i) Chytridiomycetes
(ii) Hyphochytridiomycetes,
(iii) Oomycetes and
(iv) Placodiophoromycetes

7.7 Reproduction of Fungi

Reproduction in fungi takes place by three methods:

(i) Vegetative reproduction
(ii) Asexual reproduction
(iii) Sexual reproduction

(i) Vegetative reproduction: Somatic hypha involve in this type of reproduction. It occurs by following methods (Figure7.10)

a) **By fragmentation:** During this phase, the mycelium accidently splits into two or more comparable pieces, or an outside force causes it to break. Every piece develops into a fresh mycelium. Example- *Rhizopus, Mucor, Pythium,* etc.

b) **By budding:** One or more projections known as buds are produced by the parent cell. These buds then mature into the essential structures and separate to become new individuals. Yeast and other unicellular organisms frequently undergo budding. Example-*Saccharomyces*

c) **Fission:** This process creates two equal halves from the parent cell, each of which grows into a new person. Yeast is also prone to fission. Example-*Saccharomyces*

d) **Sclerotia:** In certain instances, the hyphae intertwine to create a compact mass that is encased in a tough rind. These structures, known as sclerotia, are latent in unfavorable environments and sprout into new mycelia when favourable conditions return.
Example- *Claviceps*

e) **Rhizomorphs:** Multiple hyphae in certain higher fungi may intertwine to create structures resembling ropes. These structures are known as rhizomorphs. When the environment is right, they grow again and produce new mycelia. Example-*Armillaria*

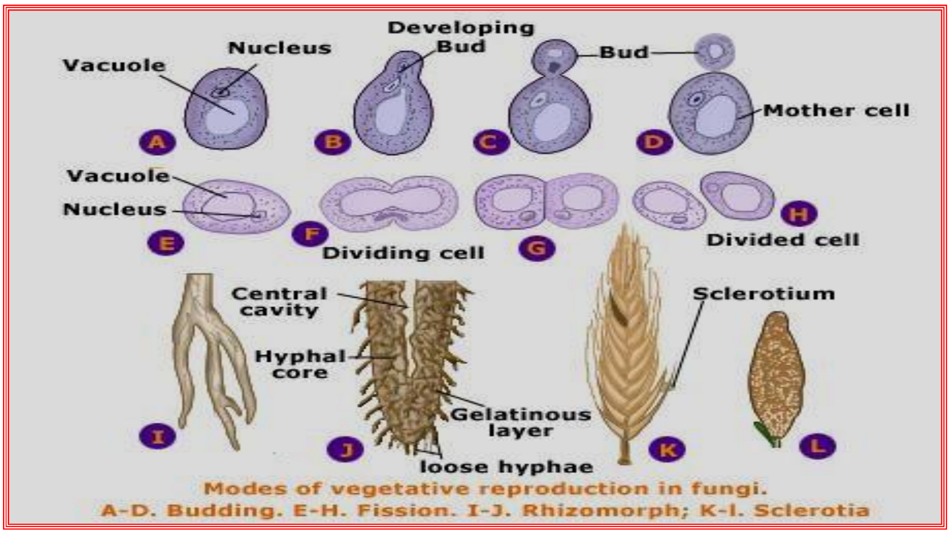


Figure: 7.10 Modes of vegetative reproduction in fungi. A-D Budding.E-H Fission I-J Rhizomorph; K-I Sclerotia

(ii) Asexual reproduction: Fungi are also known as anamorphs when they are in their imperfect, asexual mitotic state. These reproduction methods result in the formation of unique reproductive structures known as spores or propagate. Fungal spores are invariably the product of mitosis, which is why they are called mitospores. The kinds of spores that are produced by the various fungal groupings are as follows (Figure:7.11):

a) **By zoospores:** Found inside structures known as zoosporangia, these motile, flagellated spores are generated. There is no cell wall on these spores. Lower fungus is the source of these spores. Example- *Albugo, Phytophthora*
b) **By sporagospores:** These are found inside sporangia in fungi like Zygomycota, these non-motile spores are formed. Example-*Rhizopus, Mucor*
c) **By chlamydospores:** These are resting spores with strong walls that grow straight from hyphal cells. They keep food in reserve. Example-*Ustilago*
d) **By oidia:** The fragmentation of hypha cells forms these spore-like entities. They are unable to withstand adverse environments since they do not stockpile food for emergencies. *Erysiphe* spp. produces these spores.
e) **By conidia:** Also known as conidiophores, these are non-motile spores that are generated singly or in chains at the tips of hypha branches. Fungi such as *Penicillium* and *Aspergillus* create these kind of spores.

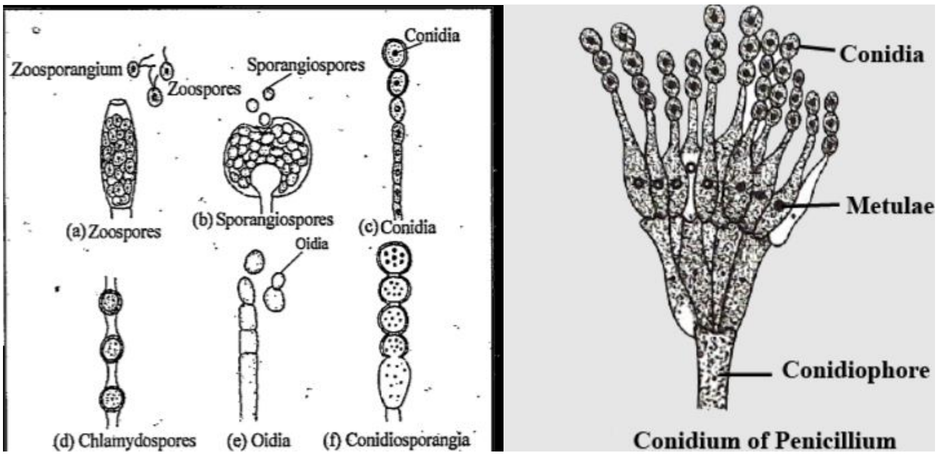


Figure:7.11 Various types of Asexual spores in Fungi

(iii) Sexual reproduction

All groups of mushrooms, with the exception of Dueteromycetes and mushrooms imperfecti, are known to reproduce sexually. Fusion of gametes, gametangia, or hyphae may be involved. The process might solely entail the creation of meiotic spores (meiospores), fusing of nuclei (karyogamy), or fusion of cytoplasm (plasmogamy). In the majority of lesser fungi, meiosis and karyogamy occur right after plasmogamy. Karyogamy in higher fungi is frequently postponed to maintain the dikaryotic state of the hyphae. We refer to this stage of the fungal life cycle as the dikaryophase. These fungi go through three stages to finish their life cycle: the haplophase, dikaryophase, and diplophase (Figure:7.12).

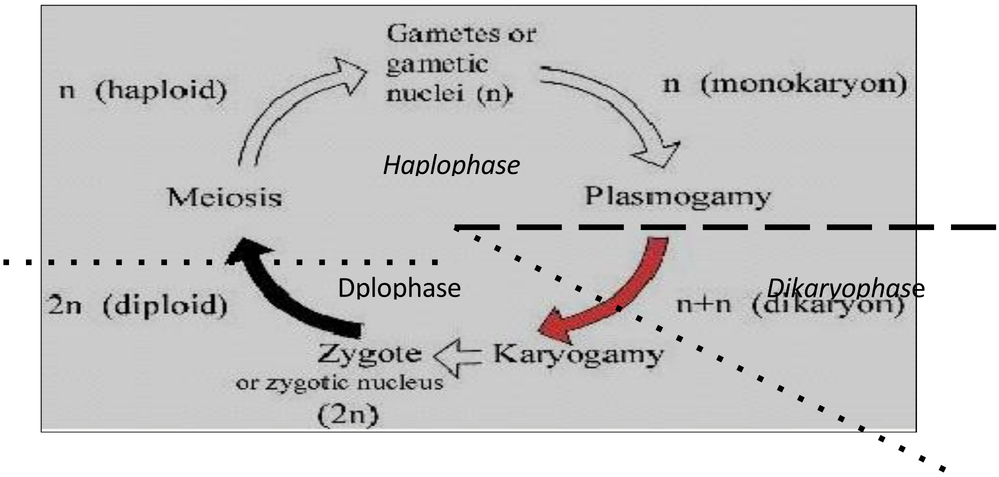


Figure:7.12 Sexual cycle

Sexual reproduction takes place by following methods:

a) **By planogametic copulation:** Planogametic copulation is the union of two motile, naked gametes, either one or both. Planogametes are the name for mobile gametes. Isomagamous planogametes are produced by the simplest fungi. Example- *Synchytrium*(Figure:7.13).

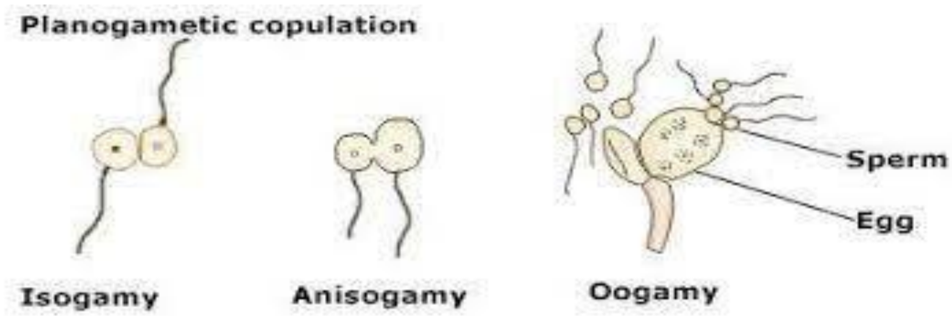


Figure:7.13: Planogametic copulation in fungi

b) **By gametangial contact:** In this scenario, structures known as gamete-bearing structures, or gametangia, become closer to one another and create a fertilization tube that allows the male gamete to pass through and become the female gametangium (Figure:7.14). Example- *Albugo, Pythium*, etc

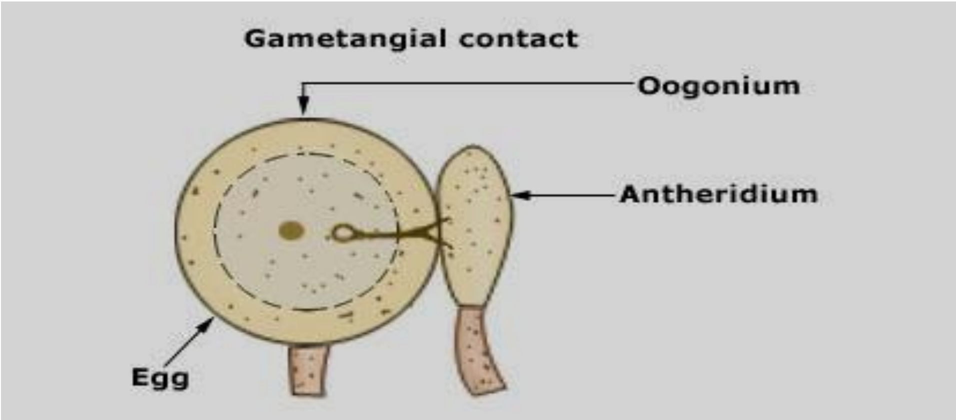


Figure:7.14: Gametangial contact

c) **By gametangial copulation:** In this process, the gametangia merge, become zygospores, and lose their individual identities (Figure:7.15). Example- *Rhizopus, Mucor,* etc.

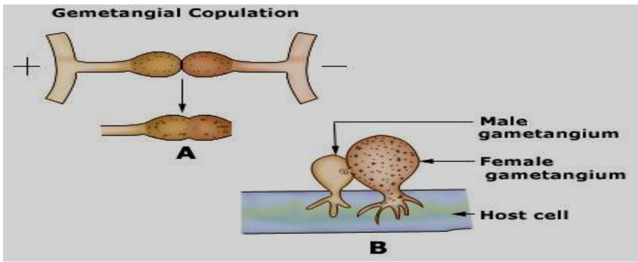


Figure:7.15: Gametangial Copulation

d) By Spermatization: Spermatia are microscopic, unicellular entities that resemble tiny spores that occur in some fungi, such as *Puccinia.* They are conveyed by several agencies to female gametangia.

e) By somatogamy: When somatogamy occurs, a fertilization tube is used to swap the nuclei of two cells with distinct hyphae of the opposing mating type. Example- *Agaricus*

7.8 Summary

Fungi are eukaryotic organisms that originally appeared on land over 450 million years ago. Being heterotrophs, they lack both organelles like chloroplasts and pigments involved in photosynthetic processes like chlorophylls. Because they consume dead and rotting matter, they are classified as saprobes. Fungi contribute significantly to decomposition and release essential elements into the environment. Enzymes from outside the fungus break down the nutrients that the thallus, or body of the fungus, consumes. The robust chitin cell wall encloses the cell. In addition to being unicellular creatures like yeasts, fungi have the ability to grow into myceliums, which are networks of filaments resembling mold. Most animals have a generational cycle and reproduce both sexually and asexually.

The Chytridiomycota, Zygomycota, Ascomycota, Basidiomycota, and Glomeromycota are the groups of fungi. Fungi may parasitically attach themselves to plants and animals. Fungi can ruin crops and contaminate food. Fungi can create compounds that are poisonous to humans and other animals. Fungal infections are known as mycoses. While systemic mycoses spread throughout the body, superficial mycoses only affect the skin. Curing fungal diseases is a challenging task.

Since fungi are saprobes, they play a significant role in decomposition. A fungus and another creature are involved in many fruitful mutualistic partnerships. They form intricate mycorrhizal connections with plant roots. Lichens are the result of a symbiotic partnership between a fungus and a photosynthetic organism—typically a cyanobacterium or an algae.

The existence of fungi is essential to human life. Fungi are an essential component of most ecosystems as decomposers. For most plant development, mycorrhizal fungi are essential. Fungi can be found in mushrooms and are used as food by using them as agents of fermentation to prepare cheeses, breads, wines, and a range of other foods. Secondary metabolites of fungi are employed in medicine as antibiotics and anticoagulants. Fungi are model organisms used in the study of eukaryotic metabolism and genetics.

7.9 Self Assessment Question

1. Citric acid is produced by fungus

(1) Aspergillus niger	(2) Claviceps purpurea
(3) Albugo candida	(4) Morchella

2. Epixylic fungi mainly belong to Group

(1) Ascomycetes	**(2) Basidiomycetes**
(3) Deuteromycetes	(4) Phycomycetes

3. Ring worm is caused by fungi

(1) Trichophyton	(2) Ustilago
(3) Trichoderma	(4) Alternaria

4. Which of the following product not obtain from fungus

(1) Cyclosporin A (2) Statin

(3) LSD (4) Swiss cheese

5. Red rot of sugarcane is caused by fungus-

(1) Trichoderma (2) Ustilago

(3) Colletotrichum (4) Alternaria

6. Spore of deuteromycetes are similar to spore of -

(1) Puccinia **(2) Neurospora**

(3) Albugo (4) All

7. Basidiocarp in Agaricus which is edible develop from

(1) Secondary mycelium (2) Primary mycelium

(3) Spore (4) Basidium

8. Septate Dikaryotic hyphae present in:

(1) Bread mould (2) Sugar fungi

(3) Puff ball (4) Pink mould

9. Few structures are given- Ascospore, Ascocarp, Basidiospore, basidiocarp, conidiophore, conidia, Zygospore and Zoospore. How many can be basis for classification of fungi:

(1) Five (2) Six

(3) Four (4) All

10. Mark the incorrectly matched -

(1) Puccinia - Wheat Rust

(2) Ustilago - Smut

(3) Alternaria - Early blight of potato

(4) White spots on crucifer- Neurospora

CHAPTER – 8

Fungi

Objectives

At the end of chapter student will be able to:

- Understand the general characteristics and life cycle of diferent pathogenic fungi.
- Differentiate the various type of mycorrhiza.
- Understand symbiosis.

The phylum Zygomycota comprises a small collection of fungi known as zygomycetes. This class involve the well-known bread mold, *Rhizopus stolonifer*, which spreads rapidly on the surfaces of baked goods, vegetables and fruits. These are mainly terrestrial in nature, dwelling on dust, animals and plants. Most of the species are saprobes, which mean they feed on degrading biological materials. Among many of the members are parasitic to insects, plants, and tiny creatures, while others have beneficial interactions with plants. Zygomycetes perform an important commercial role. Other Rhizopus species metabolic products serve as intermediates in the manufacture of partially synthetic hormones that contain steroids.

Thallus of members of this phylum is having coenocytic hyphae containing haploid (half set of chromosome) throughout the phase of vegetative growth (Figure 8.1). Molds often reproduced asexually resulting to sporangiospores. A black tip like appearance of bread mold, *Rhizopus stolonifer* inflated sporangia containing black spores.The spores reaches to appropriate host, where they germinate and forming a new mycelium.

Figure 8.1 (A) Zygomycetes grown on a host (B) Spore present on the surface of the fungal hyphea

The Sporangia of bakery fungus: Sporangia sprout at the ends of filaments as (a) white powdery appearance with dark patches on the bread, *Rhizopus stolonifer*. The bread mold's (b) tips have sporangia, which contain spores (Figure 8.2).

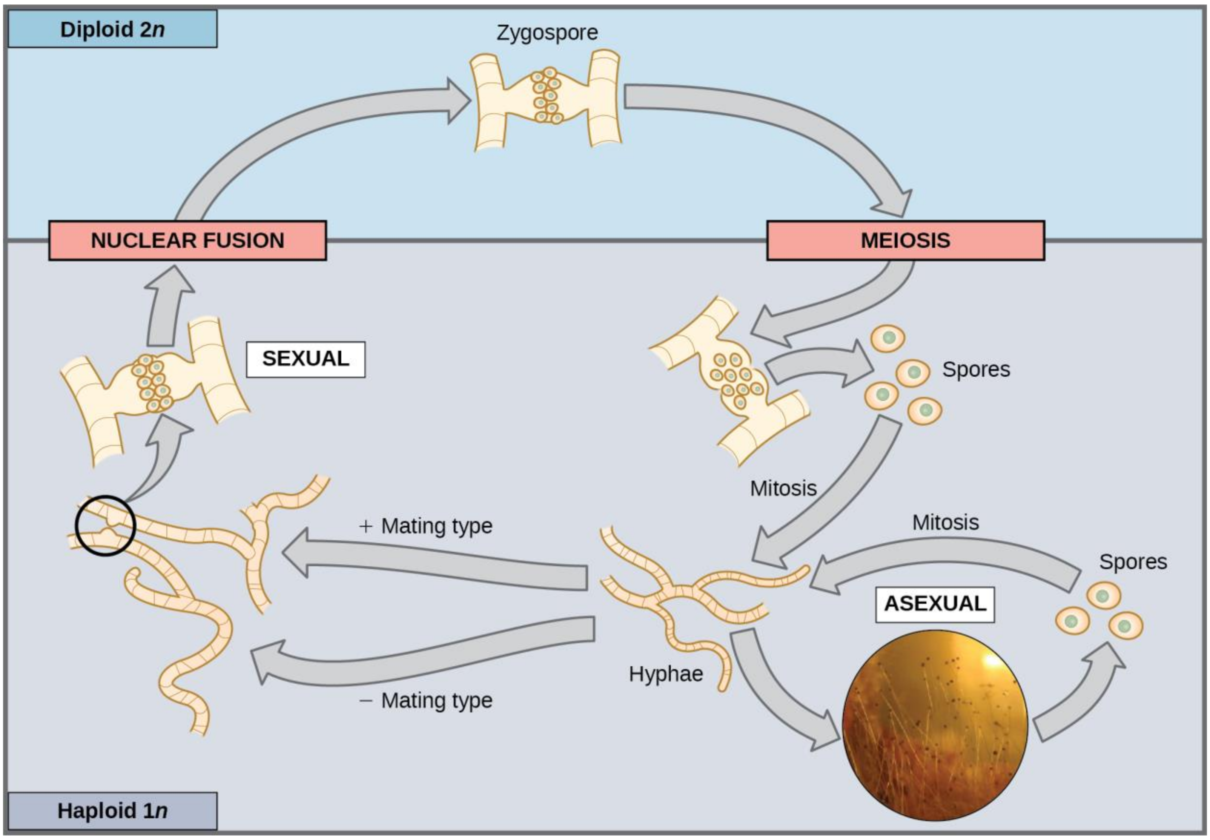


Figure 8.2 Life cycle of Zygomycetes

Reproduction through sexual activity begins when the circumstances are adverse. A pair of opposite breeding strains (type + and type -) must come in contact with each other for gametangial contact to combine, resulting in a process known as karyogamous contact. The newly formed diploid zygote outer covering thicker that keep them safe from desiccation and other risks. These stay dormant for months or years till the favorable conditions reappears.The zygospore emerges, proceeds through meiosis, producing spores haploid in nature that will eventually evolve into a new fungal cell. The phrase "conjugated fungi" originates from this type of reproductive activity in fungi, known as conjugation (though it differs greatly from conjugation in bacteria and protists).

8.2 Penicillium

Penicillium is an ordered group of saprophytes (fungi that feed on dead and rotting objects). These are generally known as green or blue-colored fungi. These have been proven highly applicable manufacturing of dairy products, acids from organic matter and pharmaceuticals. They serve a key function as decomposing agents in the environment. Penicillium can thrive in environment, like soil, air, water and food. Penicillin belongs to one of the most important antibiotics derived from Penicillium sp

Penicillium is a prominent member of Ascomycetes phylum. These are categorized on the basis of generation of ascospores throughout sexual reproduction cycle.

Penicillium literally mean as "painter's brush". The name was derived from the existence of asexually formed conidia chains that appear as a bristle distally on the mycelia (Figure 8.3).

Classification

Domain	: Eukaryota
Kingdom	: Fungi
Phylum	: Ascomycetes
Class	: Eurotiomycetes
Order	: Eurotiales
Family	: Trichocomaceae
Genus	: *Penicillium*

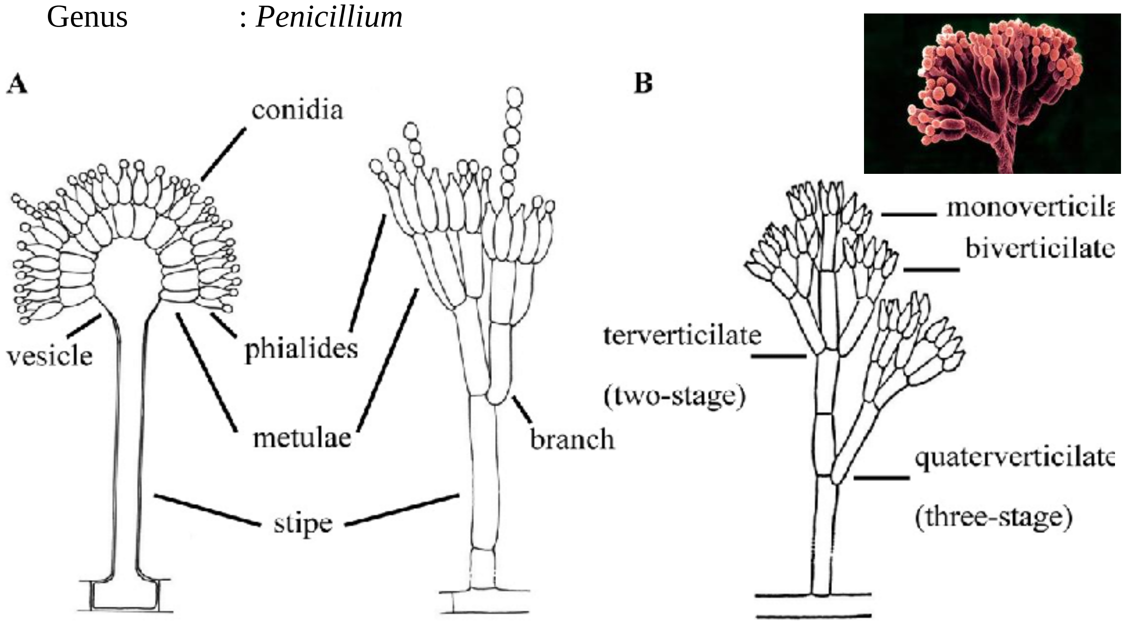


Figure 8.3: Penicillium Structure with conidia

- The Penicillium hyphae are septate, multinucleated, and colorless.
- Two forms of spores are presented by sexual, asexual forms named as ascospores and conidiospores respectively.
- As the colony grows and the conidiospores spread out on conidiophores, the ascospores are created when the antheridium and archegonium fuse.

- Penicillium may survive in a variety of climates from cold to hot. It can found on a variety of materials, such as machinery, ceilings, food items, clothing etc.

Reproduction and Life Cycle

There are three mode of reproduction:

a) Vegetative reproduction

b) Sexual reproduction

c) Asexual reproduction

Vegetative reproduction takes place by fragmentation where every fragment develops into complete mycelium

Sexual reproduction takes place by the formation of ascospores

- Penicillium species reproduce sexually through the development of ascospores.
- Certain species are homothallic; whereas others are heterothallic (presence of male and female sex organs on different thallus).
- The male and female sex organs are named as antheridium and ascogonium, respectively.
- The vegetative mycelium-based cells grow into ascogonium, which is single-celled and has only one nucleus.
- The ascogonium nucleus divides multiple times, resulting in 32 to 64 nuclei stage.
- The newly formed antheridium extends coils around the ascogonium, using its tip separating by septum, developing a single-celled antheridium with one nucleus.
- After maturation, the antheridium bends and impacts the ascogonial wall, where the cell wall dissolves and the cytoplasm of both cells intermixes. The process is known as **plasmogamy**
- **T**he ascogonium goes through an intermediate in nature dikaryon phase with two nuclei (n+n) in the cell.
- The ascogonium divides repeatedly by partitioning the wall, forming numerous binucleate cells arranged one of them over the next.
- The terminal dikaryotic cell expands up, forming the ascus mother cell.

- Karyogamy (combination of the two nuclei) takes place in the cell, forming a diploid cell (2n).
- The diploid zygote goes through meiosis and mitosis to form a stage of 8 nuclei cell.
- Ascospores are formed when the the ascus wall breaks and attaches to an appropriate substrate. They develop into a germ tube and mature into branching mycelium (Figure 8.4)

Asexual reproduction

- The Asexual reproduction takes place by the means of non-motile spores known as Conidia. The Conidia or conidiospores are produced at the tip of hyphae called conidiophores. Flask-shaped phialide ocytes arise at the end of each metulae to generate conidia.
- Conidia are produced by the mitotic division of phialide cells. Phialide cells proliferate once more, pushing the first conidium outward and creating a second conidium in the process. Repeating this process results in a chain of conidia that progresses basipetally.
- Conidia can be dark blue, a shade of green or yellow and oblong or elliptical in form.
- Following maturation, conidia are released from the progenitor and distributed by breeze. Conidia connect to a suitable substrate and germinate.
- Germination occurs by germ tube. The nucleus divides mitotically several times and all the nuclei eneters to the germ tube following the elongated and septate formation which matures into a new cell.

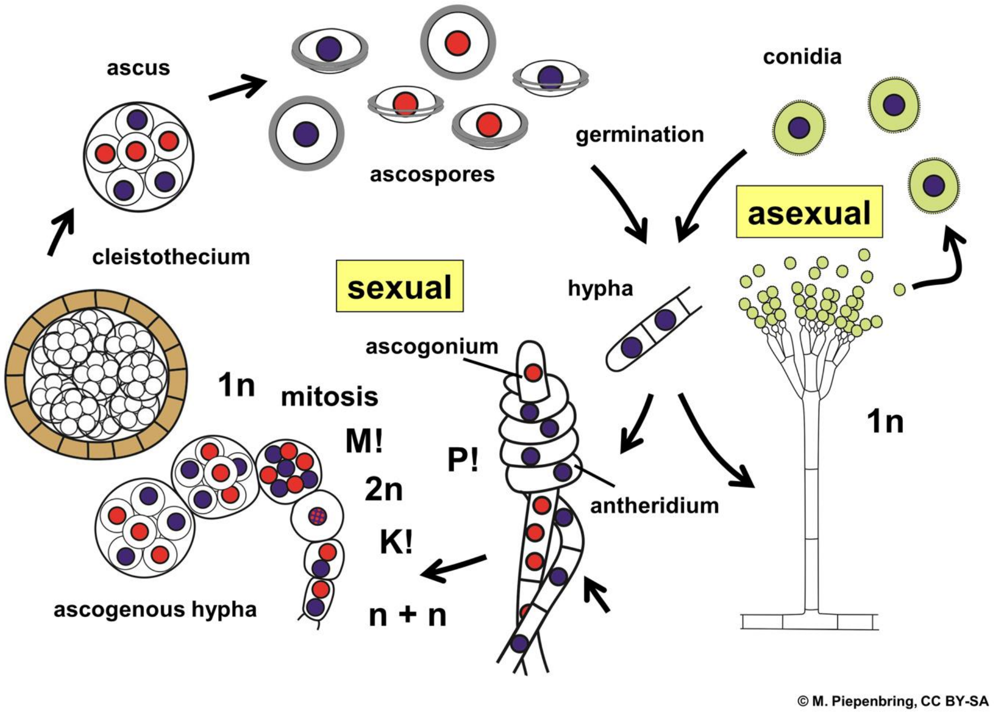


Figure 8.4: Pencillin showing asexual and sexual reproduction

Economic Importance

- In 1929, Alexander Fleming discovered an antibiotic called Penicillin from Penicillium, which had capacity to inhibit the development of gram-positive bacteria. Later, Florey and Chain isolated penicillin accidentally which was used to treat soldiers during World War II.
- The species of penicillin are extremely significant ecologically. These can be used for manufacturing numerous dietary supplements, acidic compounds, antimicrobial agents, and mycotoxins.
- Penicillium species are used to produce a variety of cheese, including blue cheese, *Penicillin camembert* is used for manufacturing Brie cheese and Roquefort cheese.
- Different kinds of Penicillium produce organic acids including citric, gluconic and tartaric acid.
- Enzymes like amylases, proteases, cellulase, lipase and pectinase are isolated from Penicillium used for various industrial applications in food, tannery and brewery.
- Penicillin is generated by *Penicillium chrysogenum*, formerly known as *Penicillium notatum.* The organically produced penicillins are Penicillin G (Benzylpenicillin),

which is administered via intramuscular injection and Penicillin V (Phenoxymethylpenicillin), which is delivered directly through mouth to treat various ailments.

- Penicillium species produce anti-fungal and anti- cancer substances.
- Certain kinds of Penicillium can be utilized in mycoremediation, a bioremediation procedure that uses fungi to disinfect the environment by breaking down pollutants.

8.3 *Puccinia Graminis*

Puccinia graminis is found to be responsible for the root rot disease in various grain crops, including rye, maize, wheat and oats. Puccinia shows host-specificity as one of the major characterstics as wheat isolates cannot infect oats or other crops vice-verse clearly demonstrating specificity for the host. The graminis species is classified into varieties, forms, and subspecies based on the aforementioned phenomenon. Stakman and others identified natural strains or subspecies as formaespecialis, abbreviated as f. sp, by adding a third term to binomials after evaluating the pathogen's primary host. So *Puccinia graminis*, which infects wheat (*Triticum aestivum*), is known as *Puccinia graminis* f. sp. tritici.

Based on the form of a parasitic relationship on different agricultural host, the subgroup is further classified into physiological races. Wheat (*Triticum aestivum*) serves as the primary host when the spores are released by the crop in harvesting season. The spore travel through air current to the hilly region to its seconday host is Barberry (*Berberis vulgaris*). The variations are caused by the graminaceous host.

Puccinia graminis f. sp.tritici has a significant impact on wheat yields in India's northern and southern regions. In the southern region of India (Nilgiri mountains), the disease appears in November, affecting crop growth more than in North India, where it arrives in late March or after the crop reaches maturity.

Vegetative Body of *Puccinia Graminis*:

The cellular component is made up of mycelium. Mycelia are of two types: dikaryotic and monokaryotic. Both forms are divided, highly branching, growing intercellularly, and generate unique haustoria that infiltrate the host cell.

The septum contains microscopic holes that preserve protoplasmic continuity between neighboring cells. Chitin and glucan form the cell wall. Glycogen bodies, oil globules, and vacuoles make up the cytoplasm.

The primary host, the wheat plant, is home to the dikaryotic mycelium (n + n), whereas the secondary host, the barberry plant, is the site of the monokaryotic mycelium (Figure 8.5).

Figure 8.5: Wheat as a primary host and barberry secondary host for *Puccinia graminis*

Different Type of Spores Found in *Puccinia Graminis*:

Puccinia graminis f. sp.tritici generates five different kinds of spores during its entire life history. They include the uredospore, teleutospore, basidiospore, pycniopore, and aeciospore.

Uredospores and teleutospores flourish on wheat, the major host; basidiospores on soil or plants that died on ground that grew from teleutospores; and pycniospores and aeciospores on barberry, the pathogen's alternate host.

Uredospores

Uredospores are carried on uredosorus (Fig. 8.6A-D). The uredosorus emerges on wheat plants from the double-nuclei mycelium created by germinating aeciospore that has been naturally transmitted from barberry bushes through air propagation. After deposition on the wheat plant, the aeciospore can attack its leaves, branches, or fruiting portion of the plant.

Upon sprouting, the aeciospore develops double nucleic mycelium, which penetrates by stomata and grows in the cellular boundaries. The mycelium that grows in epidermal region generates upright spores which are binucleate known as uredospores at the points of attachment.

Uredospores create brownish-red blisters underneath epidermis, known as uredosorus. As the spore matures, it causes the host's epidermal wall which later on ruptures, exposing the uredospore to be dispersed through different vectors or intermediate hosts.
Uredospores are stalk-like, circular, single-celled, brown, and thickly walled, with 4-round equatorial germ holes measuring 25-30 micrometer on the outer layer (17-20 picometer). The spore's barrier has dense, with a non-nucleated outer layer (Figure 8.6 B).

In optimal circumstances, uredospores germinate again during the winter season (Fig. 8.6C), infect the wheat crop (Fig. 8.7D), and develop the next crop of uredospores. The cycle repeats several times in the crop season.

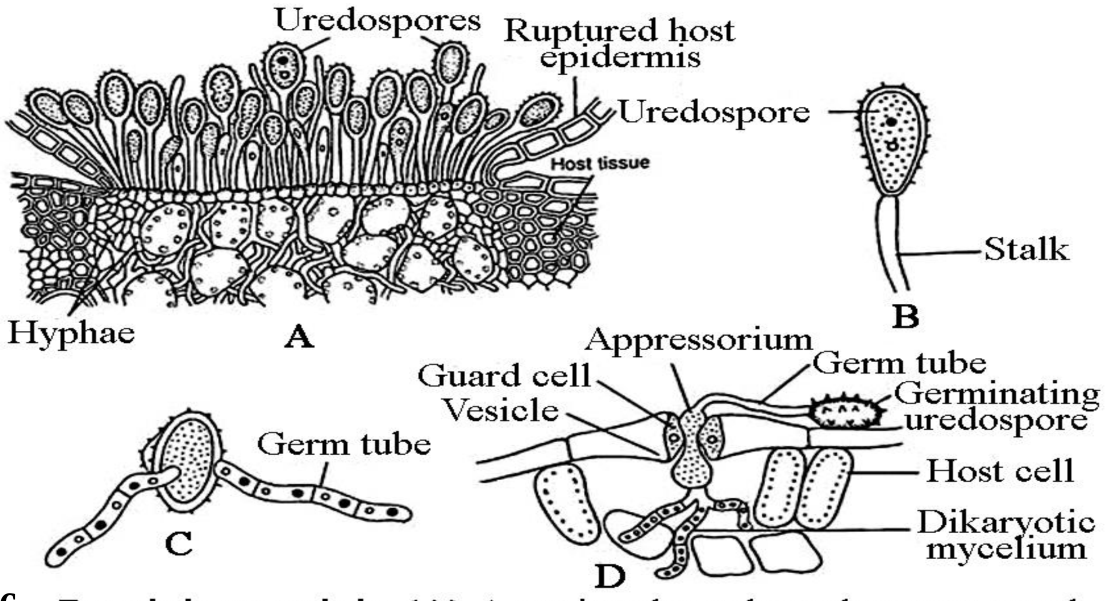


Figure 8.6 ***Puccinia graminis.*** **(A)** A section through uredosorous on wheat stem showing uredospores, **(B)** Single uredospore, **(C)** Germinating uredospore, **(D)** Infection of wheat leaf by germinating uredospore.

2. Teleutospore:

Towards the termination of the harvesting season, the uredosori generate both uredospore and teleutospore. At that point, the sorus was known as blended sorus. The combined sorus eventually transforms into teleutosorus (Fig. 8.7). Teleutosorus is only caused by uredospore infection. The teleutosori appear as a sooty elevated streak that grew on both the leaf sheath and the stem.

Teleutospores (Fig. 8.7B) are spied on spindle-like dense, even surfaced with a round or pointed apex, 2-celled, and slightly constricted at the septum. Spores are chestnut brown, measuring 15-20 µm × 40-46 µm.

Cells are dikaryotic (n + n) with one germ pore. The germ pore is at the top of the apical cell and it is below the septum in the lower cell. Both the nuclei in a cell fuse together and form a diploid (2n) nucleus stage.

Teleutospores are disclosed by rupturing the host epidermis. It works as a sleeping spore and thrives under adverse circumstances. Teleutospores grow on the ground, either unattached or connected with a deceased host, when conditions are favorable (low temperature and high humidity).

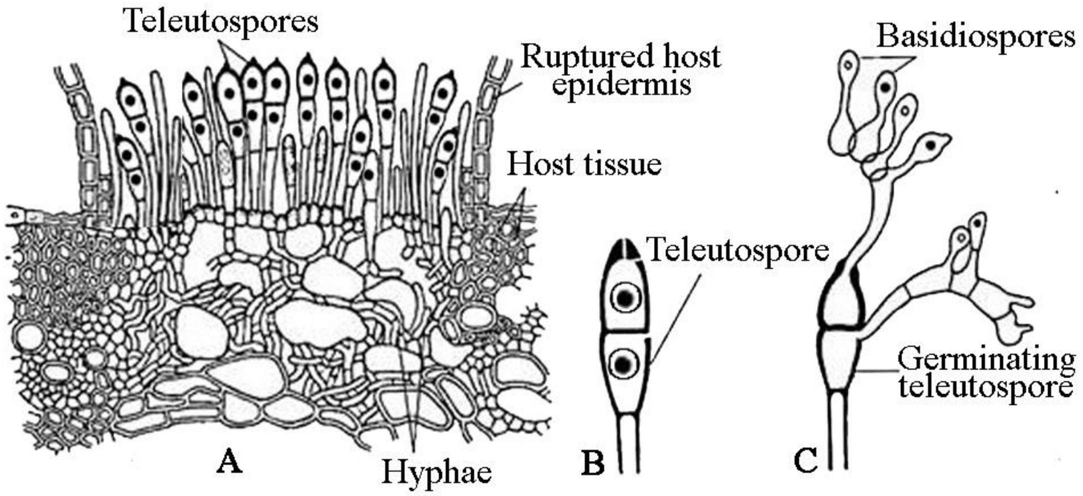


Figure 8.7 ***Puccinia graminis.*** **(A)** Section through teleutosorus showing teleutospores, **(B)** Single teleutospores, **(C)** Germinating teleutospore.

3. Basidiospore:

It grows once the teleutospores germinate. These spores germinate by creating one germ tube per cell. The germ tube, also known as promycelium, probasidium, or epibasidium, has limited development potential. The diploid nucleus enters the probasidium and performs meiosis, producing four haploid nuclei, two (+) and two (-) types.

The probasidium now has four cells connected by a transverse wall. Each cell then forms a tiny projection called the sterigma, through which the nucleus and cytoplasm push outward and produce basidiospores, two of which are (+) and two of which are (-).

Basidiospores are single-celled, thin-walled, and extremely tiny. Air current disseminates them once they are discharged from basidium via an explosive mechanism. Basidiospores can live for several days. They can only infect the leaves of their alternate host, the barberry.

Basidiospores are little, single-celled organisms with thin walls. As soon as they are released from basidium through an explosive mechanism, air circulation distributes them. Basidiospores have a few days to live. These can spread infection only the leaves of secondary host to the barberry bush, if spores donot reach the host they end upto soil leading to the dormancy.

4. Pycniospore:

In conditions that are favorable, the basidiospore germinates by creating a germ tube when it comes into touch with a barberry leaflet and moves to the upper surface. The germ tube enters the epidermis and develops inter-cellularly.

The chemical composition of the mycelium is determined by the type of basidiospore, which can be either positive or negative. Within a few days, the developing mycelium aggregates under the epidermis, forming a yellowish flask-shaped structure known as Pycnium or Spermogonium (Fig. 8.8)

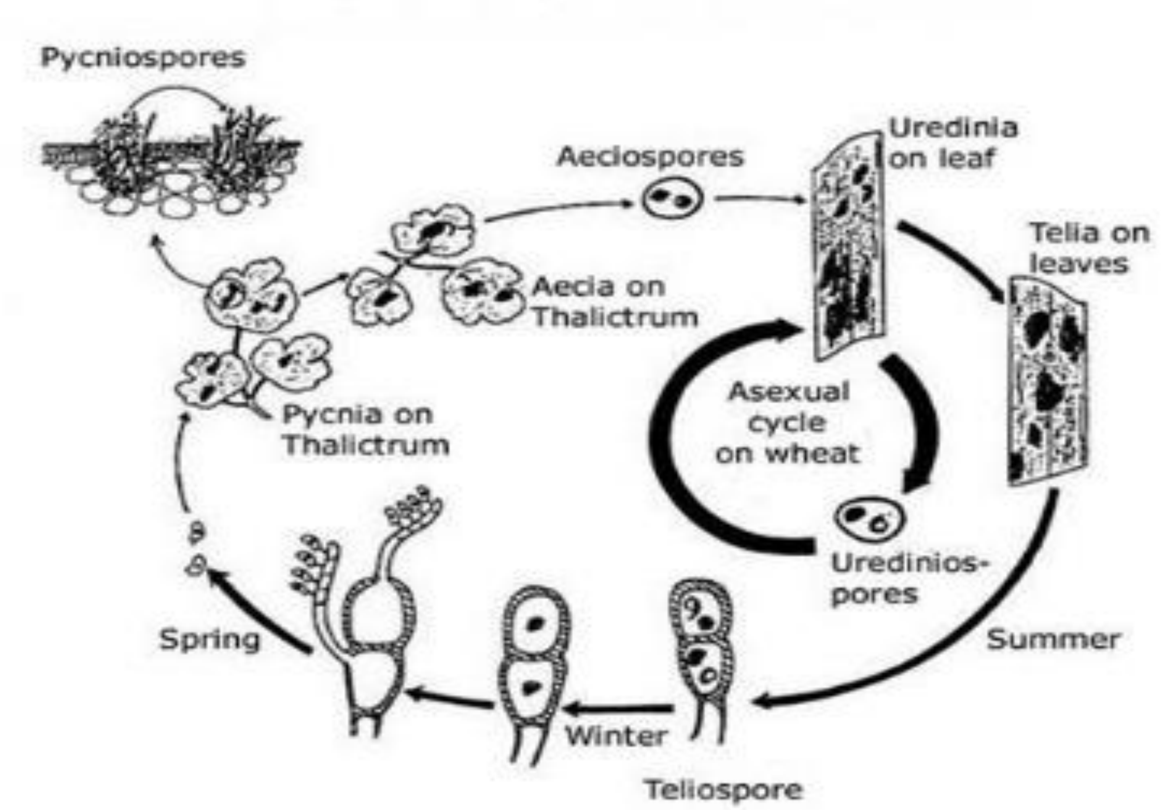


Figure 8.8: Pycniospores of *Puccinia graminis*

The Pycnium has little sterility spores at the neck, known as periphyses, which coexist with significantly more fragile basic and branched susceptible or flexuous hyphae.

Pycnium's inner side is lined by single-nucleus tapered cells termed pycmophores or spermatiophores. These cells produce little oval to spherical single-nucleus cells known as pycniospores (spermatia).

As the nature of the basidiospore, the pycnium and pycniospore can be + or - type. The pycniospore or spermatium is not transmitted to the host's cells.

The adult pycnium (+ and - type) produces nector droplets during the release of mature pycniospores, that mix. The nectar draws the insects, which then aid in the spread of pycniospores.When mature pycniospores are released and mix together, the mature pycnium (+ and - type) secretes nector drops.The nector attracts the insects, which aid in the transmission of spermatium or pycniospores to the flexous hyphae of the opposing mating type. The dikaryotic situation is produced when the wall at the point of contact dissolves and the spermatium (pycniospore) nucleus moves to the flexuous hyphae. We call this process spermatization.

5. Aeciospore:

The juvenile aecium is submerged below the subcutaneous epidermis, but as it mature, presses and breaks the dermis, exposing the spores. The aecium is an inverted cup-shaped structure with an exterior rim made up of short cells known as peridium.

The stalk of the cell then becomes dikaryotic, dividing through mitotsis into a chain of alternately organized large and small cells.The enormous cells create aeciospores (n + n), whereas the diminutive ones become sterile, known as disjunctor cells. The disjunctor cell facilitates spore dispersal.The aeciospores have thin walls, one cell, are binucleate (n + n), and have an orange hue. Aeciospores are initially polyhedral in shape, but as they mature, they become globose. Only graminaceous hosts, like wheat plants, are susceptible to infection, and they are dispersed by air currents.

They generate germ tubes (n + n) that penetrate the host tissue and start an infection after falling on a wheat plant (stem or leaf).The life cycle of *Puccinia graminis* f. sp.tritici as presented in Fig. 8.9.

Puccinia graminis f. sp.tritici is a heteroecious pathogen that requires two unrelated hosts to complete its life cycle: wheat (*Triticum aestivum*) and Barberry (*Berberis vulgaris*). It is also macrocyclic and polymorphic. With five different types of spores—uredospores, teleutospores, basidiospores, pyncniospores (spermatia), and aeciospores—it is macrocyclic, meaning it has an extended life cycle.

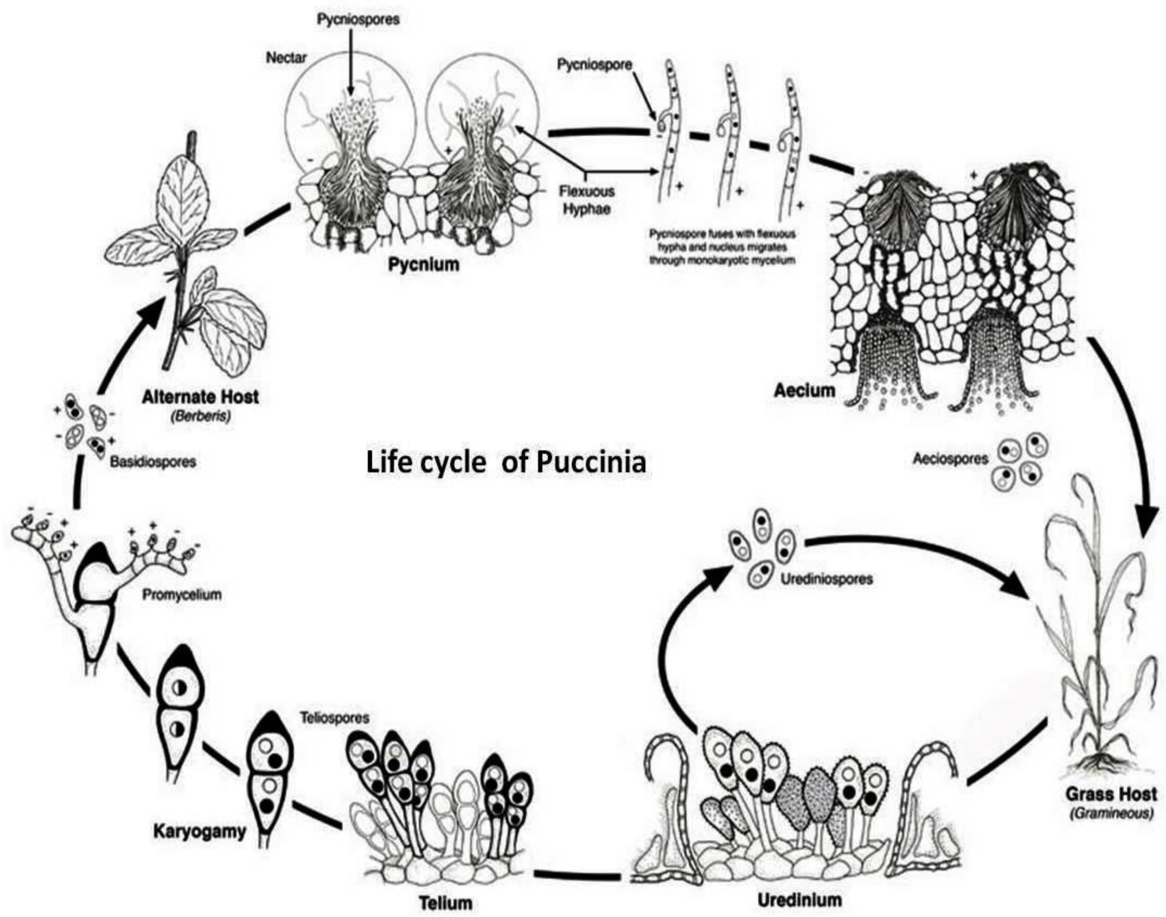


Figure 8.9: Life History of *Puccinia Graminis* Tritici

8.4 Alternaria

- Alternaria is member of deutromycotina is the source of vegetable leaf blight diseases in the Brassicaceous, Cucurbitaceous, and Solanaceous families.
- The most damaging disease to tomatoes is early blight, which accounts for 78% of yield loss at 72% disease intensity.
- About 50 species are known to exist.
- Certain species are facultative parasites that infect a vast variety of higher plants, whereas other species are found as saprobes on dead and decomposing plants.
- The conidia infiltrate homes and labs after being taken up by the wind from the soil.
- Conidia sample cultures in labs, and they cause allergies, bad skin conditions and hay fever in homes.

- *Alternaria solani* is the cause of potato early blight, which is the most prevalent disease.

Habitat

Saprophytic species, living in decaying materials and surroundings, are also frequently found in organic materials at the locations with water or moisture.

- Some are endophytic, meaning they reside in different plant components like fruits and seeds.
- In particular, *Alternaria alternata* is a saprophyte that decomposes organic waste in the soil. It may also be found on plants, where it causes illnesses, and it can spread to animals through plants that can infect humans and other animals.

Morphological and Features

Alternaria alternata is an asexual spore producer that develops in condition with moisture and excellent nutrition. It grows as long chains with dark brown conidiophores in culture. On which, the conidia grows.

The spores have a black appearance (Fig 8.10).

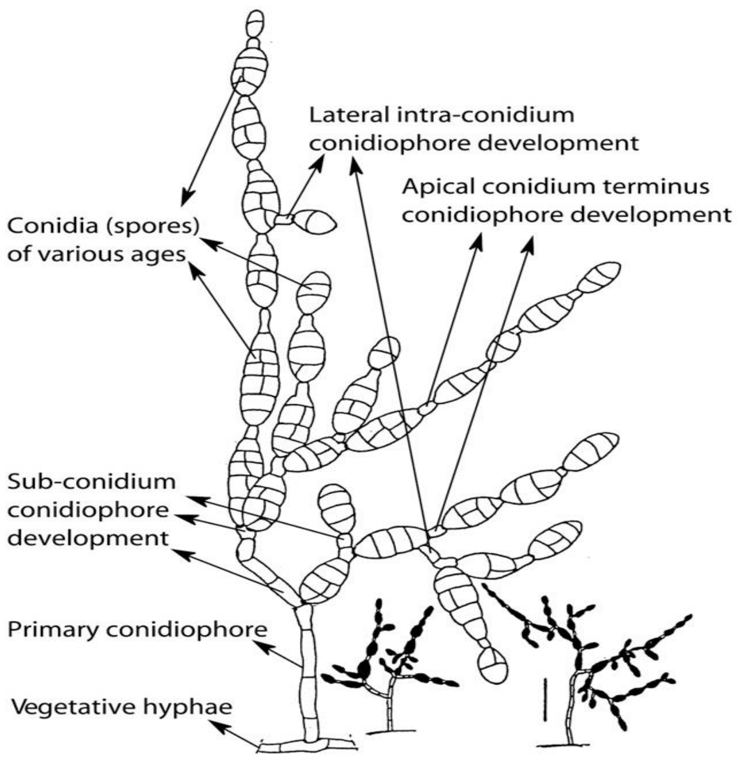
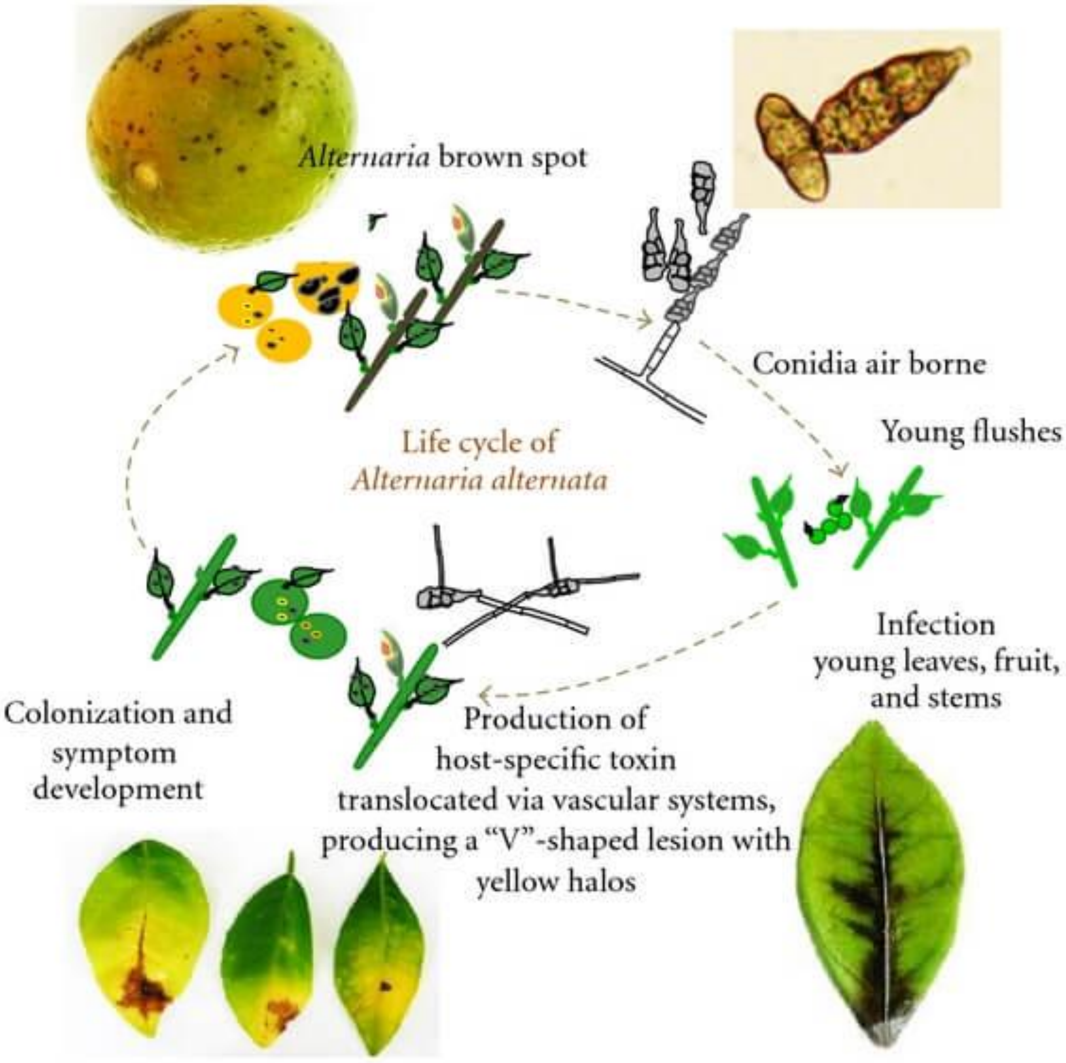


Figure 8.10: Alternaria alternata

Life Cycle of *Alternaria alternata*

- Conidiospores spread through wind and water, falling on plant parts like leaves, fruits, or kernels (Figure 8.11).
- The spore germinates at temperatures of 31-32°C and with sufficient moisture.
- Long chains produce spores from the tips of the hyphae, known as a conidiophore.
- The conidiophore can be pale or dark brown, appearing as a straight elongated chain or flexuous.
- Brownish conidia with short beaks are produced.
- Conidia have a smooth surface.



(Image Source:https://www.hindawi.com/journals/scientifica/2012/6)

Figure 8.11: Life Cycle of Alternaria alternata.

Pathogenesis in animals

- *Alteraria alternata* has been linked to opportunistic infections in people with impaired immune systems, including cutaneous and subcutaneous infections.
- Cutaneous infections cause skin lesions that are localized on the skin.
- When fungi penetrate the skin and cause symptoms on the outer layer, subcutaneous infections impact the deeper layers of the skin.
- Infections can also affect other body parts, such as the nails (onychomycosis), the sinuses (rhinosinusitis), and the cornea of the eye (oculomycosis), which can impair vision.
- Although it is unusual but not unheard of *Alternaria alternata* which produces the mycotoxins that lead to mycotoxicosis.
- The impact of mycotoxicosis on humans can range from moderate illnesses to long-term infections, but it always depends on the immunity of the host.

Pathogenesis in plants

Alternaria alternata is responsible for diseases that cause mycotoxicosis and brown and black spots on plant leaves.

Brown and Blackspot

- When spores land on plant leaves and grow there, it impacts the plants that produce the leaves.
- The disease first appears on the margins of immature leaves, where it uses the nutrients on the leaves to cause necrosis and chlorosis as the plant grows.
- The infection is typified by lesions, which can also develop on plant fruits as a result of fungal development, reproduction and dissemination.
- The consequences of mango rot on fruits, such mangos, are typified by the spread of fungal penetration into the fruit's lenticels.
- Fruit damage, specifically darkening of the insides of the fruit, is linked to the infection.

Plant mycotoxicosis: *Alternaria alternata*

Plant mycotoxicosis

- *Alternaria alternata* has the ability to produce secondary metabolites that cause plant deterioration, such as phytotoxins and mycotoxins.

- Toxicosis-related infections include olive black rot, citrus black/grey rot, tomato black mold, and black rot of apples and carrots.Experimental analysis of fungus in Laboratory

Specimen: Plant Exudates, lesion biopsy, pus cells,

Microbiological Examination

Colonies grow quickly in Sabouraud Dextrose Agar and Potato Dextrose Agar, resulting in colonies that are suede-like to floccose and black, olivaceous-black or greyish.

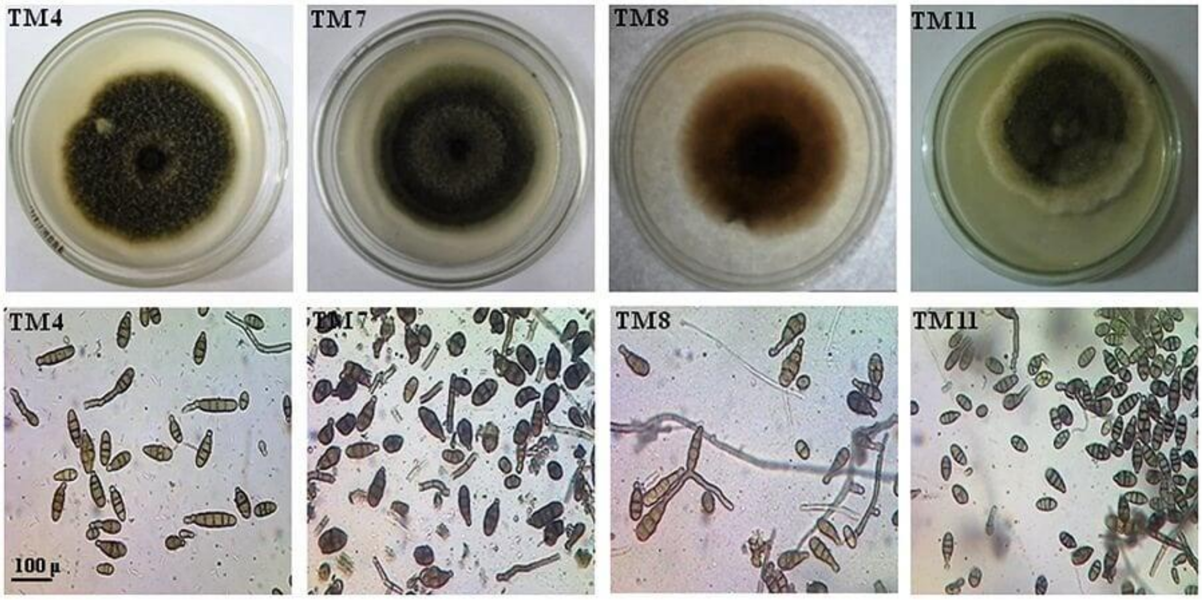


Image: Morphological characteristics, growth pattern, colony morphology, and microscopic examination of three potent toxic isolates of *Alternaria* species collected from different regions in India. Source: Scientific Reports (Mukesh Meena et al.)

Microscopic Examination

- Look for branched chains of big conidia, which can resemble short branches on a long, elongated conidiophore, using a 10–20% KOH wet mount method under the appropriate resolution of compound microscope.
- The conidia have a cylindrical beak and are ovoid or ellipsoidal in shape, smooth-walled, pale brown spores

Histological Examination

Fontana-Masson silver stain is used to identify melanin. Hematoxylin-Eosin stain is used for dark-colored filamentous hyphae from tissue biopsies and pus exudates.

8.4 Agaricus

The order Agaricales contains 197 genera and 4,000 species. The majority of species are found in environment with lots of organic debris, dead and decaying wood, and leaves.

The fleshy pileus/cap from which many radiating gills or plates emerge and releases the spores, is what sets Agaricus members apart. They are distinguished from other members of the Agaricaceae family by its chocolate-brown spores as shown in figure 8.12.

The source of the short-lived main mycelium is a homokaryotic basidiospore. The dikaryotic secondary mycelium is the main element of the Agaricus life cycle.

Figure 8.12: Fruiting body of fungus Agaricus

Cycle of Life in Agaricus

Agaricus bisporus has a life cycle that is similar to that of most other mushrooms. The life cycle of this fungus is cyclical, with adults producing spores that matures into whole fungal bady responsible for creating more spores.

Spore inoculation

It is the initial stage of *Agaricus bisporus* life cycle. Mushroom spores that are floating eventually land on an appropriate surface or substrate. If the conditions are favorable for the mushroom to survive, the spores proceed to the next stage which is germination.

Spore germination

Spore germination involves the production of hyphae, which are microscopic filaments by individual spores. Fertile mycelium is created when male and female hyphae are positioned closely together. The mycelium has an appearance similar to that of actual plant roots.

Growth of Mycelium

This stage of the life cycle is known as the mycelium growth phase, during which the mycelium expands and undergoes development. This growth is exponential. In order to sustain its continuous growth, the mycelium tries to break down organic waste and absorb the nutrients generated. The mycelium also possesses defense systems to fend off predators and rivals.

Hyphal Knot

The mycelium begins to expand and condense into the shape of a knot. The mycelium produces a large number of primordia and hyphal knots at this stage. A hyphal knot, the ultimate mushroom "body," is produced by this structure.

How Primordia Form

At last, the hyphal knot condenses to form primordia. These are little forms of mature mushrooms. On its surface, a single mycelium can generate up to a thousand microscopic primordia.

Fruiting Body Selection

The only primordia that develop into fruiting bodies are those with the highest rates of growth and productivity. A "mushroom" is the term used to describe each individual fruiting body. But these fruiting bodies are actually a single organism connected by their mycelium, not several distinct species. These fruiting bodies continue to grow and change into the mature form of the mushroom.

Fully Grown Fruiting Body

A mushroom keeps on growing like a fruiting body, subsequently undergoes reproduction, once it reaches maturity. The mushroom continues to grow and change until it reaches full maturity and starts to spore. We eat the part of the *Agaricus bisporus* mushroom called the fruiting body

Spore Release

In the final phase of its life cycle, the adult fruiting body spews a large number of little spores into the surrounding air. The spores are released by the gill structure located at the base of the mushroom cap. These spores eventually find a suitable surface during the inoculation stage, at which point they resume their life cycle as shown in figure 8.13.

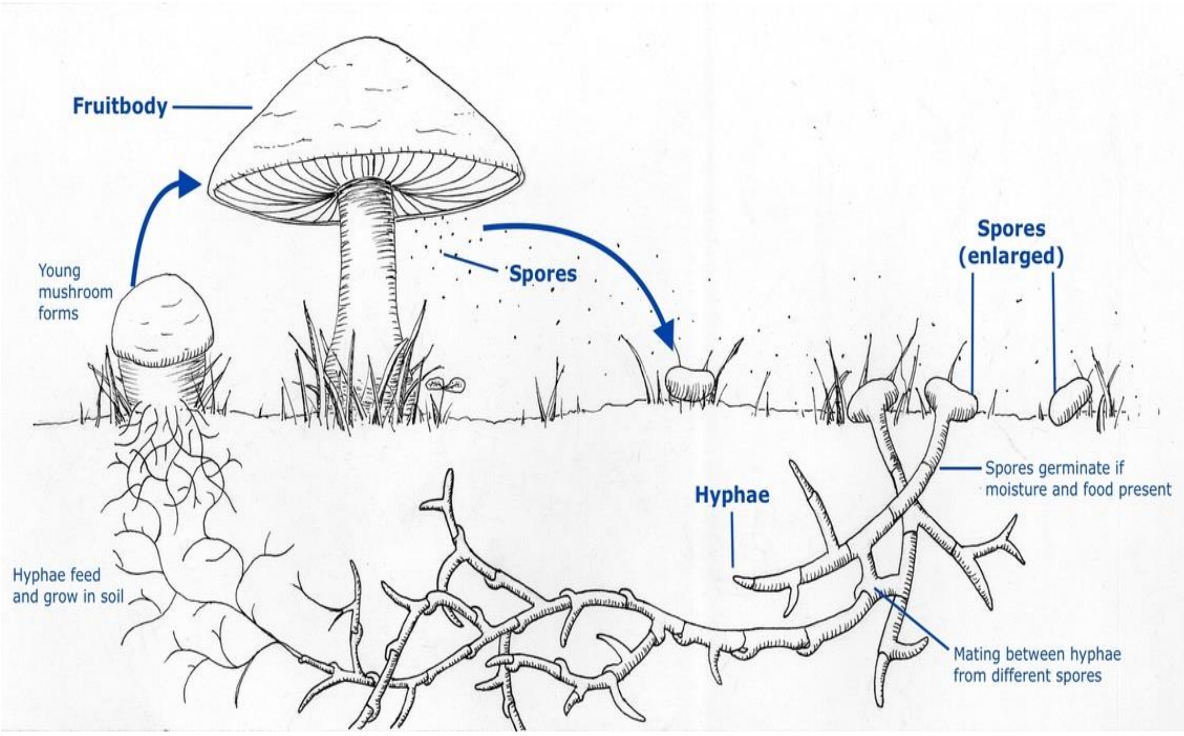


Figure 8.13: Life cycle of cycle of this fungus is *Agaricus bisporus*

8.4 Lichens

Lichens are composite organisms comprising an alga or cyanobacterium as one of the partner and a fungus as another. The two elements combine to form a lichen body when they are inextricably linked to one another. There is a symbiotic link. If the partner is a cyanobacterium, the algal or cyanobacterial component supplies both photosynthetic and atmospheric nitrogen fixation products.Water and minerals are taken up by the fungal companions from the substratum. Additionally, the fungus uses a moist mycelial coat to shield the lichen's photosynthetic component. To obtain nutrients, the fungus inserts haustoria into algal cells. Lichens are the perfect illustration of symbiosis—the process by which two taxonomically distinct species become inextricably linked to create a single composite entity. It has been feasible to split the two partners apart and grow them separately in a small number of lichens. Re-associating the initial partners has also been a method of synthesising lichens. The alga or cyanobacterium often develops well in culture when the two are grown independently. However, growing the fungal component is challenging. Lichens are some of the slowest-growing creatures found in nature. Lichens come in roughly 25,000 different species.Lichens thrive under a wide range of environmental circumstances. Some can grow in the perennially frozen Polar Regions, while others can grow on solid rocks. Nonetheless, the bulk of them favor an environment that is damp, humid, and shaded, like that found in woods. Lichens grow on tree branches, bark, and even the leaves of trees in forests. Often, lichens are the first organisms to settle on freshly exposed rocks or land. Their growth on solid rocks causes them to release organic acids that can uptake minerals, exposed due to weathering of the rocks. This aids in the creation of soil, which allows plants to develop as shown in Fig. 8.14.

Lichens may constitute a significant component in certain geographical areas, despite their apparent insignificance within the broader biosphere. For instance, they make up a sizable portion of the vegetation in the Arctic's tundra zones. The growth of *Cladonia rangiferina* in these regions serves as a vital food source for caribou and reindeer. "Reindeer moss" is the term for it.Certain lichens, like *Cetraria islandica* and *Endocarpon miniatum*, are used as food for humans. Leconera esculenta is also edible. Lichens are beneficial for further uses as well. Rocella tinctoria is the source of erythrolitmin, the acid-base indicator dye used as the active ingredient in litmus. A few species of Evemia and *Lobaria pulmonaria* are the sources of perfume. Chromosome-staining dye orcein is produced by certain Rocella species. Usnic acid is produced from usnea species. It has antimicrobial properties. Toxic lichen is called Letharia vulpine.

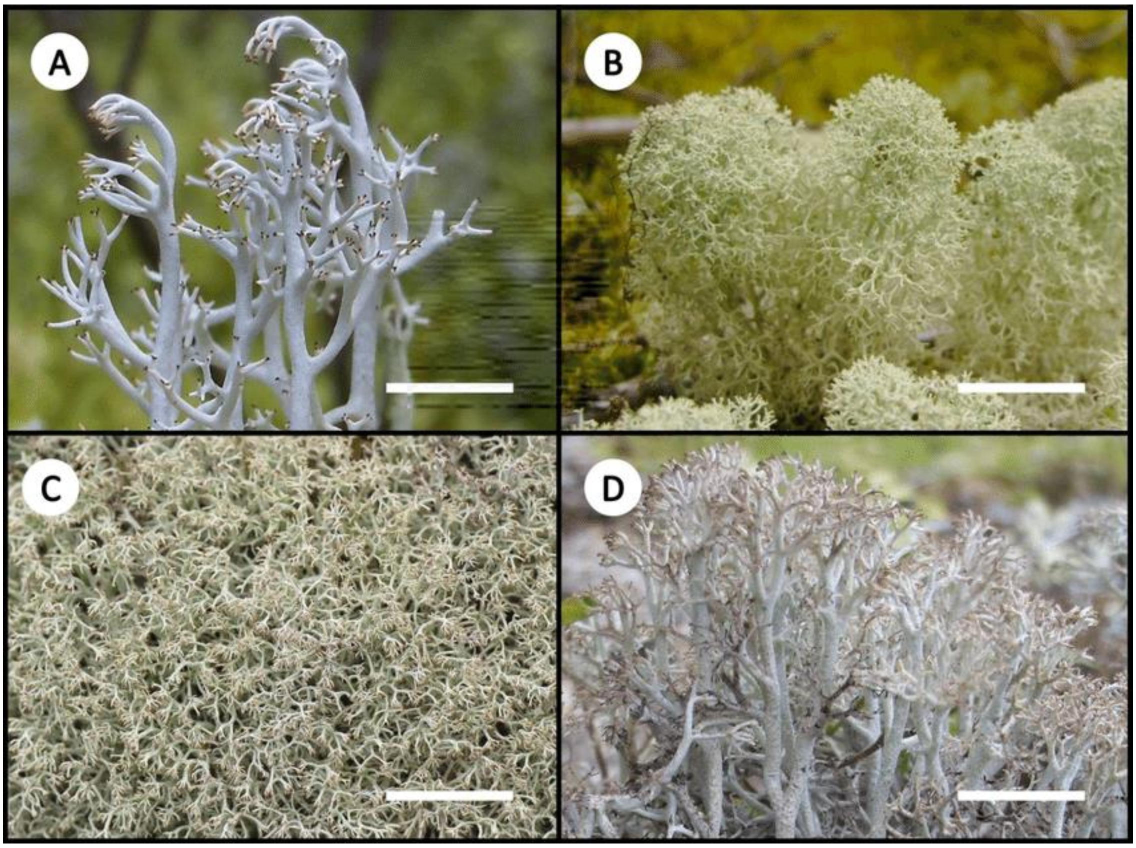


Figure 8.14: (A) *Cladonia rangiferina* (B) *Cladonia stellaris* (C) *Cladonia mitis* (D) *Cladonia stygia*
(Image Source: uploaded by Richard Troy McMullin)

As indicator organisms, lichens are important in the detection of air pollution as shown in figure 8. 15. Lichens can integrate various cations into their thalli. The atmospheric concentration of these cations is measured in lichen thalli for knowing the extent of air pollution in its Surroundings.

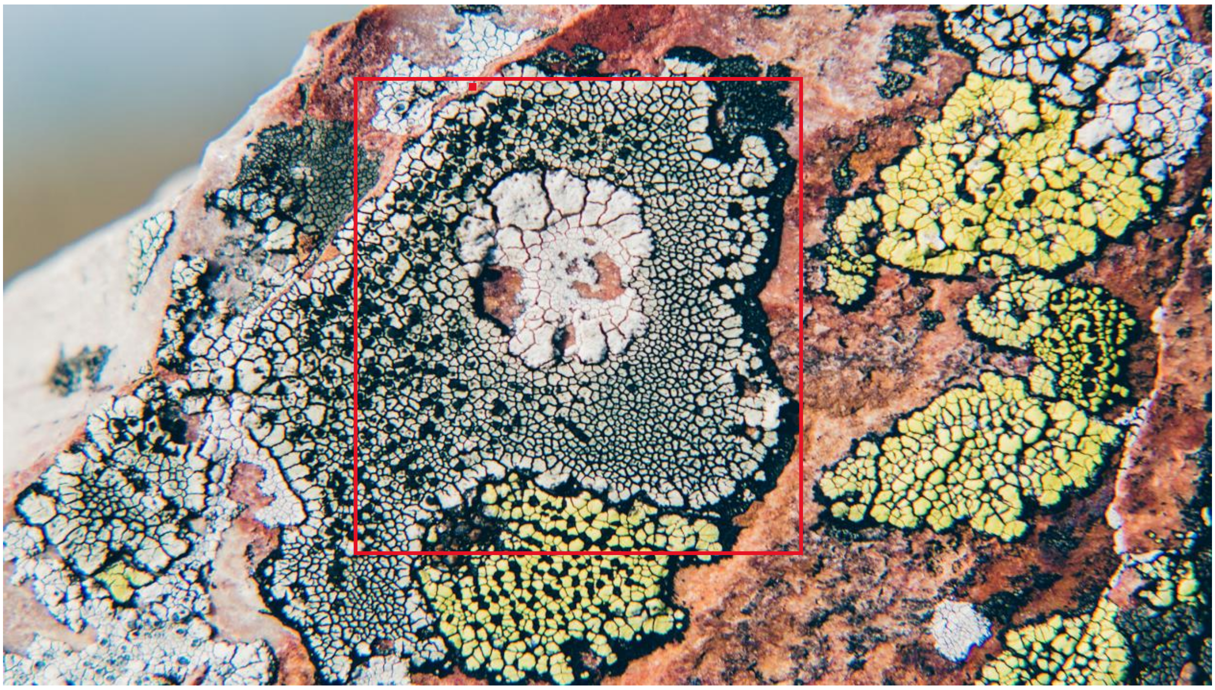


Figure 8.15: Marked area on a tree bark showing the dead lichen due to air pollution

Furthermore, some lichens are more vulnerable than others to particular contaminants, such as sulfur dioxide. The diversity of species found in the local lichen population and the recurring extinction of particular species can be used to determine the quality of the air.

Lichens absorb radioactive elements, such as Cesium 137, that leak from nuclear reactors. Because consumed radioactive lichens, it was discovered that the population of reindeer in the Soviet Union during the 1986 Chernobyl accident had significantly higher at the higher radiation levels.

Symbiotic Association of Lichens:

A cyanobacterium or green alga that is able to perform photosynthetic activity in lichens is inextricably linked to a fungus, which is usually Ascomycetes but can also occasionally be basidiomycetes. Lichens are classified as either basidiolichens or ascolichens based on the type of fungus partner they have. Some forms that resemble lichens are referred to as pseudo-lichens because they lack algae. Pseudoclients are primarily saprophytic, though they can become parasitic.

The phrases "myco" and "phyco-symbiont" refer to the photosynthetic and fungal components of lichens, respectively. In every form of lichen, there is always a single phyco-symbiont and a single type of fungus involved in the relationship. The symbiotic relationship is special since its partners are immutable.

Phyco-symbionts may consist of about thirty distinct genus of algae and cyanobacteria. Lichen thallus is made up of only one kind of algae: green algae. As far, it is possible for cyanobacteria to be filamentous or unicellular. Gloeocapsa and Chroococcus are the two unicellular cyanobacteria that are most frequently found in lichens.

Stegonema, Scytonema, Nostoc, and Rivularia are filamentous species. Green algae are found to be unicellular taxa like Chlorella, Cystococcus, and Protococcus, and filamentous species from the Chaetophorales family including Trentepohlia and Pleurococcus. Among the phyco-symbiont genera most commonly found in lichens are Trentepohlia, Nostoc, and Trebouxia. Almost all lichens are classified into these three genera.

Parmelia acetabula, *Cladonia*, *rangiferina*, Cetrariaislandica, *Usnea barbata*, Lobaria pulmonaria, *Rhizocarpon geographicum*, and other ascolichens are a few frequent types. Among the myco-symbionts of basidiolichens, *Cora pavonica* is a well-known genus, whereas Clavulinopsis is another genus that includes Clavaria. India is home to a variety of lichens from the genera Physcia, Usnea, Cladonia, Lecanora, Graphis, and Parmelia, among others.

The synthesis of specific chemical compounds only occurs when the phyco- and myco-symbionts in a lichen are paired, which is an intriguing feature of lichen symbiosis. Neither of the components can synthesize these chemicals when the symbionts are cultivated independently. In their thalli, several lichens synthesize significant amounts of lipids and unique phenolic chemicals. We haven't fully investigated lichens to find new, beneficial chemicals yet.

Type of reproduction in lichens

Thallus fragmentation is a vegetative means of lichen proliferation. Furthermore, they multiply by developing a variety of asexual forms. Of these structures, soredias are the most common. Both of the symbiotic partners are present inside these microscopic, globose, deciduous organisms. In these bodies, an algal or cyanobacterial cell is encircled by fungal hyphae.

Large numbers of soredia cover thallus surfaces, giving the surface a powdery appearance (Fig. 8.16). Splashes of rain and wind can easily keep soredia apart. Once they have located an appropriate substratum, germinates to form new thalli. Due to the simultaneous carriage of both symbionts in a soredium, the formation of a new thallus is ensured. Normally, the cyanobacterial or algal partners of lichen thalli undergo cell division. Another method is spores by which sometimes algae undergo reproduction.

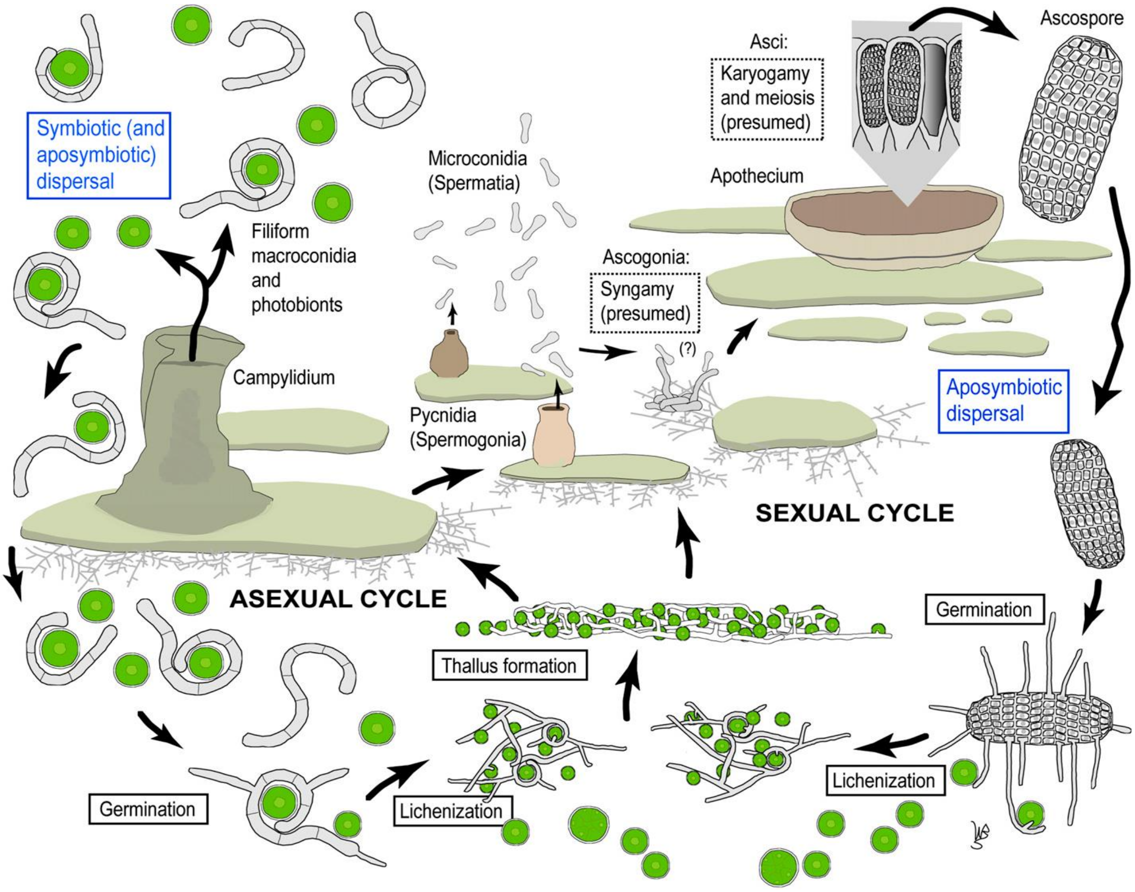


Figure 8.16: Representation of asexual and sexual reproductiom in lichen with the reproductive unit

Lichens can only reproduce sexually through the myco-symbiont. Ascospores and asci are typically generated in distinguished ascocarps by ascolichens. Since Discomycetes are present in the majority of ascolichens, ascocarps are typically apothecia. Both perithecia and pyrenomycetes are substantially less common.

Occasionally, distinct fruiting bodies are absent, resulting in the asci mixed with scattered sterile hyphae. Under any event, after being distributed, the ascospores germinate under favorable conditions to form a germ tube that eventually develops into a hypha. A new lichen thallus forms when the hypha happens to come into contact with the right algal partner and forms a symbiotic relationship. The hypha degenerates if it is unable to locate a cognate partner.

8.5 Mycorrhizae

The term mycorrhizae literally mean "fungus-root." A general definition represents mutually beneficial interaction between a plant's root and a mold which forms a colony in the roots of the plants and trees is known as mycorrhiza.These are fungus that grows in or on the surface of the roots of many plants as shown in Figure 8.17. The fungus aids the plant in absorbing water and nutrients, and the plant provides the fungus with carbohyrates synthesised by photosynthesis. This is how the mold and the plant have a complementary relationship. This exchange plays a major role in plant physiology, ecology, evolution, and nutrient cycles. Sometimes there is no mutual benefit in the partnership. The fungus can occasionally cause minor harm to the plant, while other times it feeds on dead organisms. In natural conditions it is not necessary that all plant showing the symbiotic association to any fungus. When minerals, water and other requirements of the plants are automaticaly fulfilled through its habitat there is no association with mycorrhiza takes place.

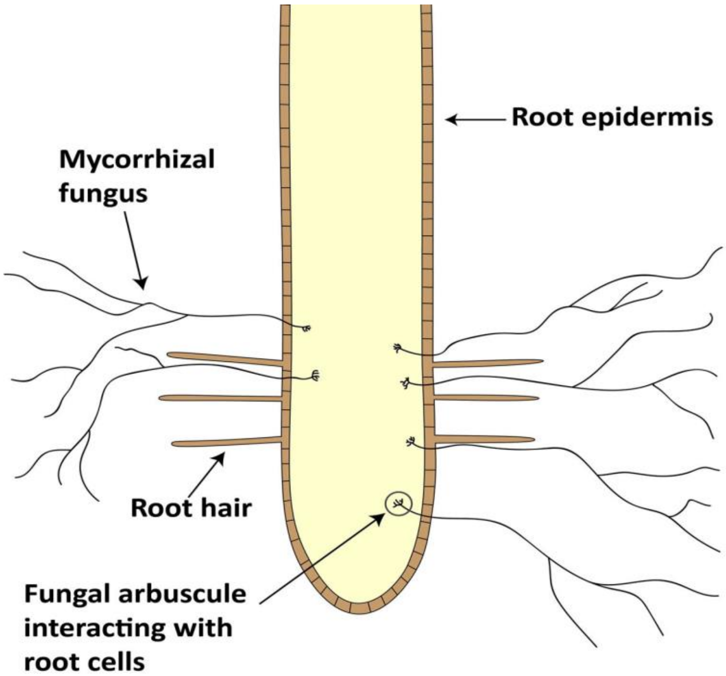


Figure 8.17: Mycorrhizae association with the plant root

Types of Mycorrhizae

Ectomycorrhizae and endomycorrhizae are the two main forms of mycorrhizae categorised on the basis of fungi growing inside or over the surface of roots as shown in Figure 8.18.

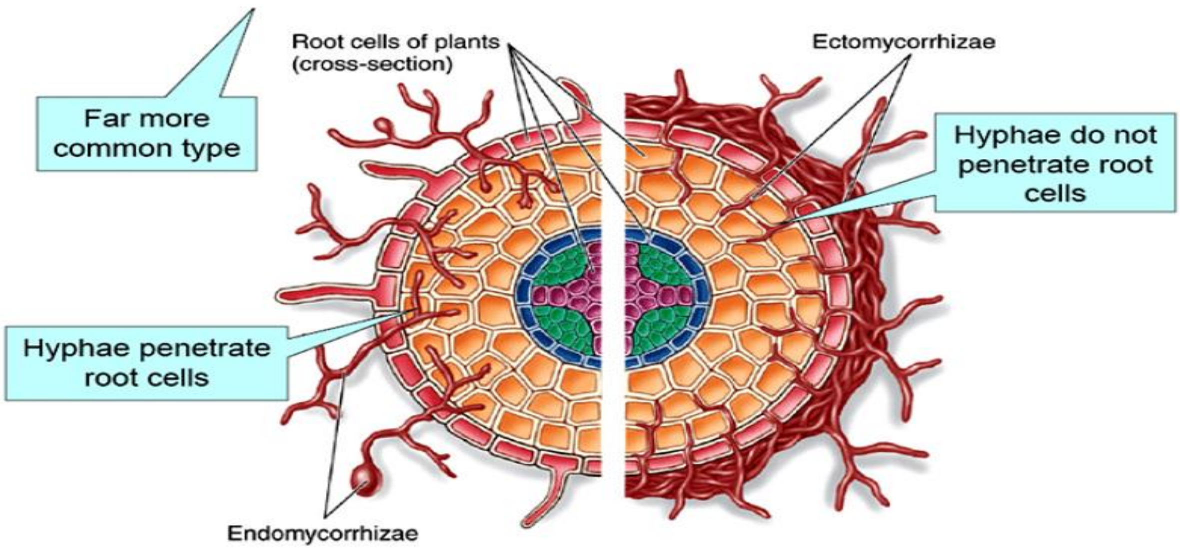


Figure 8.18: Ectomycorrhiza and Endomycorrhiza association with plant roots

Ectomycorrhiza

Ectomycorrhiza typically coexist in mutually beneficial associations with trees and shrubs such as fir trees, oak trees, spruce wood and chestnut. Ectomycorrhizal connections are distinguished by the Hartig Net, an intercellular network of fungal hyphae. The hyphae connects the cortical root cells and the epidermal cells forming the Hartig Net. Another way to recognize ectomycorrhiza is when a thick hyphal sheath forms around the surface of the root. We call this the mantle. To put it another way, ectomycorrhiza only exist on the exterior of the root. Echecorrhiza is present in approximately 5–10% of terrestrial plants and trees

Endomycorrhiza

Contrary to ectomycorrhiza the other form is endomycorrhiza is responsible to be found in the most of the plant species like grass family plants, green leafy vegetables, ornamental plants and trees used for fruits. Endomycorrhizal connections are achieved by the penetration of the cortical cells with fungal hyphae for the production of vesicles and arbuscules. To put it another way, hyphae from the fungus extend outside the root, and endomycorrhiza have an exchange mechanism inside the root. Comparing this association to the ectomycorrhiza, it is more intrusive. *Arbuscular mycorrhizae, Ericaceous mycorrhizae, Arbutoid mycorrhizae,* and *Orchidaceous mycorrhizae* are the distinct subtypes of endomycorrhiza.

Examples of Mycorrhiza

Orchid Mycorrhiza

Certain orchids those are unable to perform photosynthesis before reaching the seedling stage. But for at least a portion of life cycle, most of flowers are dependent on the sugars that fungal companion provides. Fungal infiltration is necessary for orchid seeds to start growing since the seedlings lack sufficient nourishment on their own to thrive. In this connection, the fungus that infiltrates the roots of the orchid is parasitized by it. After the rupture of seed coat roots emerge, the hyphae, or seeds, of orchidaceous mycorrhiza pierce the cells of the root and form hyphal coils, or pelotons, which are sites of nutrient exchange.

Arbuscular Mycorrhiza

Among the micorrhizae species, arbuscular mycorrhizae are the most common and well-known for their exceptional phosphorus affinity and capacity for absorption of nutrients. They combine together to form arbuscules, which serve as exchange points for nutrients including water, carbon, and phosphorus. The fungal partners in this mycorrhizal relationship belong to the family Zygomycota and seem to be obligatory symbionts. Stated differently, the fungi are dependent on their plant host for growth.

Ericaceous Mycorrhiza

A small subset of fungi known as ericoid mycorrhizae is linked to a small number of plant species belonging to the Ericaceae, Epacridaceae, and Empetraceae families. The first fungus species identified as an ericaceous endosymbiont was Hymenoscyphus (Pezizella) ericae. But more recently, it has been shown that several other fungal taxa, including Gymnascella, Myxotrichium, and Oidiodendron, develop mycorrhizal connections with ericoid plants. Like arbuscular mycorrhizae, the fungal hyphae produce hyphal coils instead of arbuscules when they infiltrate cortical cells, which are typically seen in very fine roots. Ericoid plants have fine roots that are made up of one outer layer of cortical/epidermal cells and a vascular bundle.

Arbutoid Mycorrhiza

A kind of endomycorrhizal fungus that resembles ectomycorrhizal fungus is called arbutoid mycorrhiza. They encase the plant's roots in a fungal sheath, but the arbutoid mycorrhiza differs from ectomycorrhizal fungi in that hyphae enter the cortical cells of the plant roots.

Ectotrophic Mycorrhiza

The fungal partners responsible for the association with mycorrhza belong to family basidiomycota and ascomycota. These are present in the plants growing in the mountainous area year around covered with ice. Some of the members are completely detrivorous but few of the members support the plant as a nutrient partner of the tree by deriving the nutrients from the roots of the plants growing in the vicinity of the host trees.

Advantages of mycorrhiza to the host trees

Mycorrhiza partnerships are especially helpful in places where there is limited access to water and in soil that is deficient in phosphate and nitrogen. The mycorrhizal mycelia significantly increase the surface area for absorption of water, phosphate, nitrogen, and amino acids almost like a second set of roots because they are smaller and finer than roots and root hairs. Plants with mycorrhizal connections have an advantage over their non-mycorrhizal linked counterparts that rely just on roots for material intake, as these nutrients are critical for plant growth. In the absence of mycorrhiza, plants may be outcompeted, which could alter the region's vegetation mix.

Furthermore, plants that has mycorrhizal relationships have been shown to be more resistant to some soil-borne conditions. Mycorrhizal fungi can actually be a useful tool for controlling infection. Sheathing mycorrhizae function by constructing an external barrier that keeps pathogens away from plant roots. Additionally, mycorrhiza thickens the cell walls of roots by lignification and the synthesis of other carbohydrates. They compete with pathogens for the uptake of vital nutrients; they promote the production of metabolites in plants that boost resistance to disease. They encourage the infusion of flavonolic wall, which inhibits pathogen invasion and lesion formation; and they raise the concentrations of orthodihydroxypyrroly phenol and other allochemicals in plant roots, which inhibit pathogenic activity. Apart from providing disease resistance, mycorrhizal fungi can also give their host plant tolerance against toxicity and insect resistance resulting the vigor index of the plant.

Mycorrhiza fungus can link every plant in a mycorrhizal network in increasingly intricate interactions. The system moves resources between plants, including water, carbon, and other nutrients. It also serves as a kind of defensive network, sending out chemical signals to other plants in the network to alert them to impending attacks. Plants can use these signals to initiate the production of natural insect repellents, but they can also use them to initiate the production of chemicals which attracts natural predators.Certain trees in dystrophic forests that can avoid the need for soil uptake in certain situations thanks to mycorrhizal fungus. Here, mycorrhizal hyphae immediately absorb phosphates and other nutrients from the plant material which is a dead material.

Additionally, mycorrhizal fungi have the power to interact with their surroundings and alter them in ways that benefit their host plants, enhancing the quality and structure of the soil. Mycorrhizal fungus filaments produce polysaccharides, glycoproteins, and humic substances that bond soils, increase soil porosity and encourages water and air circulation into the soil. Improved soil structure may be more crucial to plant survival in areas with heavily compacted or sandy soils than the absorption of nutrients.

Certain ectomycorrhizal partnerships produce structure that is home to nitrogen-fixing bacteria. These bacteria would be important players in the nitrogen cycle and would primarily contribute to the amount of nitrogen that plants would take up in nutrient-poor settings. Nevertheless, the mycorrhizal fungi do not fix nitrogen.

Advantage to the fungal partner from the association

The plant may perform photosynthesis and create glucose and sucrose when it receives enough water and nutrients; some of this material is made available to the mycorrhizal fungi directly. The photosynthetically fixed carbon that the fungi receive from the host also serves as a catalyst for the fungi's uptake and transportation of nitrogen. All of this is required for the growth and mating of fungi.

8.6 Self Assessment Question

1. Sexual reproduction is absent in:
   (a) Phycomycetes (b) Ascomycetes **(c) Deuteromycetes** (d) Basidiomycetes
2. Fungi can be stained by:
   (a) Iodine (b) Safranine **(c) Cotton blue** (d) Fast green
3. In lichens, sexual reproduction is carried out by:
   (a) algae only **(b) fungi only** (c) both algae and fungi (d) None of these
4. Which of the following produces citric acid?
   (a) *Aspergillus* (b) *Pseudomonas* (c) *Saccharomyces* (d) *Clostridium*
5. *Rhizopus stolonifer* belongs to class?
   (a) Acrasiomycetes (b) Basidiomycetes **(c) Zygomycetes** (d) Ascomycetes
6. Vegetative reproduction in lichens takes place by:
   (a) isidia (b) soredia (c) fragmentation **(d) all of the above**

7. Mushroom is:

(a) Saprophytic fungus (b)Autotrophic Algae

(c) Heterotrophic fungus (d) None of these

8. Heterothallism in fungi was first discovered by:

(a) **A.F. Blakeslee** (b) Robert Whittaker

(b) (c) C.B. Huggins (d) Alexander Fleming

9. Red rot of sugarcane is caused by:

(a) Puccinia (b) Albugo

(c) Colletotrichum (d) Ustilago

10. Black stem rust of wheat is caused by:

(a) *Puccinia gramini-tritici* (b) *Pythium debaryanum*

(c) *Albugo candida* (d) *Rhizopus stolonifer*

8.7 Short Questions

(i) Appressorium (ii) Coprophilous fungi

(iii) Rhizomorphs (iv) fungi imperfecti

(v) VAM

CHAPTER - 9

Bryophytes - Antheridium and Archigonium

Objectives

At the end of chapter student will be able to:

- Determine the unifying features of archegoniate.
- Understand the concept of alteration of generation.

A higher taxonomic word called "archegoniate" designates embryophytes with an archegonium which is a female reproductive organ. Ivan Nikolaevich Gorozhankin, a Russian botanist, used the name "Archegonium" in 1876 by refering to a division that included Gymnosperm, Pteridophytes, and Bryophytes. The multicellular, flask-shaped organ known as archegonia is found throughout the majority of gymnosperms, ferns, liverworts and mosses. The neck-canal cells, which are above the egg, vanish away as the archegonium grows, creating a space for the sperm entery.

9.1 STRUCTURE OF ARCHEGONIUM

The two primary components of Archegonium are: An enlarged fertile portion called the venter, which consists of two unequal cells: a smaller, elongated sterile cell (venter canal cell) and a larger, fertile cell (egg). A row of cells (4-6) known as neck canal cells is typically seen at the upper, elongated, narrow portion of the neck. The entire structure is shielded by a sterile wall made of one or more layers of cells that covers the neck and venter. The archegonia can be sessile or stalked, and four unique cells called cover cells often present its tip as shown in Figure 9.1.

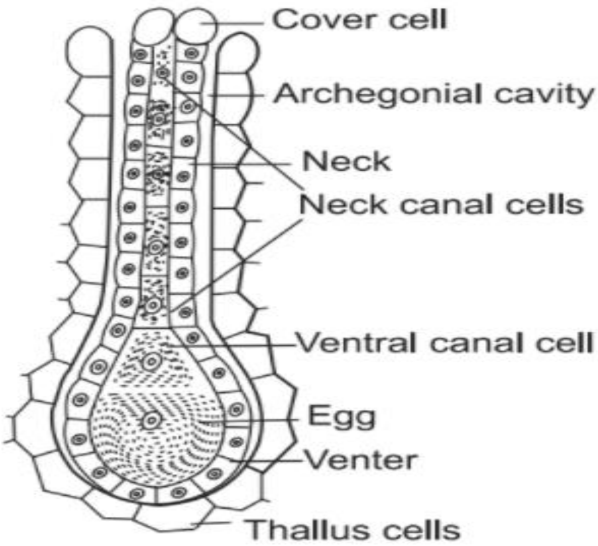


Figure 9.1: Transverse section of Archegonium

9.2 ANTHERIDIUM

The antheridium is the generalised term used for the male reproductive organ found in all archegoniate floras. The structure of anthredium shaped like a stalked club and is made up of spermatogenous cells that grow into multiple square sperm-mother cells. These cells produce male reproductive cells known as anthrozoids those are having two or more flagella for reaching to destination. Once the sperms are released from the antheridium, they swim in water and reaches to the opened channel of the archegonial neck by a phenomenon called chemotaxis as it is attracted to fertilize the egg cells.

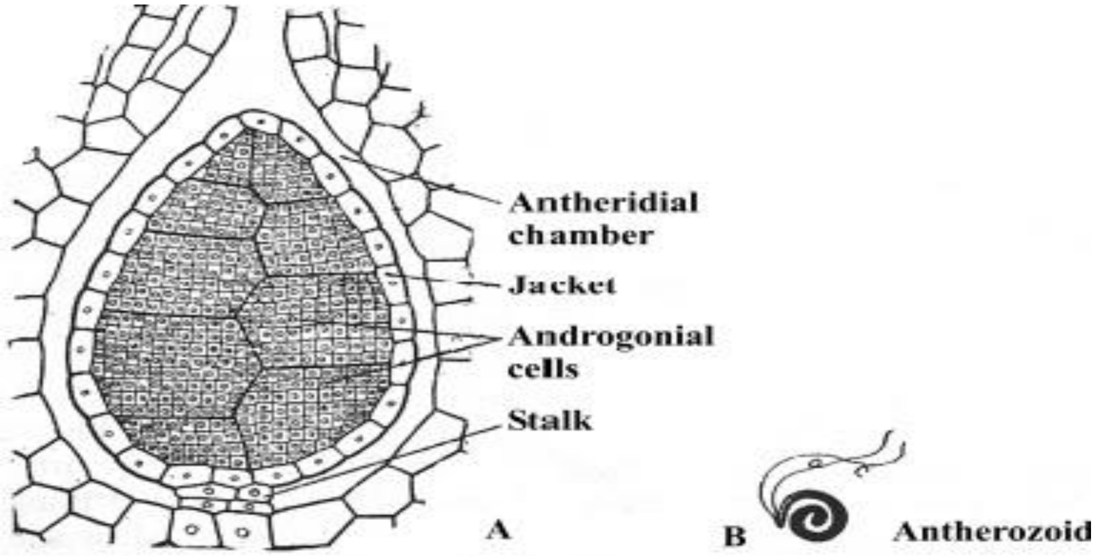
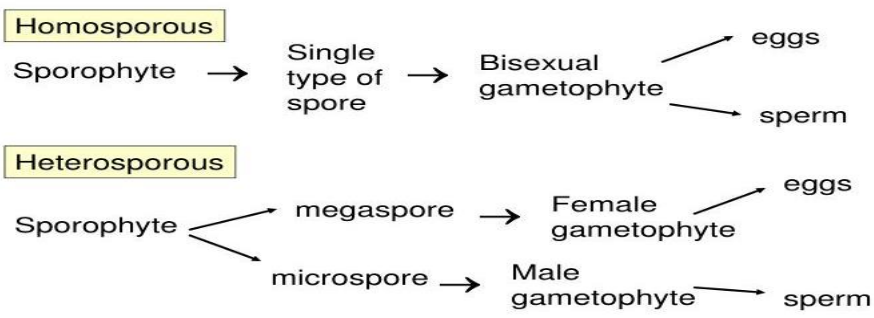


Figure 9.2: Transverse section of the (A) Anthredium (B) Antherozoid

Characterstics of the spores of the archegoniates

The spores in archegoniate plants may be of two types as shown in figure 9.3

- May be having similar or different sizes.
- In the first case the plant is known as "homosporous"
- In the second case the plant is known as "heterosporous"
- In Heterosporous type:
- The larger spore (megaspore or macrospore) gives rise to female gametophyte.
- The smaller one (microspore) gives rise to male gametophyte.



9.3 Characteristic features of archegoniates

Archegoniates are seemed to have originated from a monophyletic group of algal cells found in the water bodies. It indicates that the archegoniates descended from a single, monophyletic group of green algae found in water. These members are referred to be producers of the planet due to existence of carotene, chlorophyll pigments. The term "archegonium" refers to the female reproductive organs, whereas "antheridium" refers to male organs. The male gametes are flagellated and motile, whereas the female gamete (egg) is not.

Alternation of generation is found in these organisms with sporophytic and gametophytic generation. Offers protection to the embryo (the heteromorphic modification of generation happens when the organisms have haploid gametophytic generation while diploid sporophytic generation).

Gymnosperms do not require water for fertilization, whereas bryophytes and pteridophytes do. Gymnosperms use a process called siphonogamy, in which pollen grains germinate to produce pollen tubes that are independent of external fluids like water. The thallium has tissue like collenchyma and sclerenchyma which helps in keeping the body upright. There is a well adapted system for the spore dispersal therefore can easily survive on terrestrial habitat.

9.4 Special adaptive features for transition from water to land

Green algae are the earliest known multicellular organisms that live in water and have been proposed to be the progenitors of land plants. The terrestrial plants have been originated from aquatic plants, notably green algae (Chlorophyceae) 510 and 630 million years ago. According to molecular phylogenetics, the oldest divergent lineages of the living terrestrial plants are the bryophytes. The earliest plants those settled on land were probably closely related to mosses as they are today.Pteridophytes, or primitive vascular plants, and liverworts came after them. Those plants have many adaptations allowed them to make the switch from a watery to a terrestrial habit.

9.5 Adaptations of plants for transition from water to land habit

Assistive systems created to withstand the effects of gravity are known as body support. For example, rigid cell walls and various other tissue forming branching and stems in the plants. An organ is developed of the well-developed tissue for transportation of nutrients from roots to other parts.The atmospheric carbon dioxide effectively absorbed for making glucose by the process of photosynthesis. The reproductive organs are well developed are shielded from mechanical harm when travelled from one point to another. The growth and division of the embryo was also found in such plants.

9.6 Alternation of Generation in Archegoniates

The mechanism of Alteration of generation was reported by Hofmeister in year 1851. Sometimes, referred to as as heterogenesis or metagenesis. It is evident that "A life cycle known as alternation of generations occurs when successive plant generations alternate between haploid and diploid organisms". In plants, algae, and fungus alternation of generation occurs frequently. This is comparable to sexual reproduction in animals, where each generation contains both diploid and haploid cells.

1. **Sporophytic Generation**

   In sporophytic generation sori releases spores fuses to archegonium form zygote that is diploid is created when two haploid gametes unite resulting into sporophyte is produced.The sporophyte is a multicellular creature that is generated by numerous rounds of mitosis. The sporophyte generates sporangia, or reproductive organs, upon reaching maturity. Haploid spores are produced using these sporangia discharged into the atmosphere and transported by water, where they eventually grow into gametophytes.

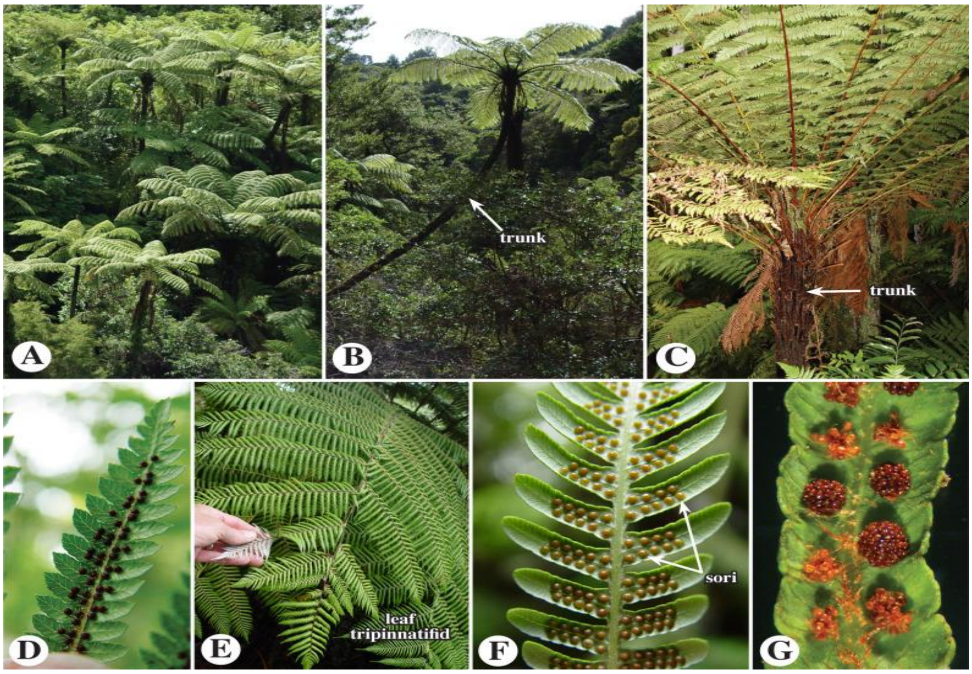


Image Source: https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/sorus

Figure 9.3: A, B. Tree fern, one of the tallest in the world. **C, D** *Cyathea cunninghamii*. **C.** Fern, **D.** Pinna **E** silver fern. **E.** Leaf. **G.** Pinna showing sori.

2. **Gametophytic Generation**

   The gametophytic stage is achieved by the gametes originated from the gametengial cells of the thallus. The gametophytic generation is transferred through water or other vectors. While mating the opposite gametes it forms the zygote later converted to the sporophytic body.

9.7 Alternation of generation in Bryophytes

In Bryophytes there are two stages one is haploid stage (n) is referred as gametophytic generation or sexual stage. Haploid phase (n) is gametophytic generation or sexual phase.

The reproductive organs of the bryophytes have capacity to generate eggs and antherozoids. In Comparison to sporophytic stage the gametophytic stage is more apparent and has a longer life-span. Throughout the life cycle, the gametophytic stage is dominant.The sporophytic stage, also known as the diploid phase (2n), is the stage in which a zygote formed during gametic union matures into a sporophyte. Meiosis occurs in the spore mother cell (SMC), forming spores that germinate to become gametophytes. The cycle continues with sporophyte and gametophytic alternation of the generation as shown in Figure 9.4.

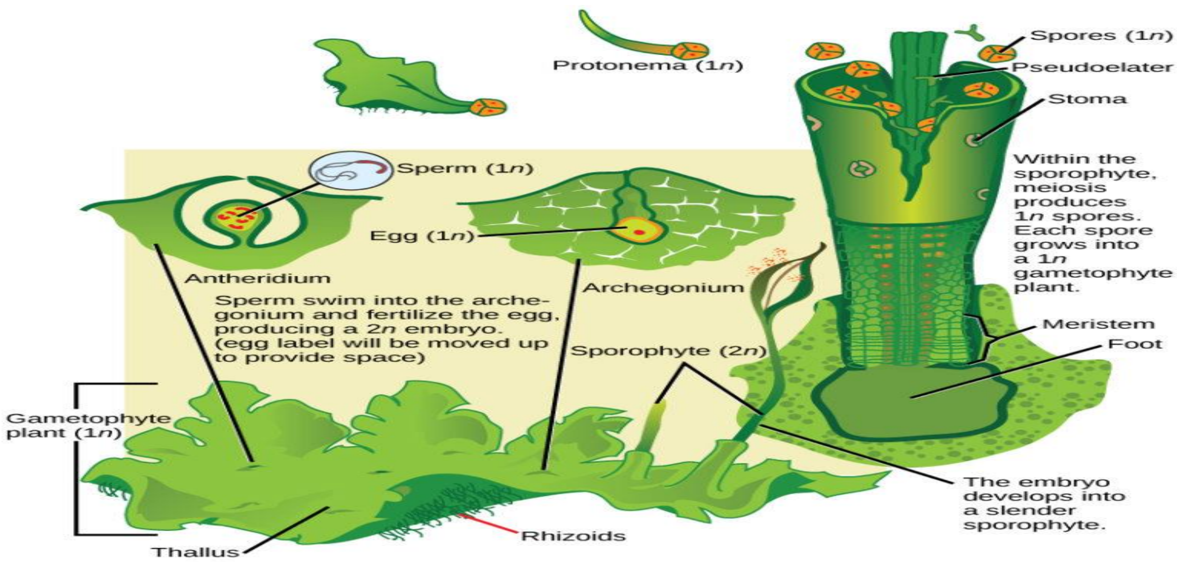


Figure 9.4: Sporophytic and gametophytic life cycle of bryophytes

9.8 Alternation of generation in Pteridophytes

Pteridophytes are reproducing and multiplying on the basis of haploid and diploid life phases. Haploid phase (n) refers to the sexual phase or gametophytic generation.the plants have an anthredia and archegonia reproductive organs as shown in Figure 9.4. Flagellate antherozoids and eggs, respectively, are generated by Anthredia and Archegonia. Gametophytic phase is found to be independent in Pteris and dependent in Selaginella. Gametophytes can vary from monoecious as in homosporous sp. dioecious in heterosporous sp. the Sporophytic stage or diploid phase (2n), developed from the zygote after fertilization. Meiosis occurs in the spore mother cell (SMC), forming non-motile haploid spores that germinate to create gametophytes once more. The cycle goes on with the gametophyte and sporophyte alternating. Microspores and male spores created in male sporangia; Spores formed may be of two types, i.e., heterosporous species as in case of Selaginella, Marsilea. But spores formed are of one type, i.e., homosporous species (Lycopodium, Dryopteris). Megaspores and female spores formed in megasporangia germinated to form male gametophyte. The sporophytic stage is found to be dominant during the life cycle independent to the gametophytic cell stage. The sporophytes are differentiated into well marked stem, leaves, and roots along with the well developed tissues.

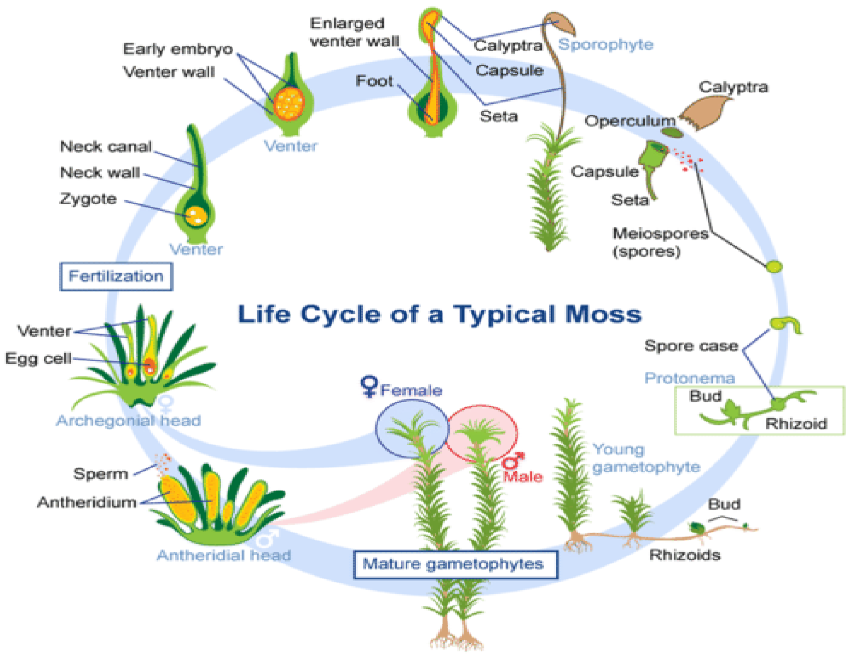


Figure 9.5 Life cycle of Pteridophyte

9.9 Alternation of generation in gymnosperms

Gametophytic stage

The Mature sporophyte contains haploid gametophyte. Two kinds of spores were generated: Male microspores, or microspores, undergo mitosis to become multicellular male gametophytes, or pollen grains, which are housed inside male cones, also known as pollen cones. Megaspores, or huge female spores, proceed through mitosis to become multicellular gametophytes. The female cone/ovulate cones, which are bigger and usually easier to notice than the male pollen cones, are home to the female gametophyte. As long as the male and female gametophytes are kept apart, the haploid stage will persist. The tree releases a lot of pollen in the male gametophyte is present in the pollen grains, which travel by air and, hopefully, settle on an ovulation cone. The pollen tube formed so that the newly formed to undergo fertilisation. The zygote matures into a sporophyte embryo after fertilization, and the entire ovule becomes the seed.The seed has a hard seed coat and contains the food supply for the embryo. Approximately two years after pollination, seeds from the cones of a typical pine tree are shed, and under the right circumstances, they germinate.

9.10 Self Assessment Question

1. Write a short note on anthredia.
2. Fertilization takes place in the ------------- of archegonium
3. The life cycle of Pteridophytes is ------------ with --------- alternation of sporophyte and gametophyte.
4. In Lycopsida the sporophyte plant body is differentiated into definite ------------, ----------------- & --------------
5. What is Rhizome?
6. ------------ is the only plant in the plant kingdom where the vascular tissues develop in the gametophytic generation.
7. Equisetum reproduces --------- and by means of spores.
8. What are elaters?
9. ------------ is a homosporous pteridophyte.
10. *Marsilea* is a ----------- sporus fern
11. ------------- is essentially a method designed to measure residual radioactivity.
12. What is *Lepidodendron*?
13. The plant body of *Calamites* was a ---------- growing to a height of ---------- metres.
14. There were no --------------------canals as in Equisetum.
15. What is polyspory?

Short Question :

(i) Alternation of generation (ii) Venter Canal Cells (VCC) (iii) Ligule
(iv) Gemma cup (v) Sulphur shower

CHAPTER - 10

Bryophytes

Objectives

At the end of chapter student will be able to:

- Determine the morphology of *Marchantia* and *Funaria*.
- Understand the concept of alteration of generation.
- Explore the economic importance of bryophytes

The words "Bryon," which means mosses, and "phyton," means smallest portion of plant stem or root, representing another important member of planet known as Bryophyta. The embryophytes such as liverworts, hornworts, and mosses belong to the group Bryophyta. These are tiny plants those thrive in moist, shaded environments. There are no well-developed vascular tissues present in them. Instead of making seeds, they proliferate by spreading spores. One of the fields of biology is referred as Bryology dealing with the scientific investigation of bryophytes. Since bryophytes are terrestrial plants that require water to complete the life cycle for sexual reproduction, they are known as the "amphibians of the plant kingdom."

10.1 Habitat

Bryophytes are resistant to a broad range of environmental factors, including temperature, moisture, and height from sea water level. These are found to be growing in a variety of harsh and diverse habitats, including the arctic and desert regions, as well as in wet, shaded areas. Species does not require roots to absorb minerals from the soil, allowing it to grow in areas that are inaccessible to vascularized plants. Some of the bryophytes are extraordinarily resilient to extended freezing and drying conditions and restart the process of photosynthesis when conditions become favourable. Numerous bryophytes flourish in soil, on the lingering remnants of their own growth, or on the decaying or live material of other plants. Some are requiring water, while another members can grow on the bare rock surface. Their primary need for growth appears to be somewhat constant.The presence of the substratum for the attachment on the rock along with the availability of optimum spectrum of the sunlight, temperature, moisture to work as a plant system.

10.2 Characterstic Features of the bryophytes

- Plants are found in damp, shaded regions.
- Their bodies are thallus-like, meaning they can be prostrate or erect.
- They are connected to the the base by rhizoids, which can be single-cellar or multi-cellular.
- They are lacking accurate vegetative form like root, stem, and are leaf-like structure instead.
- Bryophytes exhibit alternation of generation between independent gametophyte via sex organs that generate eggs and sperm and dependent sporophyte containing spores.
- The gametophyte, which is haploid, is the dominant portion of the plant body.
- The thalloid gametophyte differentiates into rhizoids, axis, and leaves.
- The gametophyte carries multi-cellular sex organs and photosynthesis-dependent.
- The biflagellated antherozoids are produced by the antheridium.
- The archegonium resembles a flask and yields a single egg.
- The antherozoids fuse with the egg to form a zygote.
- The zygote grows into a multicellular sporophyte.
- The sporophyte is not completely parasitic and feeds on the gametophyte; the sporophyte's cells go through meiosis to produce haploid gametes, which in turn forms a gametophyte; the juvenile gametophyte is called a protonema.
- The sporophytic thallus can be distinguished from the seta, foot and capsule.

10.3 Thallus strcture

- The plant is tiny and erect, growing to a height of about 1 cm.
- Its structure is made up of simple sessile leaves and rhizoid (root-like) structures.
- The gametophyte can be categorised as either foliose gametophore or protonema.
- Foliose plants have a stem in the form axial structure and leaves without a midrib.
- Rhizoids have multicellular structures with septum in oblique.
- Elaters are absent, and the sex organs are carried apically on the stem.
- The sporophyte is divided into 3 types: capsule, seta and foot. The endothecium provides rise to sporogenous tissues as shown in figure 10.1.

- The capsule breaks down for the reason of the separation of the lid, and Columella is present

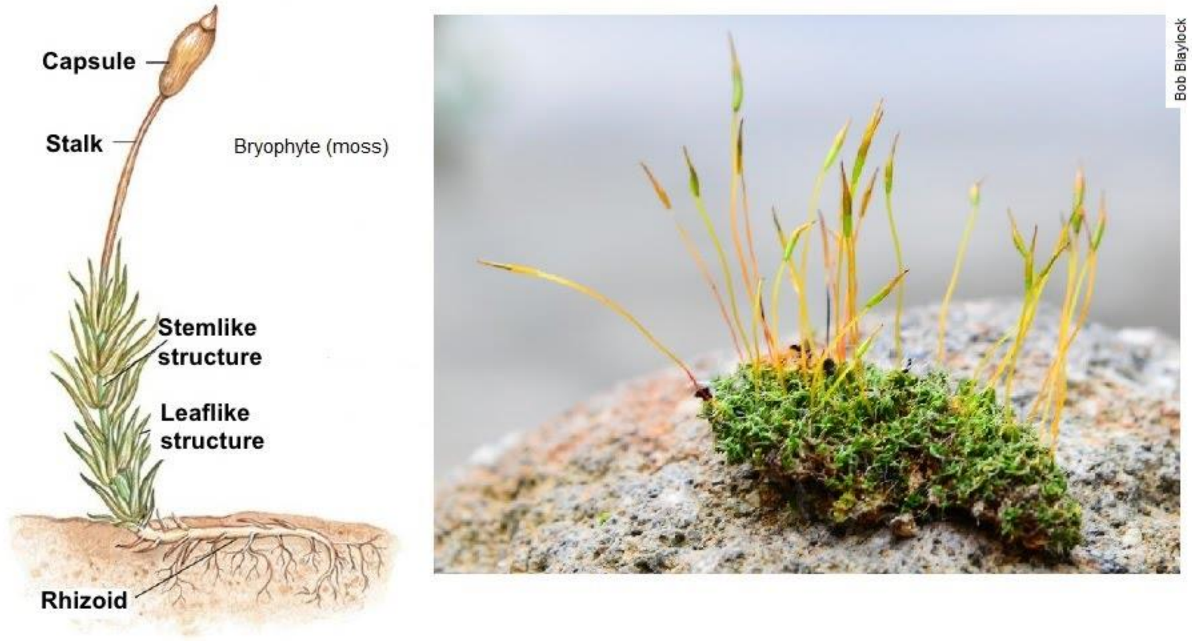


Figure 10.1. Thallus Structure of a bryophyte

10.4 Classification of Bryophyta

The primary evolutionary lines are reflected in the taxonomy that follows. The best place to show them seems to be at the order level for hornworts and liverworts, but at the subclass level for the more complexly taxonomically classified mosses as shown in figure 10.2 and 10.3.

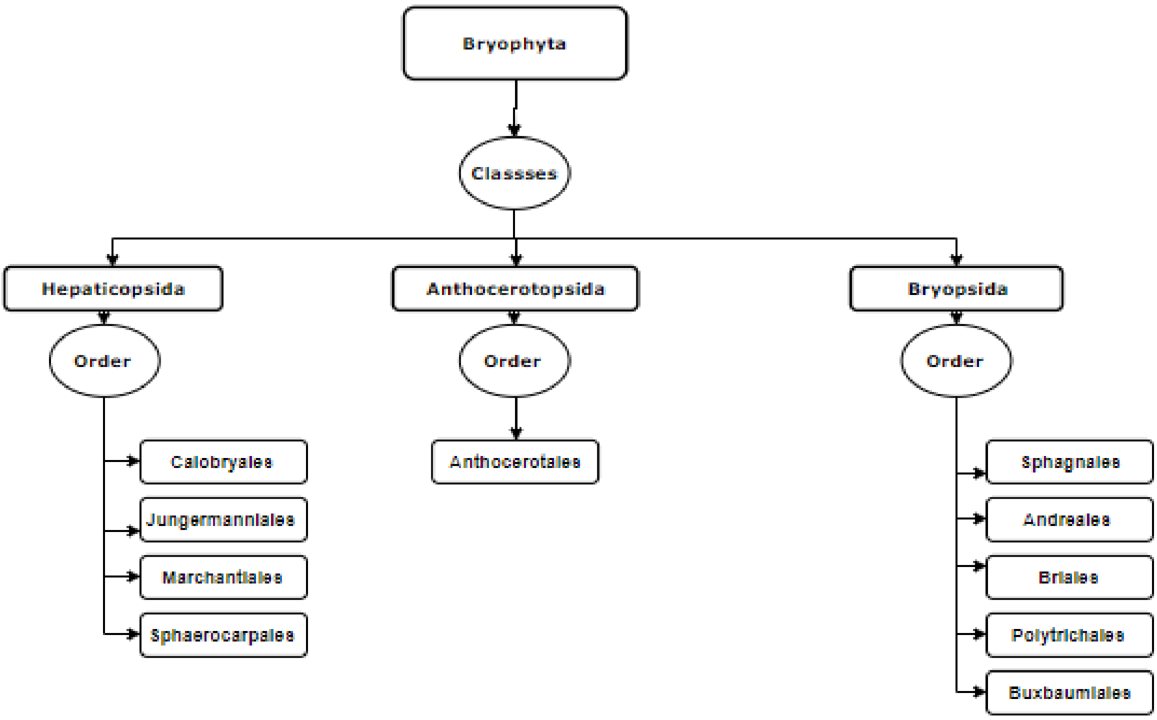


Figure 10.2: The taxonomic classification of bryophytes

A. Liverworts-Hepaticopsida

B. Hornworts-Anthocerotopsida

C. Mosses-Bryopsida

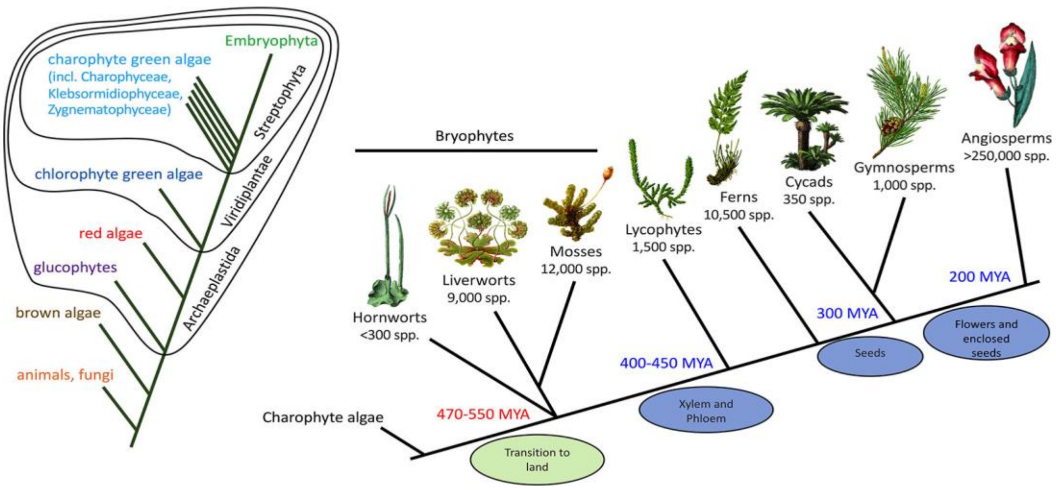


Figure 10.3: Taxonomic position of the bryophytes

A. Hepatocopsida

The term "hepatic," which means liver, is the source of the name hepaticopsida. Liverworts are included in this category.

Four orders further subdivide Hepaticopsida:

1. Marchantiales, such as Marchantia and Riccia
2. Phaerocarpales, which includes Sphaerocarpos.
3. Cabobyales (for example Calobryum)
4. Jungermanniales (including Pellia)

The primary traits as mentioned below of the hepaticopsida class:

- Foliose forms of gametophytes have dorsiventral, lobed leaves without a midrib; thalloid forms have dichotomously branched, dorsiventral leaves.
- The thallus comprises numerous chloroplasts without pyrenoids in each cell. Rhizoids are single celled, branched, and without septa.
- Sexual organs are carried dorsally embedded in gametophytic tissues.
- The sporophyte is composed solely of a capsule (in Riccia) or a foot, seta, and capsule (in Marchantia).
- The capsule lacks a columella**.**

10.5 Reproduction

Asexual reproduction-Gemma formation or fragmentation is the methods used. Gemma cups are used to create gemmae. Asexual, multicellular, green buds are called gemmae. The gemma cup separates from the mother plant forming the next generation.

Sexual reproduction- It the male organ, antheridium, and the female organ, archegonium, to exist on separate or adjacent thalli. They yield eggs and sperm, in that order. Zygote formation occurs following fertilization. After dividing into a diploid sporophyte from the zygote, a small number of sporophyte cells proceed through meiosis to produce haploid spores. These spores grow into free-living, photosynthetic haploid gametophytes.

10.6 Anthocerotopsida

In this class, about 300 species are found named "hornworts" in general. It belongs to the single order Anthocerotales. Examples are Notothylas, Megaceros, and Anthoceros.

The primary attributes of Anthoeropsida are:

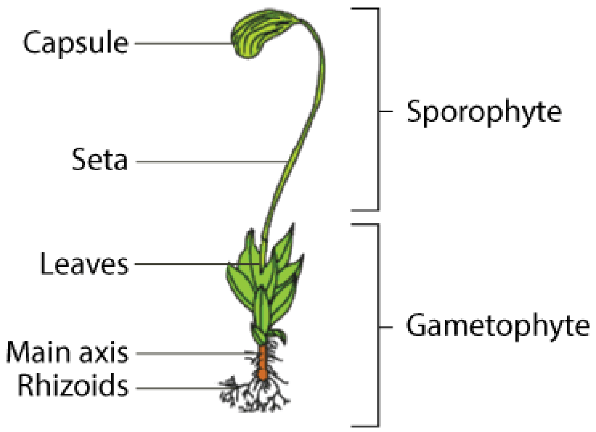
- The sporophyte is differentiated into a foot, meristematic zone, and capsule.
- The gametophytic body is flat, dorsiventral, simple thalloid without internal differentiation.
- Rhizoids have smooth walls.
- Each cell has one chloroplast with a pyrenoid.
- The sex organs are present dorsally embedded in the thallus.
- Pseudoelaters are present in the capsule
- The columella is present in the capsule, which is derived from the endothecium
- Sporogenous tissues emerge from the amphithecium

10.7 Reproduction:

i. **Asexual reproduction:** Under unfavorable circumstances, thallus fragmentation and tuber formation result in vegetative proliferation.

ii. **Sexual reproduction:** Sperm carried by water move from the antheridium to the archegonium to reproduce sexually. A sporophyte is the offspring of a fertilized egg. The gametophyte is formed when the sporophyte splits longitudinally and releases spores.

10.8 Bryopsida (Mosses) - With about 1400 species, it is the biggest class within the Bryophyta. Most people refer to them as mosses. Examples are Sphagnum, Polytrichum, and Funaria.



10.9 Bryopsida is further divided into 5 orders:

1. Bryales
2. Andreales
3. Sphagnales
4. Polytrichales
5. Buxbaumiales

10.10 General attributes:

- The sporophyte is differentiated into foot, seta, and capsule.
- Sporogenous tissues develop from endothecium.
- Columella is present.
- The gametophyte is differentiated into protonema and foliose gametophore.
- Foliose is composed of stem as an axis and leaves without midrib.
- Rhizoids are multicellular with oblique septa.
- The sex organs are borne apically on stem. Elaters are absent.

10.11 Reproduction:

i. Asexual reproduction: This process involves the fragmentation and budding of secondary protonema.

ii. Sexual reproduction: The apical portion of leafy shoots contains both archegonia and antheridia. Sporophyte, which is more differentiated than liverworts, is created following fertilization. The spores give rise to the gametophyte.

Examples of Bryophytes:

Bryophytes consist of around 20,000 plant species. Bryophytes are broadly categorised into liverworts, mosses and hornworts. Some common examples are:

Liverworts	**Mosses**	**Hornworts**
• Marchantia • Riccia • Pellia • Porella • Sphaerocarpos • Calobryum	• Funaria • Polytrichum • sphagnum	• Anthoceros • Notothylas • Megaceros

Figure 10.4 Liverworts, hornworst and moss

10.12 Ecological Importance of Bryophytes-

- In terms of ecology, bryophytes are quite important.
- The earliest living things to inhabit rocks are lichens and mosses, which break down the stone and prepare it for the growth of higher plants.
- Soil formation is aided by the acid secreted by lichens, the death and decay of mosses, the dense growth of bryophytes, which act as soil binders, and the significant role that mosses play in the succession of bogs.
- Mosses have the power to transform an area from climax forest to open soil.

- Because humus and water are present, the dense moss mat provides an ideal substrate for the germination of hydrophilic seeds.
- The hydrophilic plants and decomposing mosses combine to create a firm soil that supports mesophytic growth.
- They minimize soil erosion in hilly regions at the time of rainy season.
- Over the time, the dead and decomposing mosses and hydrophilic plants build a solid soil for mesophytic development
- These can help the nutrient recycling in the environment.
- These help in building rock.
- The plants grow well in the areas which is rich in calcium carbonate.
- The mineral deposition keeps on growing upto several hundred sq feet area.

10.13 Economic importance of the bryophytes:

1. **Medical application:** Sphagnum is used as a surgical dressing because of its strong ability to absorb and certain antibacterial qualities. It can be used to cure blisters and drain wounds by using absorbent bandages instead of cotton.

   A solution made of dried sphagnum is used to treat eye infections and acute hemorrhage. Marchantia has been used to treat liver disease and pulmonary tuberculosis.

   Peat-tar serves as a preservative and antiseptic. Skin conditions are treated with sphagnol, a peat-tar distillate.

   It has been demonstrated that certain species of Polytrichium can dissolve kidney and gall bladder stones. Certain bryophytes can yield compounds with antibacterial qualities.
2. **In research:** Liverworts and mosses are employed in genetics research. In liverworts, the process of sex determination in the plant is revealed.
3. **Packing material:** Dried mosses are a great way to cushion breakable items like glassware and lightbulbs. Because they can retain water, cuttings and seedlings are suitable for transshipment of living materials.
4. **Food:** Certain mosses are nutritional source for birds, animals and herbivorous mammals.

5. **As Plant Indicators:** Certain bryophytes are specialized plants that can be used as a soil acidity and basicity indicator. For instance, Polytrichum revealed the soil's acidity, while Tortella species, which are calcicoles, flourish in soil that is high in lime or other bases.
6. **In seedbeds:** Due to its ability to hold water, it is utilized in nurseries, greenhouses, and seedbeds for root cuttings. Sphagnum is also utilized to keep the high acidity of the soil that some plants demand.
7. **Peat formation:** Peat moss, or sphagnum, is another name for it. Decomposition is slowed down to generate peat. In bogs, partially decomposed plant debris gradually compresses and becomes carbonized, forming peat, a black material.
8. **Formation of Stone:** A lot of travertine rock is utilized to make building stones.
   In addition to being used as fuel, peat also produces ethyl alcohol, ammonium sulphate, ammonia, color, paraffin, tannins, and other chemicals. It also helps with soil texture in horticulture.
9. **An Antioxidants:** Bioactive materials from *Marchantia linearis*, *Marchantia paleacea* and *Conocephalum conicum* may be significant sources of bioactive materials that can effectively shield cells from oxidative damage, which is a major cause of aging and cancer.
10. **Building Materials:** To stop fires, the aquatic moss *Fontinalis antipyretica* is placed between chimneys and walls by the Nordic people. A variety of mosses are employed as chinking materials (chink is a crack or small fissure). Similarly, bryophytes are used in Alaska to chink log and timber cabins. Bryophytes also used by shepherds in the Himalayan highlands for chinking. Sphagnum is stuffed between house timbers in Northern Europe to reduce noise. Herdsmen in the Alps also utilized mosses to build shelters. The purpose of Neckera complanata is used to fills the cracks in water-boats.
11. **Household application:** As an absorbent in Hiking boots have a layer of sphagnum to cushion the foot and absorb odor and moisture. Dry sphagnum is used to manufacture mattresses, beddings, cushions, and pillows by packing mosses into coarse linen sacks. It is also used in cradles and diapers to keep babies warm and dry.
12. **Ornamental Materials:** One of the most significant economic uses of bryophytes is in the production of decorative materials. Examples of these uses include the employment of *Dicranum scoparium* to create banks of green in store window displays, *Rhytidia*

delphusloreus to make green carpets, and dyed Hylocomium splendens to adorn women's hats.

Other uses: Fuels such as coal, ethyl alcohol, ammonia, dye, paraffin, and peat formation can be utilized.

10.13 Self Assessment Question

1. What is the General characteristic of the Bryophytes? Give a detailed note about the call wall composition, classification and Economic importance of the Marchantia.
2. Write about Alteration of Generation in Bryophytes? What is economic importance of peat moss.
3. Write the similarity and dissimilarity between Bryophytes and Algae. What is the economic importance of the Bryophytes?
4. Write about the morphology, anatomy, reproduction and gametophytes of liverwort and hornworts.
5. Give examples of liverworts, mosses along with the characteristics features.
6. Write a short note on type of reproduction takes place in bryophytes.

CHAPTER – 11

Bryophytes - Marchantia, Funaria, Sphagnum

Objectives

At the end of chapter student will be able to:

- Determine the morphology of Bryophytes.
- Understand the concept of classification.
- Explore the economic importance of bryophytes

Marchantia is a prominent genus of liverworts, a type of bryophyte. These plants are commonly found in damp, shaded areas. Unlike most plants, they do not have true roots, stems, or leaves. Instead, they possess a thalloid body as per Figure 11.1.

Bryophytes, including Marchantia, are often referred to as the amphibians of the plant kingdom due to their requirement of water for sexual reproduction and completion of their life cycle.

Marchantia are capable of both sexual and asexual reproduction. These plants have a haplodiplontic life cycle, in which the haploid gametophyte is the dominant phase. In contrast, the gametophyte is essential to the short-lived diploid sporophyte phase.

11.1 Marchantia

Marchantia, a type of liverwort, possesses a distinct structure that sets it apart from many other plants (Figure 11.1).

Figure 11.1: Marchantia in its habitat

11.2 Thallus

A thallus is a flat, green structure that makes up the main body of Marchantia. In contrast to plants having stems, leaves, and roots, the thallus is an example of a single, cohesive organism that performs all vital plant functioning. Two separate strata can be seen inside this thallus:

- **Upper Photosynthetic Layer:** This layer has a distinct upper epidermis with pores and includes chloroplasts, which are essential for photosynthesis. These pores, which are seen as diamond-shaped patterns on the upper surface, help the plant and its surroundings exchange gases.
- **Lower Storage Layer:** This layer stores food and water is devoid of chloroplasts.

11.3 Scales and Rhizoids

There are two primary structures on the thallus' underside.

Rhizoids: These hair-like structures help the plant absorb minerals and water by anchoring it to the earth. Rhizoids are made up of a single cell, unicellular, in contrast to roots.

Scales: These multicellular, purple-colored structures probably shield the thallus underside in addition to aiding in water absorption.

11.4 Reproductive Organelles

Marchantia reproduces asexually as well as sexually.

1. Asexual Reproduction: Gemma cups are tiny cup-shaped structures found on the thallus' top surface. Gemmae, or clusters of cells, are found inside these cups. Gemmae have the ability to grow into new Marchantia individuals after being separated from the plant.
2. Sexual Reproduction: Marchantia's sexual reproductive system clearly demonstrates the plant's dioecious nature, which results in separate male and female plants.

   Antheridiophores have Antheridium produces sperm cells.

   The apical notch at the apex of the thallus is where these structures originate. A generation of sporophytes is produced following fertilization by sperm cells carried by water droplets. The short, flattened form generates spores that complete the lifecycle by germinating into new gametophyte (thallus) plants.

11.5 Classification of Marchantia

Marchantia belongs to the division Hepaticophyta, which encompasses all liverworts. Another example of a liverwort is Riccia. Bryophyta is subdivided into three primary classes:

Kingdom	Plantae
Division	Hepaticophyta
Class	Hepaticopsida
Order	Marchantiales
Family	Marchantiaceae
Genus	*Marchantia*

The genus Marchantia comprises approximately 65 species, found globally in moist and shady places. Some examples include Marchantia polymorpha, Marchantia berteroana, Marchantia palmata, and Marchantia nepalensis.

11.6 Features of Marchantia

- This is usually live in moist, shady environments.
- The thallus of the thalloid plant is flat and dichotomously branching. The major stage of plant development is the gametophyte.
- Diamond-shaped marks with center pore for gas exchange are seen on the dorsal surface. Beneath these polygonal patterns are internal chambers.
- Rhizoids and scales cover the ventral side. The unicellular rhizoids serve as the plant's roots, attaching it to the substrate and taking up nutrients and water.
- The dorsal surface houses the reproductive organs.
- They have a structure called a gemma, which is cup-shaped, for asexual reproduction.
- The antheridiophore and archegoniophore are stalks that support the sexual reproductive organs. These include the reproductive organs of both sexes.
- The pores are present on the dorsal side opening into photosynthetic zone, the epidermal surface have few choloroplast.
- Underneath the photosynthetic zone and air chamber is the storage zone. It is made up of parenchymatous cells and is devoid of chloroplasts. These hold mucilage, carbohydrates, protein, and oil.
- The lower epidermis extends into rhizoids.

11.7 Reproduction in Marchantia

Marchantia reproduces both asexually and sexually.

Mode of reproduction-Asexual

In Marchantia, asexual reproduction takes place by fragmentation or the development of specialized structures called gemmae.

Gemmae

Asexual buds develop in containers called gemmae cups. These cups are situated close to the gametophytic thalli's midrib on the dorsal surface. Gemmae are green, multicellular organisms.To create a new plant, gemmae separate from the parent plant and germinate.

Mode of reproduction-Sexual

Because Marchantia is dioecious, its sex organs develop on different thalli for male and female individuals. The antheridia are the reproductive organ found in males, whereas the archegonia are found in females. These are erect, modified stalks known as archegoniophore and antheridiophore, respectively, that are born on adult gametophytes.The antheridium is the source of antherozoids. They come from androcytes and are biflagellated.

Fertilisation

Marchantia requires water for fertilization, same as other bryophytes. When the archegonia swells after absorbing water, the neck canal cells and the ventral canal cell break down to form a mucilaginous mass that oozes out. Chemical components in this bulk cause a chemotactic reaction. Attracted to the archegonia, the antherozoids swim in its direction. Fertilization occurs when an antherozoids unites with an egg. A diploid cell, also called a zygote, is created when the male and female nuclei unite.

Sporophyte

The diploid zygote does not go into reduction division, or meiosis, right away. Rather, it undergoes mitosis and grows into the sporophyte, a multicellular structure. There is a foot, seta, and capsule differentiation in the sporophyte. It is dependent on the gametophyte for survival it is not a free-living stage.

11.8 Life cycle of Marchantia

Marchantia exhibits an alternation of generations with haploid sexual and diploid asexual phases alternating. Marchantia is a haplodiplontic organism, meaning that its multicellular structures represent both the haploid and diploid phases of its life cycle.

The gametophyte (haploid) is the primary free-living plant body. The gametophyte provides anchoring and food for the short-lived (diploid) sporophyte stage.

The diploid zygote is formed by the fusion of an egg and antherozoids produced by the male and female gametophytes, respectively. The zygote differentiates into a multicellular sporophyte through mitotic division. Meiosis occurs in the spore mother cells to produce haploid spores, which germinate to produce haploid gametophytes. A portion of the sporogenous tissue's cells, referred to as diploid spore mother cells, divide meiosisally to create haploid spores. The capsule's dehiscence releases these haploid spores. They germinate to produce the gametophyte, or new haploid plant, under the right circumstances (Figure 11.2).

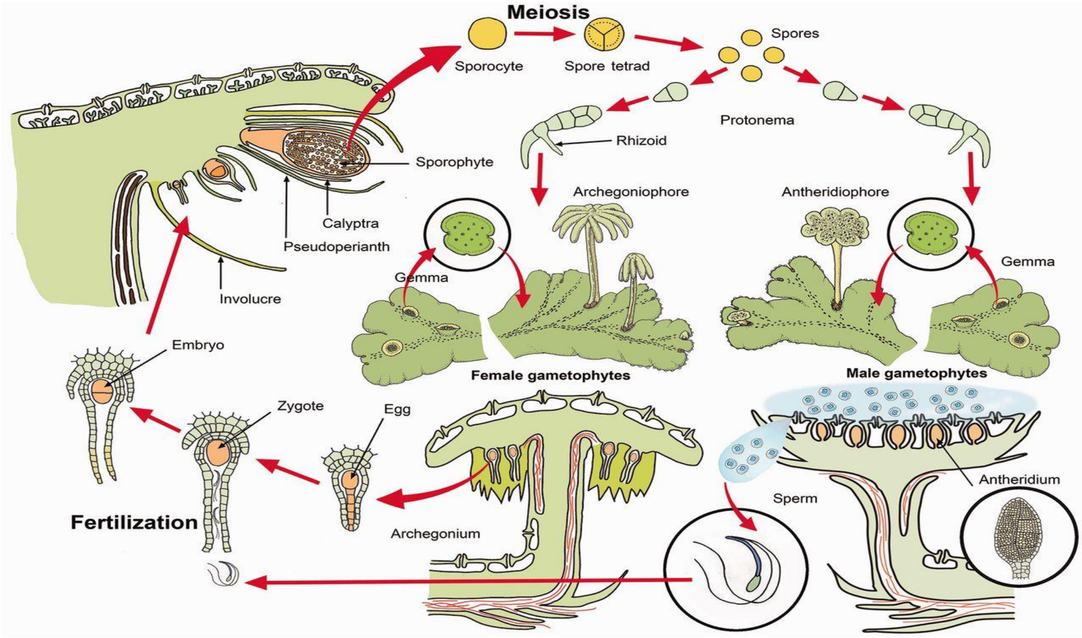


Figure 11.2: Life cycle of the Marchantia

Plant Cell Physiol, Volume 57, Issue 2, February 2016, Pages 230–256,
https://doi.org/10.1093/pcp/pcv192

11.9 Funaria

There are 210 recognized species of funaria, 18 are found in India. It is frequently referred to as "cord moss." The Latin word "Funis," which meant rope, is from where the name "Funaria" originated. This is one of the globally distributed bryophyte that can be found in both tropical and temperate climates as shown in Fig 11.3. It thrives in damp, shaded areas. In regions of vivid green, it grows profusely. It thrives in cracks in rocks, damp walls, river banks, moist soils, and tree trunks.

Figure 11.3: Fuaria in the natural habitat

Classification of *Funaria*

Kingdom	Plantae
Division	Bryophyta
Class	Bryopsida
Order	Funariales
Family	Funariaceae
Genus	*Funaria*

11.10 Morphology

- There are two stages in Funaria: the sporophyte and the leafy gametophyte.
- The primary plant body, known as the gametophytic stage, is represented by both a mature and juvenile stage.
- The stem leaves, and rhizoids make up the haploid plant body.
- The stem is green, photosynthetic, upright and branching. The lowest part of the stem is where the branches start.
- On each stem, the leaves are arranged in a spiral order. They are grouped near the peak and dispersed toward the base. There is a feature noticeable at the midrib of the leaves. These are sessile, nearly oval in shape.
- Rhizoids hold the stem fixed to the substratum. This resemble to root hairs and are multicellular, branching structures.
- The gametophytic plants have homothallic and monoecious traits. The antheridium or male reproductive organ, and the archegonium female reproductive organ.
- At the termini of the antheridial and archegonial branches, respectively, clusters of the sporophyte, which is separated into a foot, seta, and capsule and is attached to the archegonium, arise.
- The gametophytic plants have homothallic and monoecious traits. On distinct branches of the same plant, the female reproductive organs, known as the archegonium, and the male reproductive organs, known as the antheridium, are carried.

11.11 Types of reproductive mode in Funaria

Funaria reproduces by both vegetative and sexual methods.

Reproduction through Vegetation

1. **By Primary Protonema:** When the spores start to grow, they are multicellular organisms filamentous in appearance, branched structures known as primary protonema. These cells split apart to form additional protonemal cells, which grow into a gametophore with leaves.
2. **By Secondary Protonema:** A protonema formed by a mechanism other than spore germination is referred to secondary protonema. It grows from damaged or fragmented stems, leaves, or rhizoids. An entirely new gametophore may emerge as a result.
3. **By Bulbils:** The rhizoids give rise to tiny resting buds known as bulbils. When conditions are appropriate, they begin to divide and create filamentous protonema, which can develop into foliage gametophytes.
4. **By Gemmae:** Under adverse conditions, the protonema's terminal cells divide both longitudinally and transversely to 10 to 20 celled green bodies known as gammae. The structurally divided cells develop into a new plant when conditions become favourable.
5. **Apospory:** The growth of gametophyte from sporophyte in the absence of spore production is known as apospory. Green protonemal pieces from the sporophyte's vegetative cells develop into gametophytes later on. Apoptotic plants produce diploid gametophytes, which develop into tetraploid cell stage and sterile sporophytes.

11.12 Sexual Reproduction

Oogamous sexual reproduction is found in the Funaria. The antheridium is the reproductive structure found in male branches and the archegonium is found in branches having females. The plant is dioecious —that is, its reproductive organs grow on different branches—and monoecious—that is, it has both male and female reproductive organs on the same plant.

The male branch of the gametophyte is its main stalk, which bears the antheridium in clusters. From the base of the male branches, lateral branches containing archegonia arise. The female branch develops more than the male branch does. Funaria is protandrous, meaning that the anther matures before the archegonia, as illustrated in Figure 11.4 to promote cross-pollination.

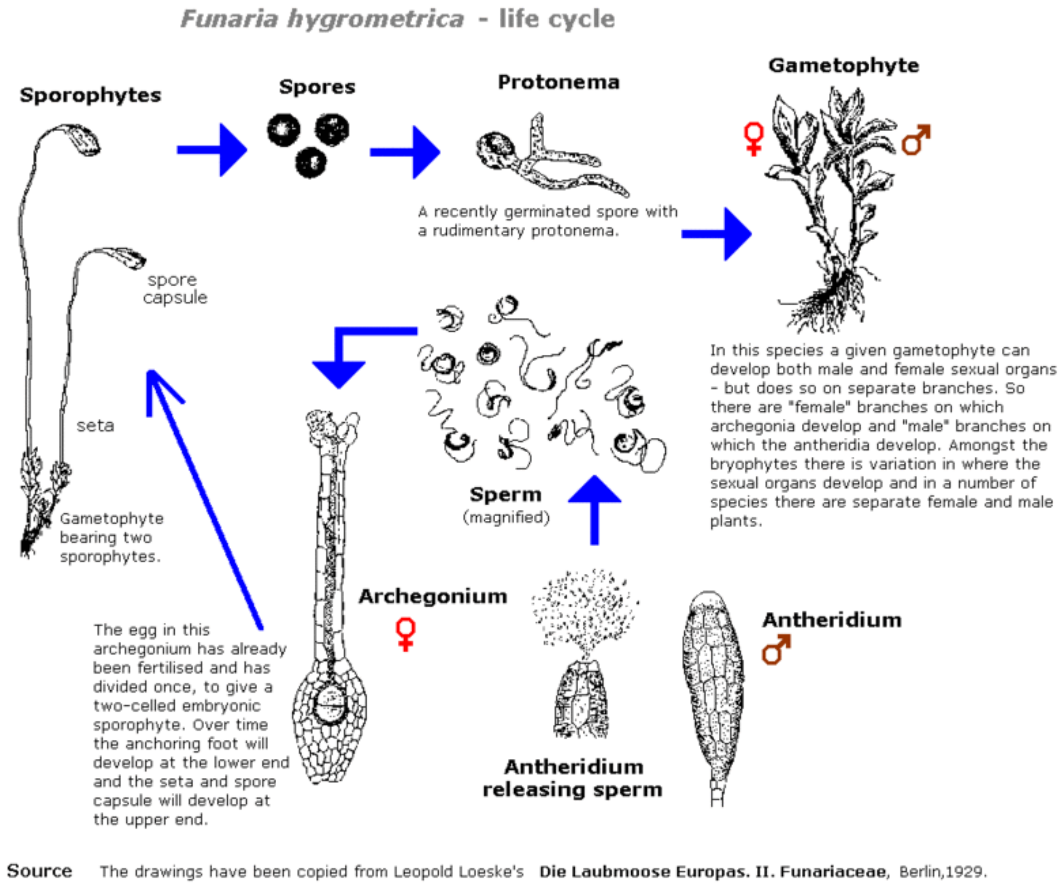


Figure 11.4: Life cycle of Funaria showing the sporophyte, archegonium and anthredium

Antheridium

Antheridium is the name of the male reproductive organ. The antheridial branch has a height of approximately 1 cm as shown in Figure 11.4. At different stages of development, the branch displays antheridium ranging in color from reddish-brown to orange. Perigonial leaves are a type of rosette of leaves that encircle the antheridia. The leaf rosette and the antheridial cluster are referred to as the perigonium. The antheridia include a variety of club-shaped, sterile, hair-like structures called paraphyses. They guard the developing male reproductive organs, retain water, and aid in photosynthesis of antheridia's dehiscence.

Organization: The multicellular stalk of the club-shaped antheridium is short and robust. The huge, elongated antheridial body is present. The antheridial wall, also known as the jacket, is a layer of sterile cells that covers it. Operacular cells are a few layers of thick walls found at the apex of the antheridium. Below the exterior layer are the androcyte mother cells. After the androcyte mother cell divides into two androcytes, biflagellated and elongated sperm, or spermatozoid, are produced.

The opercular cells swell up and absorb water when they reach maturity. At the tip of the antheridium, a terminal pore forms when the walls of the opercular cells and androcytes gelatinize. This mucilage-covered orifice releases the androcytes. When the mucilage dissolves in water, androcytes transform into sperm with five flagella.

Archegonium

The archegonium is the name of the female sex organ. Compared to the male branch, the female branch is carried higher. At the end of the archegonial branch, clusters of archegonium are produced.

Organization: The archegonium is a structure fashioned like a flask. It is made up of a thin neck, a bulging ventr, and a neck. It has a stalk connecting it to the female branch. The venter is made up of a double-layered venter wall enclosing a venter cavity. An egg and a ventral canal cell are found in the venter cavity. An axial row of eight to twelve neck canal cells makes up the neck. There are four cover cells that shut the tip of the neck.

The cells in the ventral and neck canals disorganize to generate mucilage when they reach maturity. The outer cell present at outside of the archegonium separates forming an open passage leading to the canal.

The process of fertilization

The spermatozoid particles are transported to the archegonium through wind or raindrops. Spermatozoids are drawn to archegonias due of the mucilage in their mouths. The neck canal serves as the spermatozoid's entry point into the venter cavity. A spermatozoid and an egg cell combine to form a zygote, which then matures into a sporophyte.

Sporophyte

The diploid plant of Funaria is called a sporophyte. It has a parasitic attachment to the gametophyte. The zygotic cell divides multiple times to produce a spherical proembryo. After this, the proembryo matures into a diploid sporophyte. The female branch tip is where the sporophyte is connected. For part of its sustenance, the sporophyte depends on the gametophyte.

The sporophyte can be divided into following parts

1. Foot: This is the sporophyte's enlarged basal portion. It stays lodged in the female branch's convex tip. It is made up of cells called parenchyma. The part that joins the sporophytic to the gametophytic stage is called the foot. It assists in obtaining food from the gametophyte.
2. Seta: This is a structure with cylindrical, long brownish-red in appearance. It joins the foot to the capsule. It is made up of a center cylinder, a middle cortex, and an outer layer of epidermis. Long, thin-walled cells make up the core cylinder, whereas thick-walled cells make up the cortex. Its purpose is to transport water and food from the foot to the capsule.
3. Capsule: In the sporophyte's body, or capsule, is where spores are born. It appears in color range from yellow-orange to green. The structure is shaped as pear. The fertile portion is consisting of three parts.
4. Apophysis: The base of the capsule, which is sterile, is in direct touch with the seta. It consists of an exterior layer called the epidermis that has stomata for exchanging gases. The cortex, which makes up the center part, is composed of spongy parenchyma cells that are photosynthetic in nature and contain chloroplasts. Food and water are transported from the seta to the theca by the elongated, thin-walled cells that make up the central cylinder.
5. Theca: Theca is the capsule's central section. It is composed of a columella, or central sterile core. The spore sac encircles the columella. The spore mother cells in the spore sac go through meiosis to create a tetrad of spores.
6. Lid: The sterile terminal section of the capsule is called the operculum, or lid. The thick-walled epidermis is the outermost layer, whereas the parenchymatous, thin-walled deeper layers are found within. The theca and lid are divided by a small, round constriction. The annulus, a ring of five to six thin-walled cells, is located directly above the constriction.

There is a two-ringed structure of peristome teeth beneath the lid wall. Exostome refers to the outer ring of the peristome, while endostome refers to the inner ring. They participate in the capsule's dehiscence.

Dehiscence of the Capsule

The operculum is flung off when the capsule matures due to the annulus rupturing, exposing the peristome teeth to the air. The peristome teeth break when the capsule gradually dries out. Small amounts of spores are released by the peristome teeth, which create a fringe around the spore sac's mouth.

Spore germination

Meiospores are the spores that sporophytes create. Reductional division occurs inside the capsule to form the haploid spores. An outer layer known as exine and an interior layer known as intine make up a spore. After absorbing moisture, the spore expands and ruptures the exine. The intine develops into a germ tube initially, and then into a protonema, which is a branching filamentous structure. The protonome fixes itself with rhizoids and grows on the substratum. The developed protonema produces several lateral buds, which give rise to gametophytes.

11.13 Sphagnum

Sphagnum is the mosses commonly referred to as "bog-mosses" or "peat mosses." This appears to be a sign of the plant’s preferred environment and the fact that the primary ingredient in peat is their partially degraded remains. Sphagnum, on the other hand, seems far more intriguing although they belong to a distinct genus and are of a unique kind. The term "sphagnos," which was previously used to refer to a little shrub or moss, is where the name originates.

Figure 11.5: Sphagnum in its normal habitat

Classification

Kingdom	: Plantae
Division	: Bryophyta
Class	: Sphagnopsida
Order	:Sphagnales
Family	: Sphagnaceae
Genus	: Sphagnum L.

11.14 Habitat

Moist environments are the only places sphagnum mosses may be found. Although the number of Sphagnum moss species is debatable, there are about 120 species are found around the world. One unique quality of sphagnum mosses is their ability to completely dominate the environment in which they reside. The potential of such mosses to control entire landscapes is belied by their very unassuming and harmless appearance. Because of their many special biological characteristics, sphagnum mosses are excellent habitat attackers.

Hyaline cells, a unique type of water-retaining cell found in sphagnum mosses, absorb water and release it gradually. As a result, the ecosystem is continuously kept damp and moist, which is exactly how sphagnum mosses prefer it. Additionally, by actively creating unique acidic compounds and adding hydrogen ions, they actively acidify the environment in which they reside, inhibiting the growth of other plants that cannot withstand such conditions. The habitat may dry up if other plants remove too much water.

11.15 Structural Features

Branching: Sphagnum has a unique branching pattern that is not found in other mosses. One characteristic that sets Sphagnum mosses apart are the bundles of two or more branches that emerge from the stem; these are known as "fascicles."

Protenema: A protonema is essentially a group of cells that serve as the seed for a new moss plant. This first phase of Sphagnum mosses before the gametophyte develops is referred to as "thalloid." This denotes a somewhat flat structure. Other mosses have cell fibers arranged in a form resembling a more intricate network.

Pseudopodium: In Sphagnum mosses, the sporophyte that produces spores grows on what is called a pseudopodium. In literal terms, this is a "false foot." This stem is really short. Some mosses have a structurally appropriate "foot" to support them.

Peristome: Sphagnum mosses lack a peristome, in contrast to other mosses. The operculum, a hole in the spore capsule through which the spores are expelled into the environment, is where they proliferate. A structure that surrounds the operculum and aids in spore dispersal in the atmosphere is called the peristome. Sphagnum mosses don't require such a structure because they almost usually reside in water.

Hyalodermis: The stem of sphagnum mosses is covered in a layer of transparent cells called the hyalodermis. None of the other mosses exhibit this.

Rhizoids: Despite lacking roots, mosses have supporting rhizoids on their bodies. These are little structures that protrude from the bottom of the developing plant and resemble short hairs. Sphagnum mosses do not even have them; they are completely absent because the water surrounding them provides them with all the support they require.

Cells: There are two different kinds of cells: the chlorophyll-containing chloroplast cells, which are known to perform photosynthesis and the specialized water-bearing cells, also called hyaline or retort cells. Sphagnum mosses are the only ones with hyaline cells. They are organized differently in every species of Sphagnum.

11.16 Structural features

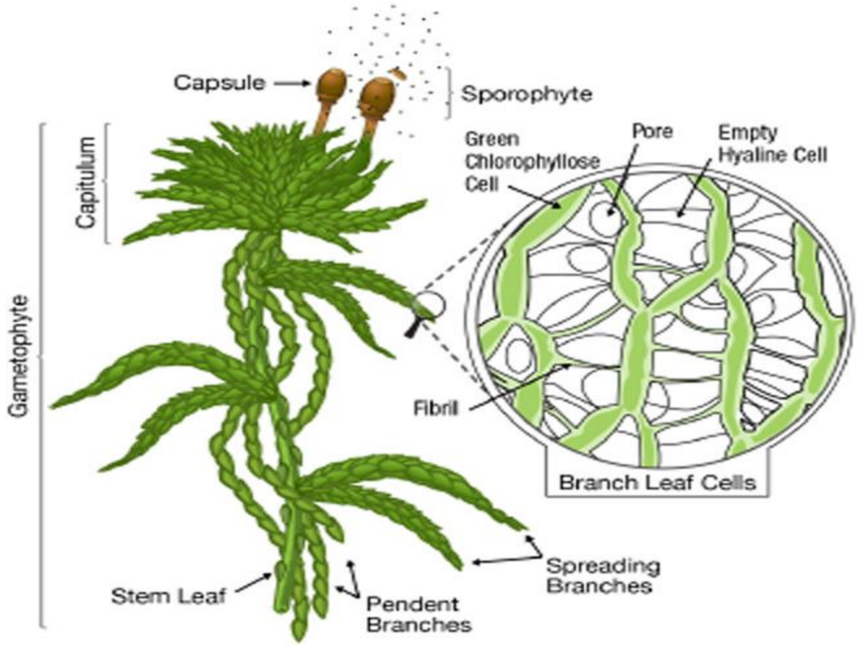
There are four primary components that make up a sphagnum moss plant. Each of these components has unique characteristics that change between species, making it possible to utilize them to help identify distinct species. The four distinct parts of the moss are:

Head or Capitulum

A developing portion is located at the tip of the moss. Many little branches sprout up all around this. This constitutes the capitulum, or head, of the Sphagnum plant. The capitula of various species vary somewhat in shape. Depending on how tightly the branches grow, they can change.

The Fringed Bog-moss (*S. fimbriatum*) is one species that has a stiff growing tip. When this plant is grasped, the capitula are easily felt and are quite hard to the touch. Certain species have heads that are noticeably rounded in profile, such the Blunt moss (*S. palustre*).

In some, on the other hand, the heads are clearly flattened, as in the Flat-topped Bog-moss *S. fallax*. Certain sphagnum species, such as Feathery Bog-moss *S. cuspidatum* which lack characteristic capitula. Some species, such as Austin's Bog-moss *S. austinii*, have stunning star-shaped crowns that give them a unique look.



Plant Cell & Environment, Volume: 38, Issue: 9, Pages: 1737-1751, First published: 30 September 2014, DOI: (10.1111/pce.12458)

Figure 11.6: structural features of Sphagnum

Stem

The stem has a straight structure, consisting of a single, thin, upright tube. It is covered with tiny leaves that are arranged in a 2/5 configuration, close to the stem. Needless to say, these are referred to as stem leaves.A sideways developing branch emerges from the stem every 4 to 6 mm. These converge at the highest point of the stem to form the distinctive capitulum of Sphagnum mosses.

The stem's structure consists of two distinct layers. This occurs after the cell material has differentiated, which takes five to six months to occur. There is a more resilient outer layer and an inner cortex.

Parenchyma cells make up the inner cortex. The translucent parenchyma substance in the center can be regarded as biological "filler," although it does let substances circulate throughout the plant. It performs a support role as well. However, in older plants, this central substance may disappear, and the mature Sphagnum plant may develop hollow tubes inside of it. A thin layer of epidermal cells, up to four cells thick at most, but varying depending on the species, surrounds this core substance.
Cortical cells have a harder cell layer on the outside. The outer cortical layer, which mostly consists of dead cells, shields the plant.

Sphagnum moss tissues and cellular structures are typically simple with thin structure. Due to specialised structure the nutrient uptake tends to be easier still these mosses do not have vascular system for transportation in sphagnum.

Most of the time, the stem is visible in between the branches; but, in certain species, including Feathery Bog-moss *S. cuspidatum* and Blunt-leaved Bog-moss *S. palustre*, the branches cover the stem, making it difficult to distinguish between the branches.

Leaves

The Sphagnum plant’s leaf structure has appearance are contingent upon their specific location. There are differences in size and shape among the leaves on the stem and the branches. This is presumably due to the fact that branches held perpendicularly are far more positioned to catch light from above than branches supported against the main stem horizontally. In leaves middle ribs are absent.

11.17 Life Cycle of Sphagnum

The life cycle of sphagnum mosses has similarities to that of other mosses. With only half of the whole genetic material, the "Gametophyte" is what we know as the Sphagnum plant. The only organism with all of its genetic components is the "Sporophyte." The small organism that grows from the gametophyte and generates spores is called the sporophyte as shown in Figure 11.7.

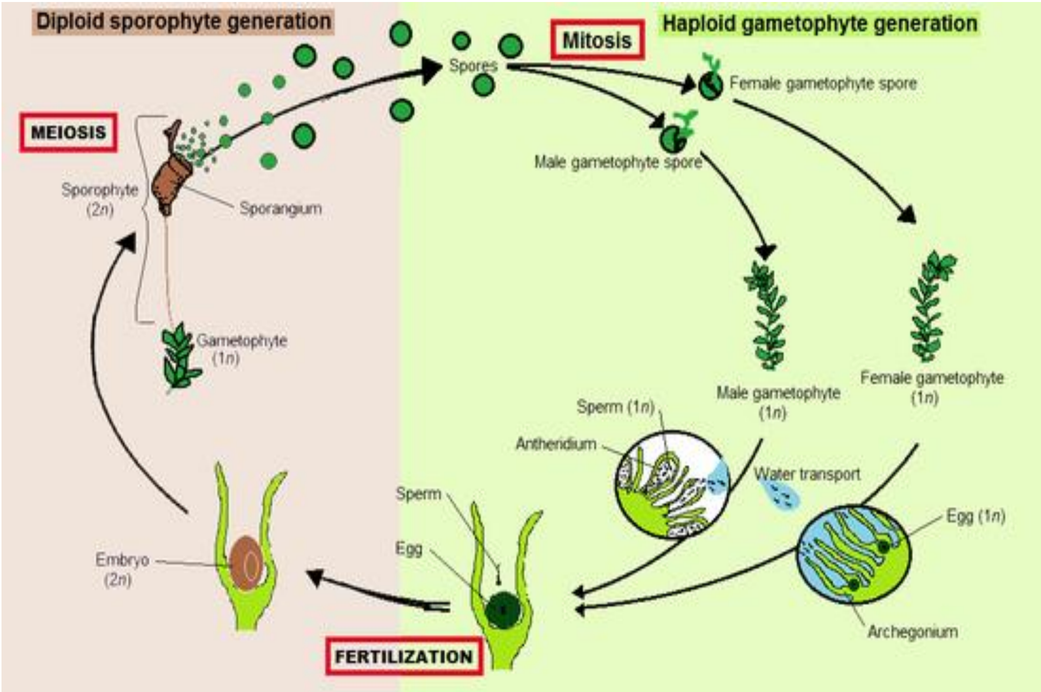


Figure 11.7: life cycle of a typical Moss

11.18 Type of Reproduction in Sphagnum

Vegetative Reproduction: One vegetative branch emerges strongly and vertically, much like the main stem. We refer to this division as breakthroughs. It breaks out from the main stem and develops into a stand-alone plant.

By gemmae: Gemmae are produced by some species.

By protonemal branches: a portion of protonemal branches develop into new gametophytes and become meristematic.

Sexual Reproduction:

This type of sexual reproduction is advanced oogamous. In the same (monoecious) or distinct (dioecious) plants, antheridia and archegonia are generated in specialized branches known as antheridial, or male, and archegonial, or female branches. These branches develop at the lower nodes or at the tip of the stem (in the coma).

Antheridial branch and antheridia structure: Compared to vegetative branches, antheridial branches are shorter and resemble catkins. Their leaves are reddish-brown in color.

Antheridia are club-shaped, with a globular body and a long, multicellular stalk distributed acropetally in the axils of these branches' leaves. The body is coated in a single-layered jacket that encircles a large number of androgonial cells. Every sperm is in a spiral formed; the androgonial cells differentiate into antherozoids or sperms.

Mature sperm are expelled from the antheridium by the splitting of the jacket cells. Each sperm is an elongated structure with two flagella that is spirally coiled.

Architecture of the archegonia and archegonial branch: The archegonial branches are dense and quite short. Their color is purple. Perichaetial leaves, which are big leaves, cover them. At the end of every branch are groups of three to five archegonia.

The mature archegonium has a flask-like form, a long, twisted neck, and a swelling ventriloquy. Six vertical rows of cover and neck cells cover the neck. There are 8–9 neck canal cells enclosed.Two to three layers of cells encase the venter. It has a basal egg cell and a venter canal cell.

11.19 Self Assessment Question

Choose the correct option:

(i) The female sex organ of Marchantia and Funaria is:

(a) Archegonium (b) Antheridium (c) Zygote (d) None of these

(ii) Protonema is found in the life cycle of:

(a) Ulothrix **(b) Funaria** (c) Equisetum (d) Cycas (iii)Peat moss is common name of:

(a) Sphagnum (b) Funaria (c) Frullania (d) Riccia

(iv) Gammae cup is found in:

(a) Marchantia (b) Anthoceros (c) Sphagnum (d) Riccia

(v) Funaria is a bryophyte because:

(a) It lacks vascular tissue (b) It lacks seeds

(c) It has multicellular and jacketed sex organs **(d) All of the above**

Answers: (i) a (ii) b (iii) a (iv) a (v) d

11.20 Short Question Answers

(i) Retort cells

(ii) Pollution indicator

(iii) Gemmae

(iv) Elaters

(v) Ligulate and appendiculate scales

CHAPTER - 12

Pteridophytes

Objectives

Upon successful at the end of chapter student will be able to learn:

- The general characters, classification and representative plants of non-flowering vascular plants.
- Explain the geographical time scale and palaeobotanical evidences.
- Compute the models and the applications of Pteridophytes, Gymnosperms and Palaeobotany.

The word Pteridophyta (Greek: Pteron, feather, phyton, plant) originally referred to those species taxa possessing complete pinnate or frond-like leaves. Pteridophytes having advanced vascular tissue (Greek: kruptos, meaning concealed; Gamos, meaning married). Consequently, these plants are also referred to as "amphibians" of the plant kingdom or vascular cryptogams.Approximately 10,500 species and 400 living and extinct genera serve as their representatives. According to paleobotanical research, these plants evolved in the Silurian period of the Paleozoic era approx 4 billion year ago and became dominant on Earth during the Devonian period. Cooksonia is the first known Pteridophyte. Majority of Pteridophytes that are living are terrestrial in nature, and they like to thrive in cool, damp, shaded areas—such as ferns as shown in figure 12.1. A few members are xerophytic (*Selaginella rupestris*, Equisetum), aquatic (Marsilea, Azolla), or epiphytic (*Lycopodium squarrosum*).

Figure 12.1: Fern in in its natural habitat

12.1 Classification of Pteridophyta

Pteridophyta is classified into four main classes:

Psilopsida

- They're the most archaic (primitive).
- The stem has dichotomously branching ends and is photosynthetic.
- There are rizoids present as roots.
- They donot have many leaves.
- Homosporous synangium is the sporophyte.
- Tmesipteris and Psilotum are two examples.

Lycopsida

- Plants belonging to lycopsida are referred as club moss.
- A plant body that is well-differentiated, featuring adventitious stem, rhizophores, leaves, and roots.
- The sporophyte can be either heterosporous or homosporous.
- Lycopodium and Selaginella are two examples.

Sphenopsida

- Commonly known as horsetail.
- Well-differentiated plant body with roots emerging from nodes of the subterranean rhizome, stem, and scaly leaves.
- Sporangia are homosporous and borne on strobili.
- Equisetum is the main example

Pteropsida

- These are usually referred to as a fern.
- A distinct plant body is divided into leaves, stem, and roots.
- The sporophyte can be either heterosporous or homosporous.
- Therozooids have many flagella.
- Pteris, Dryopteris, and Adiantum as examples

12.2 Characteristic features of Pteridophyta

- Pteridophytes are herbaceous in nature some, like Angiopteris, are perennial and tree-like. The largest Pteridophyte is Cyathea, a tree fern, while Azolla, an aquatic fern, is the smallest.
- The sporophytic plant body can be divided into roots, stems, and leaves.
- Adventitious roots can have dichotomous or monopodial branching. They are typically diarch on the inside.
- A branching structure typically has ramifications. Monopodial or dichotomous branching occurs. Branches do not emerge in the leaf axil.
- Leaves can be simples and mostly a sessile (e.g., Selagrinella), huge and pinnately compound (e.g., Dryopteris, Adiantum), or small, thin, and scaly (e.g., Equisetum).
- Rhizomes are frequently used to symbolize stems in Pteridophytes.
- The stem and root have vascular tissue. It is made up of phloem and xylem. There are only tracheids in xylem and only sieve tubes in phloem. The steel is either polycyclic (e.g., Angiopteris), siphonostele (e.g., Equisetum), dictyostele Adiantum, or protostele (e.g., Rhynia, Lycopodium).
- Absence of cambium, therefore do not exhibit secondary growth.

12.3 Anatomical features of Pteridophytes

The vascular system of the root and stem is well developed and is made up of xylem and phloem. The sporophyte is the only one with discernible conducting tissue development. There are few known examples of this type of tissue in gametophytes, and there is not much xylem and phloem.Only sieve tubes make up the phloem, while tracheids comprise the xylem. Leaves have photosynthetic tissue, with the exception of the lowest group. The megaphyll displays the mesophyll's differentiation into spongy and palisade tissues. Considered a conservative organ, the root exhibits a diarch structure that is nearly constant throughout the pteridophytes.

Sporangia: They procreate through the spores that sporangia produce. Sporophylls, the leaves on which the sporangia are carried, or the axils between the leaves and the stem are where they are found. At the tip of the stem (Equisetum), spores are either grouped into compact units (strobilii) or dispersed uniformly (Pteris).In Ferns dewelling in aquatic habitat like azolla and Marsilea, sporangia is aggregated in groups referred as Sori/Sorus.Many of the Pteridophytes produces only one type of spores known as homosporous ahile in others it is heterosporus.

A. Eusporangiate type: When the group of superficial cells by periclinal cel division gives rise to outer layer of the primary cell wall and inner sporogenous tissue as in case of Psilotum, Lycopodium. The eusporangiate are massive.

B. Leptosporangiate Type: comparatively small sporangia are developed from single cells by periclinal cell division from inner and outer cells.This is comparatively samller in size. The outer cells forms the sporangium and inner cells give rise to stalk as in case of Marsilea and Salvinia as shown in Figure 12.2.

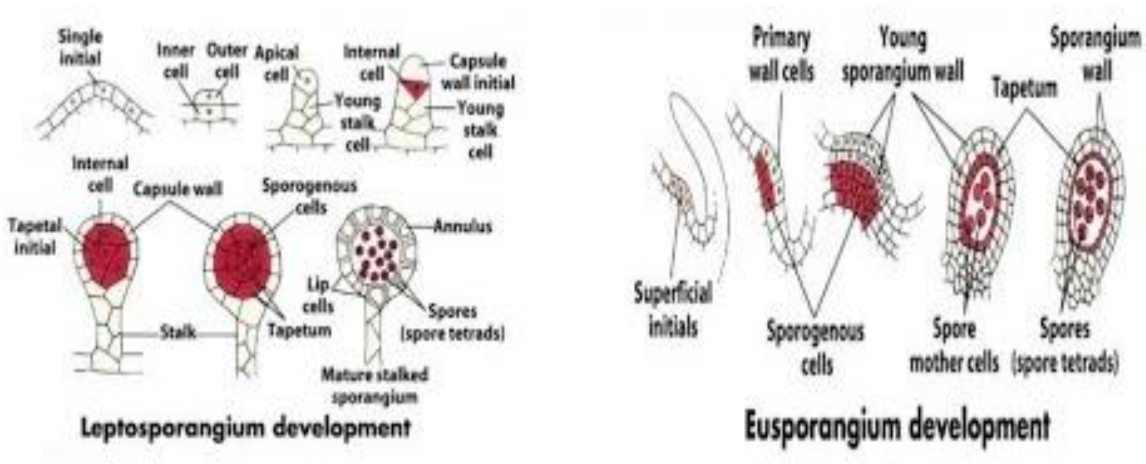
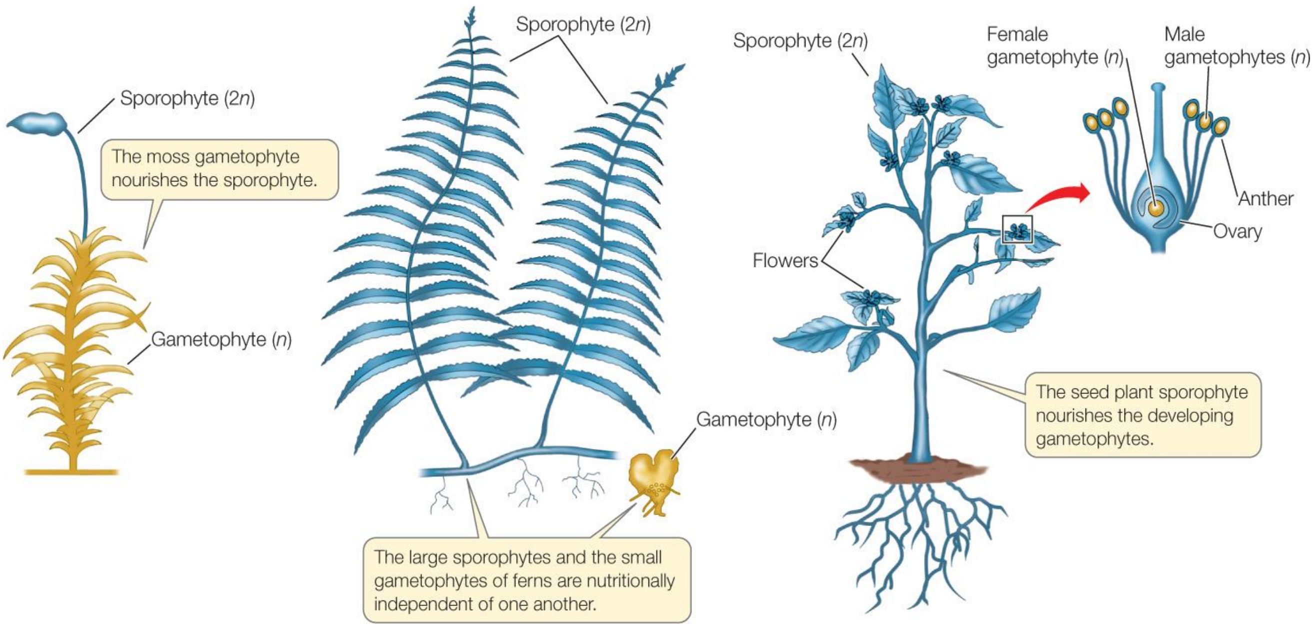


Figure 12.2: Types of Sporangia in different pteridophytes

Gametophyte

After germination, the haploid spores produce the haploid gametophyte, also known as prothalii. The fact that the gametophyte has significantly decreased and the sporophyte has taken center stage in the life cycle is one of the most distinctive characteristics of pteridophytes. There are two kinds of gametophytes: heterosporous and homosporous. When a gametophyte is homosporous, it grows in the soil and develops into an independent plant. Exosporic gametophytes (Psilotum, Lycopodium, and Ophioglossum) are the name given to such gametophytes. In heterosporus species the gametophytes for most of its life is retained with sporangium and therefore reffered as endosporic gametophytes. Selaginella and Marsilea, Isoetes are the representative members of this type. In many of the vascular cryptogams the exosporic gametophytes grows in vicinity of the sunlight and stay attached to rhizoids as in shown in Figure 12.3.



12.3: Comparitive analysis of sporogia of Pteridophytes and angiosperm.

Sex Organs of Pteridophytes

The antheridia and archegonia are the sex organs borne by the gametophyte or prothallus. A homosporous species' gametophyte is monoceous, meaning that many antheridia and archegonia are born on the same gametophyte. The gametophyte in heterosporous species is dioecious, meaning that separate gametophytes grow into antheridia and archegonia. Antheridia may protrude from the gametophyte or be embedded in the tissue. The latter are known as projecting antheridia (leptosporangiate ferns), whereas the former are embedded antheridia (Lycopodium, Selaginella). Antheridia are globular structures with a high androcyte count when they reach maturity. A single motile antherozoid is produced by each androcyte. The venter, a short neck, and an embedded structure with swelling at the base make up the flask-shaped archegonium.

Reproduction cycle in Pteridophyta

1. Spores, particularly develop inside sporangia, are used for reproduction.
2. The sporangium may develop in a leptosporangiate (originating from a single cell) or eusporangiate (developing from a group of cells) manner.

3. Sporangia can be carried on leaves or stems. They may be lateral (like Lycopodium) or terminal (like Rhynia) on the stem. They might be ventral, marginal (Pteris, Adiantum), or dorsal (e.g., Polypodiceae) on the leaves (sporophylls). The sporangia in Equisetum are carried on unique structures known as sporangiophores, which come in the form of a cone. Sporadic bacteria are formed in sporocarps in Azolla,Marsilea, and Salvinia.
4. Prothalli (Sg. protothallus) are multicellular gametophytic entities that develop from spores during germination.
5. Prothalli are monoecious in homosporous in nature Pteridophytes, meaning that archegonia and antheridia form on the same prothallus. Prothalli are invariably dioecious in heterosporous species. Upon sprouting, microspores develop into male prothalli and megaspores into female prothalli.
6. Prothalli are where archegonia and antheridia originate.
7. A sterile jacket with one layer surrounds the Antheridium.
8. Four vertical rows of neck cells, 1-2 neck canal cells, ventral canal cell, and egg make up the archegonium.
9. Antherozoids are unicellular, motile, biflagellate (like Selaginella) or multiflagellate (like Equisetum and ferns).

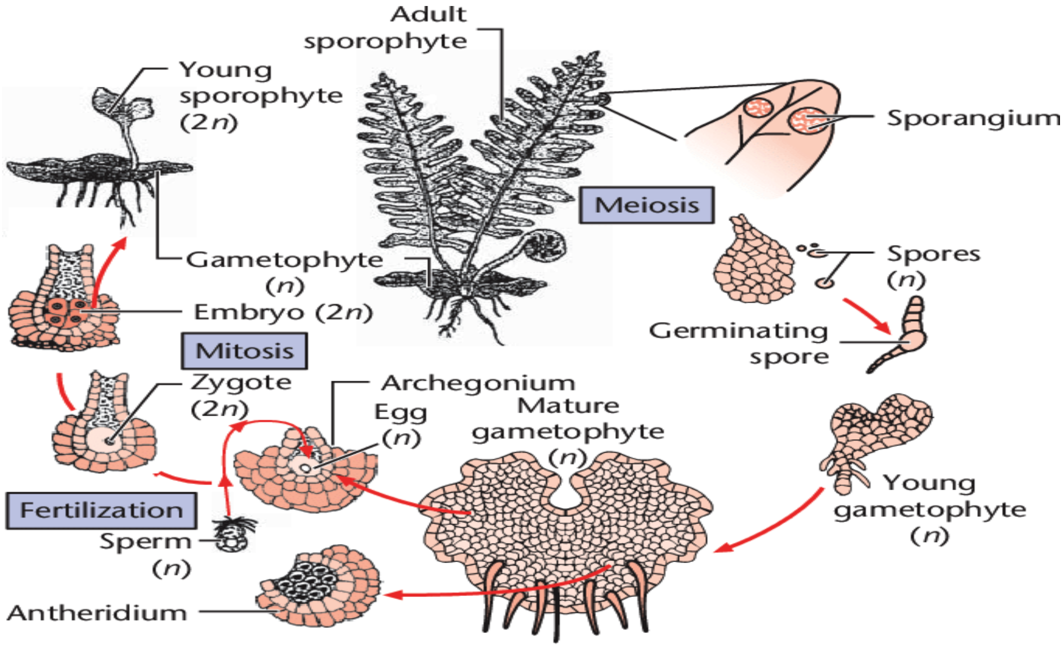


Image Source: Boavida, Leonor C; and McCormick, Sheila (January 2010) Gametophyte and Sporophyte. In: Encyclopedia of Life Sciences (ELS). John Wiley & Sons, Ltd: Chichester.DOI: 10.1002/9780470015902.a0002038.pub2

Figure 12.4: Life cycle of the Pteridophytes

10. Specific chemicals, such as malic acid, which are present in the mucilaginous substance generated by the degeneration of neck canal cells and venter canal cells, chemotactically draw antherozoids towards the neck of the archegonium.
11. The supply of water is necessary for zooidogamous fertilization. As a result, Pteridophytes are sometimes referred to as plant kingdom amphibians.
12. A zygote, also known as an oospore, is created during fertilization and eventually matures into a well-developed sporophyte.
13. The fertilized egg splits either vertically or transversely. A quadrant stage that produces the stem, leaf, foot and root is formed by another cross wall.
14. Plants exhibit heteromorphic generational alternation. Sporophytic, the primary structure of the plant forms a prominent phase in its lifespan.

12.3 Similarity of Pteridophyts with gymnosperms

1. Pteridophyte and gymnosperms are sporophytic and divisible into roots, stems, and leaves.
2. The gametophytic phase lasts only for a short time.
3. Circinate vernation is evident in young leaves.
4. Vascular tissue has a mature state. Except in the order Gnetales of gymnosperms, xylem lacks vessels, and phloem lacks partner cells.
5. Many Pteridophytes, such as Marsilea and Selaginella, are heterosporous, just as Gymnosperms.
6. Several Gymnosperms, such as Cycas and Ginkgo, have ciliate antherozoids, just as Pteridophytes.
8. The sporophytic and gametophytic phases alternate regularly.

12.5 Difference between Pteridophytes and Gymnosperms:

1. Habitat Pteridophytes are hygroscopic means moisture loving but gymnosperms are xerophytic in nature.
2. Roots of pteridophytes are adventitious and in gymnosperms it is found to be a tap root system.
3. In pteridophytes cambium tissue is absent but in Gymnosperms it is present.
4. In archegonium the necessary feature is presence of neck canal cells, venter canal cell but it is absent in Gymnosperms.

5. Water is required for fertilisation in Pteridophytes but it is not essesntially required in gymnosperms.
6. Pollen tube cell is absent in Pteridophytes and present in gymnosperms.
7. Ovules are not formed in pteridophytes and they are formed as seeds in Gymnosperms.
8. Seeds are absent in Pteridophytes and present in well developed stage in Gymnosperms

12.6 The Telome Theory

The Beginning of Telomes and the Progenitors of Early Terrestrial Plants

The Telome theory states that the green algae that inhabited the tidal zones along the Cambrian and Silurian sea beaches is where the earliest land plants came from. Those algal ancestors had an undifferentiated, branching thallus as their plant body (primitive telome). Zimmermann claims that the following five basic mechanisms were responsible for the formation of these primitive telomeres from the unicellular stage:

(i) Cell inter connection; (ii) meristem differentiation; (iii) axis rotation; (iv) principal phase shifting in generation alternation; (v) differentiation of distinct permanent tissues

A core strand of mechanical tissue was present in the dichotomously branching thallus. These algae's progenitors displayed generational change.

Advantages of telome theory

1. It offers a first-rate explanation of the genesis and development of land plant sporophyte.
2. The basic method put out by Zimmermann offers a foundation for interpretation that eliminates notable morphological challenges in lower vascular plants, such as the characteristics of the aerial section of the plant body in coenopterid ferns and the Ophioglossaceae family of plants.
3. This idea emphasizes how the plant body is an axis with the root, which is the descending portion, and the shoot, which is the aerial section, the appendages of which are modified elements of the stem.

4. Although Eames bases his theory on the anatomy of the lowest known vascular plants, he also claims that higher plants can be safely interpreted in this manner. Additionally, it attempts to connect the fossils and living plants on the basis of phylogenetic relationship.
5. The theory is very simple and applies very easily but due to its over-expolitation the value of theory degraded with the time.

12.7 Self Assessment Question

Choose the correct option:

(i) Which one is a fossil pteridophyte?

(a) *Rhynia* (b) *Lycopodium* (c) *Marsilea* (d) *Psilotum*

(ii) Father of Indian Pteridology is known as:

(a) Prof. S.S.Bir (b) S.P. Khullar (c) P.N. Mehra (d) K.K. Dhir

(iii) Telome theory was given by…………

(a) Walter Zimmermann (b) Birbal Sahni (c) P.N. Mehra (d) K.K. Dhir

(iv) The scientific name of Sanjeevani is………

(a) *Selaginella kraussiana* (b) *S.bryopteris* (c) *S.radiata* (d) *S. lepidophylla* .

(v) Which of the following is not correctly matched?

(a) *Lycopodium* ----Club moss (b) *Osmunda*-------Royal fern

(c) *Adiantum*-----Maiden hair tree (d) *Equisetum*-------Horse-tail

(vi)In Pteridophytes, the dominant generation is:

(a) Gametophytic phase (b) Sporophytic phase

(b) (c) Both phase (d) None of these

(vii) Who discovered *Rhynia*?

(a) Kidstone and Lang (b) Stanley Walker

(c) Alex Cowan (d) William Henry Phillips

(viii) When was *Cooksonia* discovered?

(a) 1937 (b) 1945 (c) 1932 (d) 1940

(ix) How many species of *Rhynia* are present in the world?

(a) 2 (b) 3 (c) 1 (d) 4

12.8 Short Question Answers

(i) Living fossil **(ii)** Protostele **(iii)** Amber **(iv)** Alternation of generation

(v) Syngenesious

CHAPTER - 13

Pteridophytes – Selaginella

Objectives

Upon successful at the end of chapter student will be able to learn:

- Categorize the diversity of Pteridophytes.
- Appraise Evolutionary trends between Pteridophytes
- Introduction, morphology, characterstics of equisetum, pteris.

13.1 Selaginella

Selaginella Known by botanists as "spike moss" or "small club moss," which is single living genus in the Selaginellales order. Over 700 species spread all across the globe, it is a substantial genus. It grows abundantly in tropical rain forests. The majority of the species like damp, shaded areas to grow, although some, like *S. lepidophylla* and *S. rupestris*, are also reported to thrive in xerophytic environments include dry, sandy soil or rocks. Only a small number of species—like *S. oregena*—are epiphytes. It grows on the trunks of trees.

A small number of Selaginella xerophytic species, such as S. *lepidophylla* and *S. pilifera*, exhibit a preference for dry habitat and are marketed as collectibles under the label "resurrection plants" in adverse conditions. Resurrection means curling plants which look like ball. In favourable conditions then it again start to look like normal green foliage as shown in Figure 13.1. There are approximately 70 species found in Indian sub-continent. These are mainly grows in eastern and western himalian region. Species are known as *S.repanda*, *S. biformis*, *S.denticulata*, *S. monospora*, *S. semicordata* and *S. adunca.*

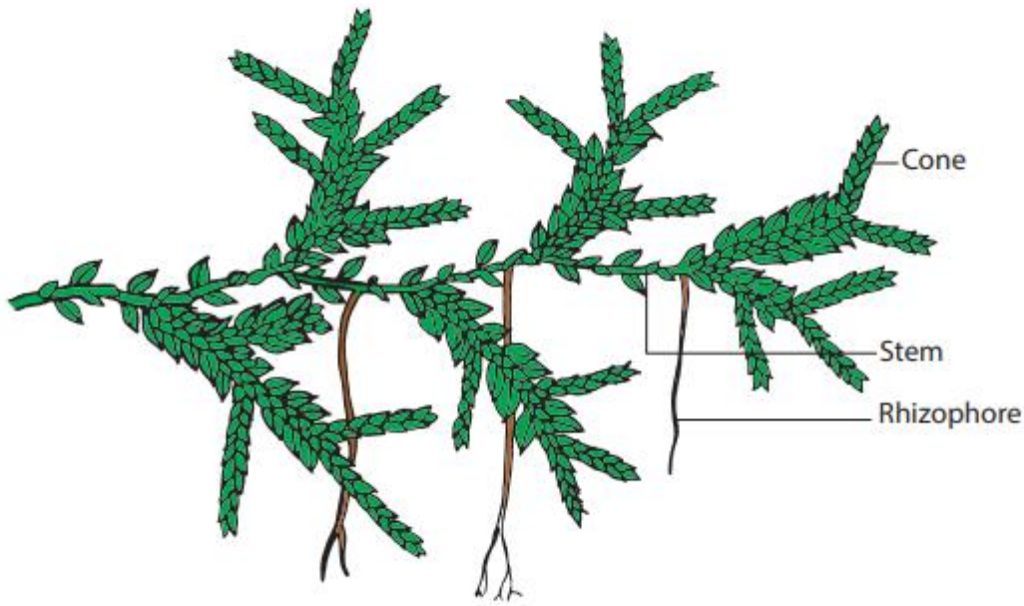


Figure 13.1: Structural features of Selaginella

Classification

Kingdom:	Plantae
Sub-kingdom:	Tracheobionta
Class:	Lycopodopsida
Order:	Selaginellales
Family:	Selaginellaceae
Genua:	Selaginella

Morphology

The sporophyte is a fragile, everlasting herb. Its size ranges widely between species, from a few centimeters upto twenty meters. Plants can vary in their erectness or prostration based on the subgenus.

The plants in the subgenus heterophyllum (various types of leaves) are prostrate whereas the plants in the subgenus homoeophyllum (same leaves) are erect.

The plant's body is divided into the following structures.

Stem

Leaves

Ligules

Rhizophore

Roots

Stem: In general, evergreen, and heavily branched stems are observed. The branching pattern is monopodial, meaning it has a single primary axis. One apical cell or meristematic tissue makes up the growing tip of the stem. The stem is prostrate with sturdy upright branches and is dorsiventral in the subgenus heterophyllum, whereas it is erect and somewhat cylindrical in the subgenus homoeophyllum.

Leaves: Typically, they have a pointed tip, are lanceolate, and are small and simple. There is one single unbranched midrib on each leaf. All of the leaves in the subgenus Homoeophyllum are spirally organized and due to the same size, creating a dense covering. The leaves of the subgenus Heterophyllum are paired and dimorphic, meaning they come in two sizes: tiny and large. On the dorsal side of the stem, smaller leaves are found, while larger leaves are found on the ventral side Typically, the leaves that are closest to the apical part of the branch are known as sporophylls, which are either mega or micro-sized sporangia. Typically, the sporophylls group together to form Strobilus.

Ligules: A little membranous outgrowth known as a ligule is present close to the base of the leaf on the adaxial side. It is located in the ligule pit, a structure that resembles a pit at the base of a leaf.It could resemble a tongue *S. vogelii*, a fan shaped (*S. martensii*), fringed (*S. cuspidata*) or lobed (*S. caulescens*) with the exception of the apex, it is thicker than one cell. The glossopodium and the ligule body are the two distinct components of the ligule structure.

Rhizophore: The structure extends downward from the prostrate axis at the site of dichotomy. It is a cylinder-like, colorless, not branched structure without leaves.

The free end of the rhizophore forms a tuft of adventitious roots as soon as it comes into contact with the soil. A few species—like *S. krciussiana*—have rhizophores, while other species—like *S. cuspidata*—do not have rhizophores. It is different from a stem in that it doesn't have leaves, and it doesn't have a root cap.

13.2 Anatomy of selaginella

Cut thin transverse sections of stem, root, rhizophore and root by introducing the material in pith, staining with safranin-fast green combination, mount in glycerine and observe under microscope. Also compare your preparations from the prepared permanent slides of these parts.

Stem: The stem has structural similarities with other pteridophytes, despite its diminutive size. A transverse section of the stem reveals the epidermis, which is the outermost layer and is made up of prosenchymatous (long, pointed) cells. Epidermal cells have a cutinized outer wall. There are no stomata. Below the epidermis is a cortex with many layers. The inner cortex is made up of thin-walled parenchymatous cells without intercellular gaps, whereas the outer half is made up of thick-walled lignified cells that create a sclerenchymatous cortex (Fig. 13.2). The whole cortex of certain xerophytic species (*Sclerenchymatous lepidophylla*) is made up of thick-walled sclerenchymatous cells. The majority of organisms possess a protostele, or fully formed stele. The stele is siphonostele in certain species. The circular mass of metaxylem has two protoxylem groups at its ends, so the stele in exarch and diarch**.**

Anatomy of stem

The stele is diarch and exarch because the two protoxylem groups are located at the ends of the oval mass of metaxylem. With the exception of a few xerophytic species like *S. lepidophylla* and *S. rupestris*, the endodermis is unique in that it is broken up by wide intercellular air spaces. The trabeculated-endodermis is the term for this. The endodermis's casparian strips, or band-shaped thickening, are present in the trabeculae (the word "little beam" in Latin). Certain species have a single, tiny stele positioned in the middle of the stem, whereas other species have multiple separate steles. The xylem is made up solely of tracheids and has a solid band form. According to Duerdon (1929), certain species, including *S. oregana*, *S. rupestris*, and *S. densa*, have genuine vessels. In phloem, companion cells are not present. Parenchymatous cells with thin walls make up the pericycle as shown Figure 13.2.

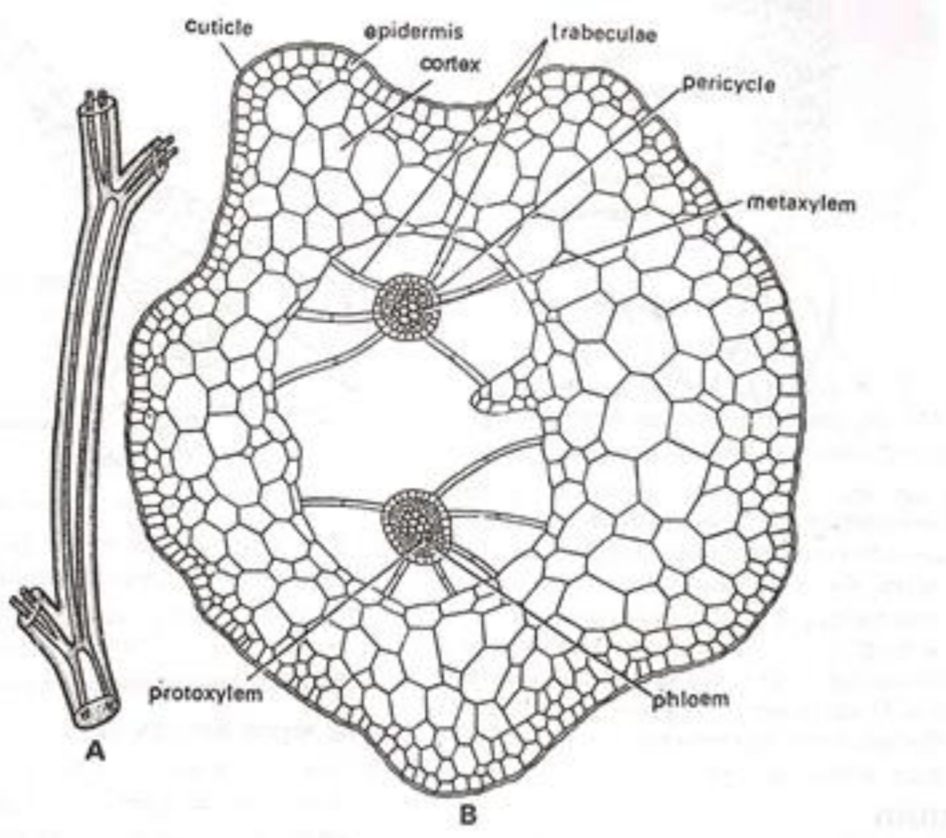


Figure 13.2: T.S of stem of Selaginella

Many species of Selaginella exhibit different types of stellar alteration.

1. In species with a dorsiventral stem (*S. martensii*), as in the erect system of *S. spinulosa*, the xylem becomes polystelic; in trailing stems, it may become endarch rather than exarch.

2. In some circumstances, the stems may develop into polyarchs with several protoxylem groups. There are three to sixteen steles total. Every stele has a trabeculae surrounding it.

3. Bower (1935) shown that the immature rhizome of *S. laevigatalyalli* exhibits a -solenoxylic‖ structure, which is succeeded by a solenostele with a central pith and, ultimately, breaks into several meristeles in the upright stems.

Rhizophore: The rhizophore has a structure that resembles a root. It is not the same as a root except in little ways. Thick-walled cells make up the single-layered epidermis, which is followed by multiple layers of thick-walled cells in the hypodermis. Parenchymatous cells with thin walls make up the cortex. Typically, the stele is protostele. Depending on the species, protoxylem has different positions. The protozoa in *S. delicatissima*, *S. poulteri*, and *S. kraussiana* are centroxylic, or located in the center. The structure of *S. martensii* exhibits a monarch and exarch. In *S. atrovirdis*, the structure can take the shape of many strands that are positioned in the crescentric metaxylem. The xylem is entirely encircled by phloem (Fig. 13.3).

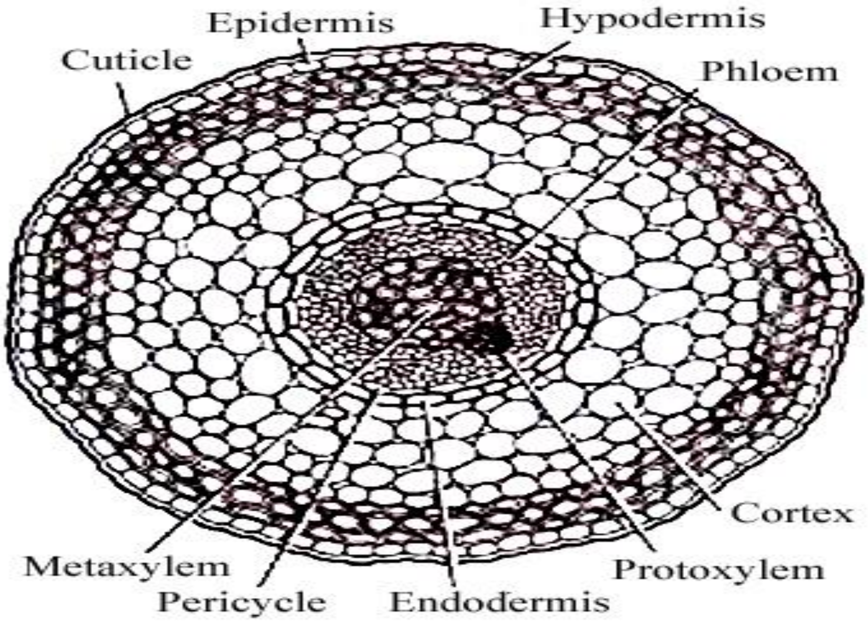


Figure 13.3: Selaginella rhizophora

The morphology of the rhizophore

Rhizophore morphology has long been a source of botanical conundrums. Various botanists have offered different interpretations. The three main perspectives that have occasionally been put forth to demonstrate its potential are as follows:

First of all the rhizophore is a capless root, according to Gibson, Van Tieghem, and Uphof (1920), for the following reasons: it is geotropic, leafless, structure similar to a root. Its exogenous origin (it formed always from the angle meristem which is present between the two branches of the stem), its absence of a root cap and root hairs, and its ability to develop into leafy shoots under controlled experimental conditions led Treub (1920), Pfeffer (1871), Bruchmann (1905), and Troll to view it as a leafless shoot (Bruchmann and Williams 1937).

Leaf:

The leaf has a simple structure. Chloroplasts are found in the cells of the upper and lower epidermis. Only on the lower epidermis, close to the midrib, are there stomata. Loose, spongy mesophylls located between the two layers of epidermis are typically not distinguished into palisade and spongy-parenchyma (Fig. 13.4). Certain species, such as *S. lyalli*, exhibit palisade and spongy-parenchyma differentiation in *S. concina* mesophylls. A mass of green, spongy cells with wide intercellular gaps that form a loose network is called mesophyll. Intercellular spaces are lacking in the vicinity of the vascular bundle. Species-wise, every mesophyll cell contains one or more chloroplasts with central pyrenoid-like structures structured like spindles. A single concentric amphicribral-bundle, or a central strand of xylem, is located in the center as shown.

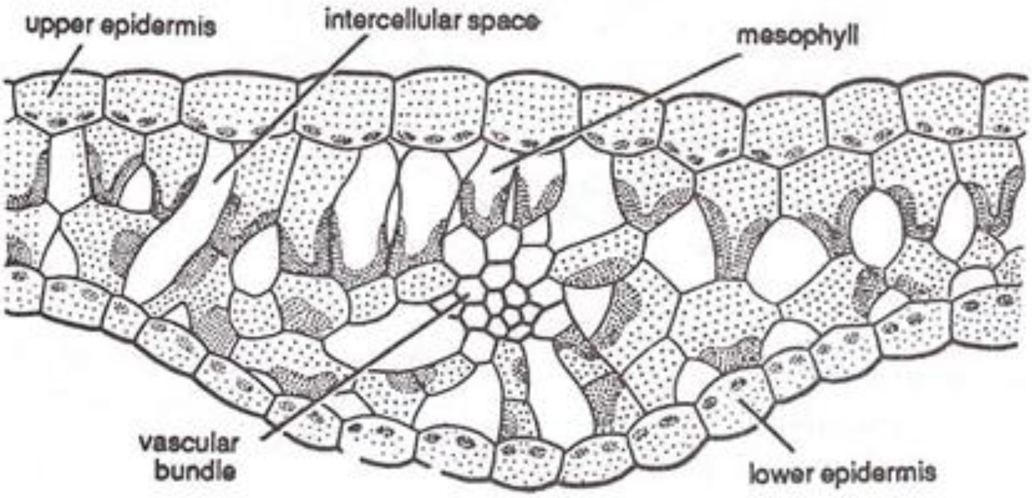


Figure 13.4: T.S of Leaf of Sileginella

Root

The tips of the rhizophores are where the adventitious roots begin. The roots are hairy and have caps on them. In certain instances, such as with *S. densa*, the roots only emerge from the locations where the stems branch. There are two types of branches on the roots.

Internal Structure

The root has an extremely basic structure. Its outermost layer of piliferous epidermis gives birth to root hairs. A few or many layered outer sclerenchymatous hypodermis layers and a multilayered parenchymatous cortex follow. Only sclerenchymatous cells make up the cortex of *S. densa* (Webster and Sleeves 1963).The endodermis is typically poorly defined. This contains a pericycle with one to three layers. The prototoxylem is exarch, and the root has a protostelic monarch structure. There is a xylem surrounded by phloem represents horse-shoe shaped structure.

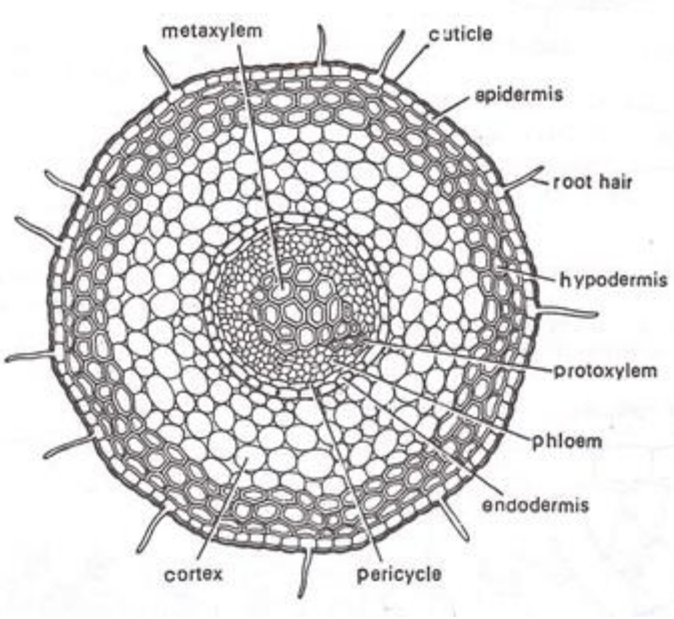


Figure 13.5 T.S. of the Sileginella Root

13.3 Life Cycle of Selaginella

1. Vegetative reproduction

It is uncommon in a small number of species and can be caused by:

a. **Fragmentation:** In the presence of favorable conditions, the prostate branches take on roots and split into little pieces, each of which grows into a new plant, such as S. rupestris.

b. **Bulbils:** Some species, like *S. chrysocaulos* and *S. chrysorrhizos*, reproduce by means of bulgbils or tiny tubers. In the first scenario, the tubers are referred to as "surface tubers" since they form at the ground's surface. Since they grow underground in the latter scenario, they are referred to as "underground tubers." When favorable conditions arrive, the tubers sprout into new plants.

2. Sexual reproduction

As a sporophyte, the Selaginella plant produces spores. The haploid spores then develop into gametophytes, which carry gametes and sexually reproduce through them. Compact in nature, the reproductive structure forms at the tips of the branches. It is a sessile structure known as a strobilus, or spike. It often tapers toward the tip, and depending on the species, its length can range from 1/4 of 1 inch to 2-3 inches. The two aberrant species are *S. patula* and *S. cuspidate*, in which vegetative development may persist past the spike at the terminal section of the branch. An intriguing example is provided by *S. erythropus*, where the intercalary sterile section is followed by the production of the second strobilus on a fertile branch. The strobilus can be horizontal or upright.

The strobilus is made up of numerous clusters of ligulate sporophylls, each of which has a small, short-stalked sporangium near its base and on its top side. The sporangia are divided into two different forms rather than being all the same. On the same strobilus, these are found. There are four huge spores in one form of sporangia and many little spores in another. Megaspores are huge spores, and the sporangium that contains them is called a megasporangium. Megasporophylls are the leaves on which the megaspores are borne. In a similar vein, the tiny spores are microspores, and each microsporangium is carried by a microsporophyll. Every sporophyll has a ligule in its axil, just like a leaf. Heterospory is the term for this dimorphic state of spores (Fig.13.6).The location of megasporophyll and microsporophyll differ.

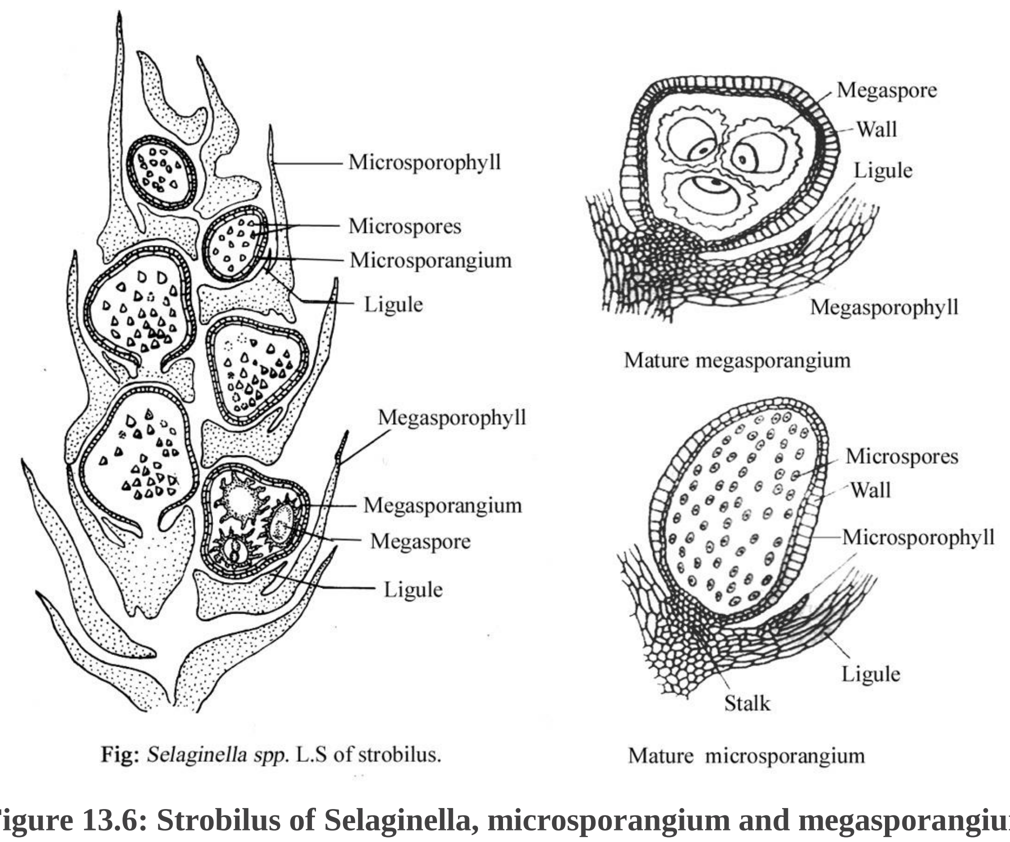


Figure 13.6: Strobilus of Selaginella, microsporangium and megasporangium

Development of sporangia

Both kinds of sporangia grow similarly in the early stages, reaching the level of the spore mother cell.They are eusporangiate in development, meaning they originate from a collection of initials.The sporangium grows from the axis cells in most cases, but when it reaches maturity, it is located in the sporophyll axil. The periclinal division of the sporangium initials forms an outer tier of cells that includes the jacket initial and the archesporial cells. A two-layered sporangium wall is produced by the jacket division that follows (Figure 13.7). Following multiple divisions, the archesporial cell yields a mass of sporogenous tissue. The cells in the outer layer of the two-layered jacket develop thick walls.

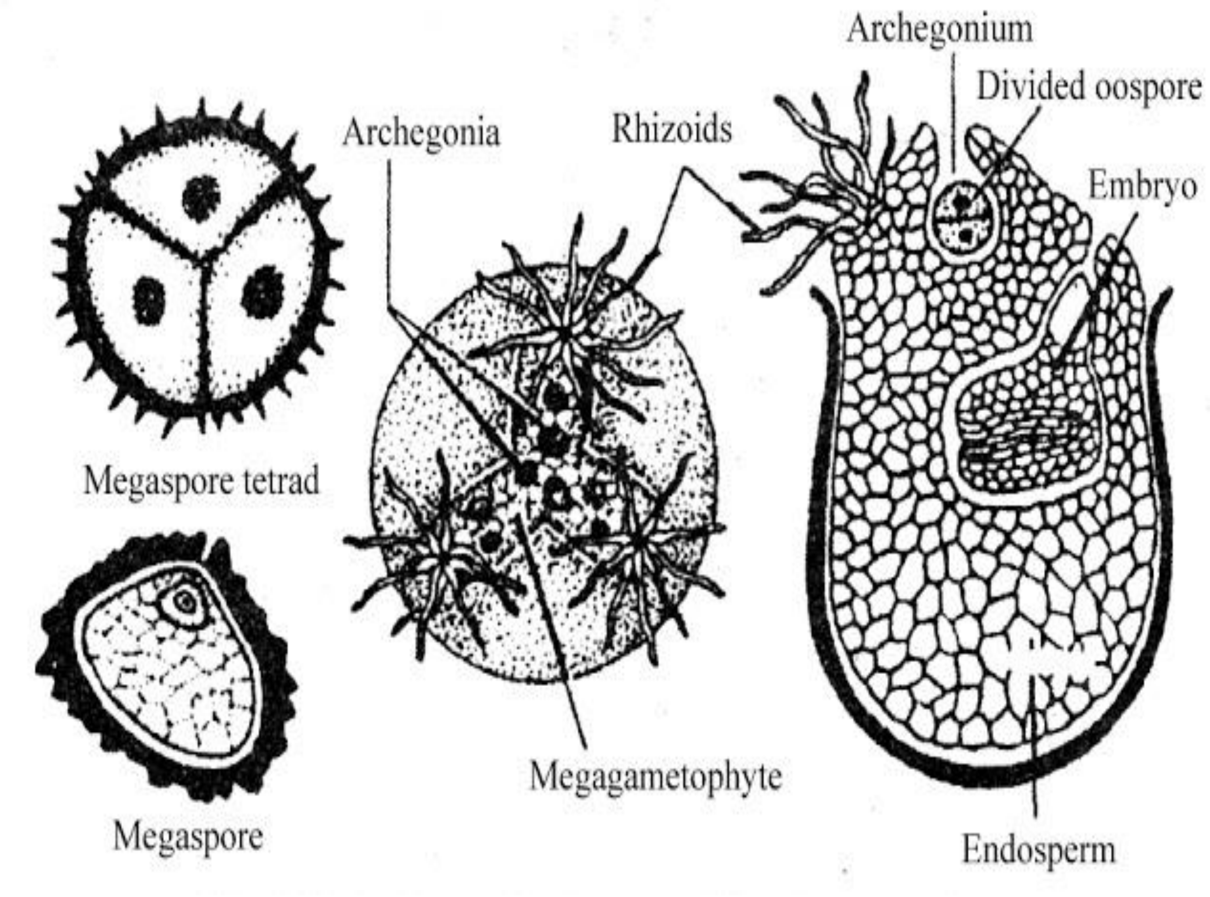


Figure 13.7: Development of female gametophyte

Structure of Sporangium

A microsporangium is made up of a short stalk and an oval, reniform, or spherical capsule that can be red, yellow, or brown in color. This is the structure of a mature sporangium. The walls of the sporangium are composed of two layers. Columnar cells make up the outermost layer, which gradually thickens, while thin-walled cells make up the interior layer. Many tetrads of haploid microspores are enclosed within the wall tapetal layer.

In comparison to microsporangium, megasporangium is bigger and has a lighter, greener, or whiter color. Megaspore growth caused the megasporangium to become four-lobed, with a megaspore enclosed in each lobe.The wall's structure is comparable to that of the microsporangium.

Mechanism of sporangial dehiscence:

A mature sporangium breaks into two valves that gap apart solely in its upper portion, splitting vertically. Cohesion as a result of distinct hygroscopic alterations in the apical and lateral portions of the sporangial wall causes this. The unbroken base of the sporangium eventually dries up and takes on the appearance of a boat, aggressively expelling spores a few centimeters out. Spores are released in small amounts at regular intervals. Goebel claims that this violent spore dispersal is an adaptation for cross-pollinating since it facilitates the movement of spores from several plants close to one another. The strobilus's protandrous nature serves as more evidence for this.

Spore germination:

Selaginella spores germinate inside the sporangium prior to being expelled from their individual sporangia, in contrast to Lycopodium spores, which germinate on soil. Selaginella spores are unique in that they exhibit intrasporangial germination, which Bold (1957) refers to as "precocious germination." There is a connection between the two spores' different sizes and differences in their functions. Whereas the microspore produces male gametophytes, the megaspore develops into a female gametophyte. The microspore resembles a megaspore in most aspects, with the exception of its very smaller size (0.015–0.05 mm) and red color. Unlike other pteridophytes, it germinates into a 13-celled male gametophyte while imprisoned in the microsporangium. As a result, the spores are found in a various stages.

Microspore germination and male gametophyte development:

A large and a tiny cell, both located inside the microspore wall, are produced by the initial division. The smaller cell, known as the prothallial cell, is equivalent to the vegetative tissue of the fern prothallus. The big cell is the antheridium's mother cell. Through subsequent divisions, it gives rise to a center clump of six to eight primordial cells around by a single layer of jacket cells.

S. martensi and *S. caulescens* are two examples of the antherozoids that arise when all primordial cells that initially develop in the antheridium divide again and eventually give rise to them, contrary to what Millardet claimed just two inner cells create the mother cells of the spermatozoids.

Usually, during sperm development, the microsporangia rupture and release the microspores. It takes the spermatozoid cells thirty to forty-five minutes to travel. It takes about three weeks for the microspore to germinate and eventually mature into sperm. When the spore wall bursts open, approximately 256 free sperm are released from their mature state. The sperms are quite little, with a rough measurement of 2.5 μm. In comparison to the body, their cilia are twice as large.

Megaspore germination and female gametophyte development: The megaspore resembles a low, broad, triangular pyramid with a circular base in terms of shape. Compared to the microspores, they are twenty times bigger. It is easy to perceive them with the unaided eye. The size is in a range of 0.5 mm to 5.0 mm. Every megaspore has a well-marked triradiatic prolonged with beak-like appearance.

This is the area where the spore breaks.Each has an exospore, a fragile endospore, and a very thick, rough, cutinized, sculptured exterior wall.

The megaspore typically germinates in its original location, such as inside the megasporangium. Different species shed their developing female gametophytes (megaspores) at different stages. In certain instances, they are freed right away following the initial divide. In some intriguing cases, such as *S. apoda* and *S. rupestris*, the megaspores in *S. kraussiana* may be shed soon after the development of the first archegonium, or they may not be released from the megasporangium at all until fertilization has occurred and a fully developed embryo has formed.

Fertilization: The male gametophytes typically fall off the microsporangium onto the ground after fertilization. Here, they finish developing and eventually produce spermatozoid cells.

The microspore wall breaks down to release these. The sperm swim from the male gametophyte to enter archegonia if the microspore or male gametophyte has the opportunity to fall close to the mature female gametophyte or megaspore and moisture is present. In the end, the sperm and egg merge, resulting in conception.

However, *S. apoda* and *S. rupestris* occasionally shown an approach to the seed habit. Here, a mature megasporangium splits open, but not enough to allow a developing female gametophyte to escape. In every megasporangium, a single megaspore forms. When fully grown, the megasporangia explode open, and the developing microgametophytes are thrown out of the cell.A few of them fall into partially-open megasporangia after migrating downward between the sporophytes mat. The two types of gametophytes are currently finished developing and are resting inside the megasporangium. Fertilization occurs when there is enough water present. The immature embryos grow inside the megasporangium's wall and exit as soon as they form a root and main shoot. Subsequently, the megasporangium opens out wider, allowing the megagametophytes to drop to the ground along with their developing embryos.

This is particularly noteworthy because it closely parallels the spermatophytes' seed production and pollination behaviors throughout their life cycle. Consequently, Selaginella approaches the seed habit because when the megaspore, along with its freshly produced embryonic sporophyte, falls to the ground, it effectively becomes a seed.

Development of the Embryo or Sporophyte: Following fertilization, the oospore forms a wall around itself and develops into a zygote. It split transversely into the lower hypobasal cell and the higher epibasal cell. As the developing embryo elongates and descends into the gametophytic tissue, the epibasal cell forms the suspensor cell. The embryo has two lateral cells on either side that differentiate into the foot, root, and major stem. The cotyledon originates from each of the lateral cells.The foot's function is to take up nutrients from the gametophytic tissue for the growing embryo. The embryo's axis lies at a right angle to the suspensor as a result of the foot's continued expansion pushing the stem apex to one side.

Each cotyledon has an extension that forms close to its base from the inner side and eventually matures into a ligule. According to Brockmann (1912), the apical cell of the root divides into cells to form a structure known as a rhizophore. The roots are developed by this main rhizophore. The juvenile sporophyte finally separates from the gemetophytic tissue inside the old megaspore wall due to the outward development of the stem and root.After a while, the juvenile sporophyte separates from the megaspore and descends to the ground, where the primary rhizophore sends roots into the ground, allowing the plant to begin its independent life (fig. 13.8).

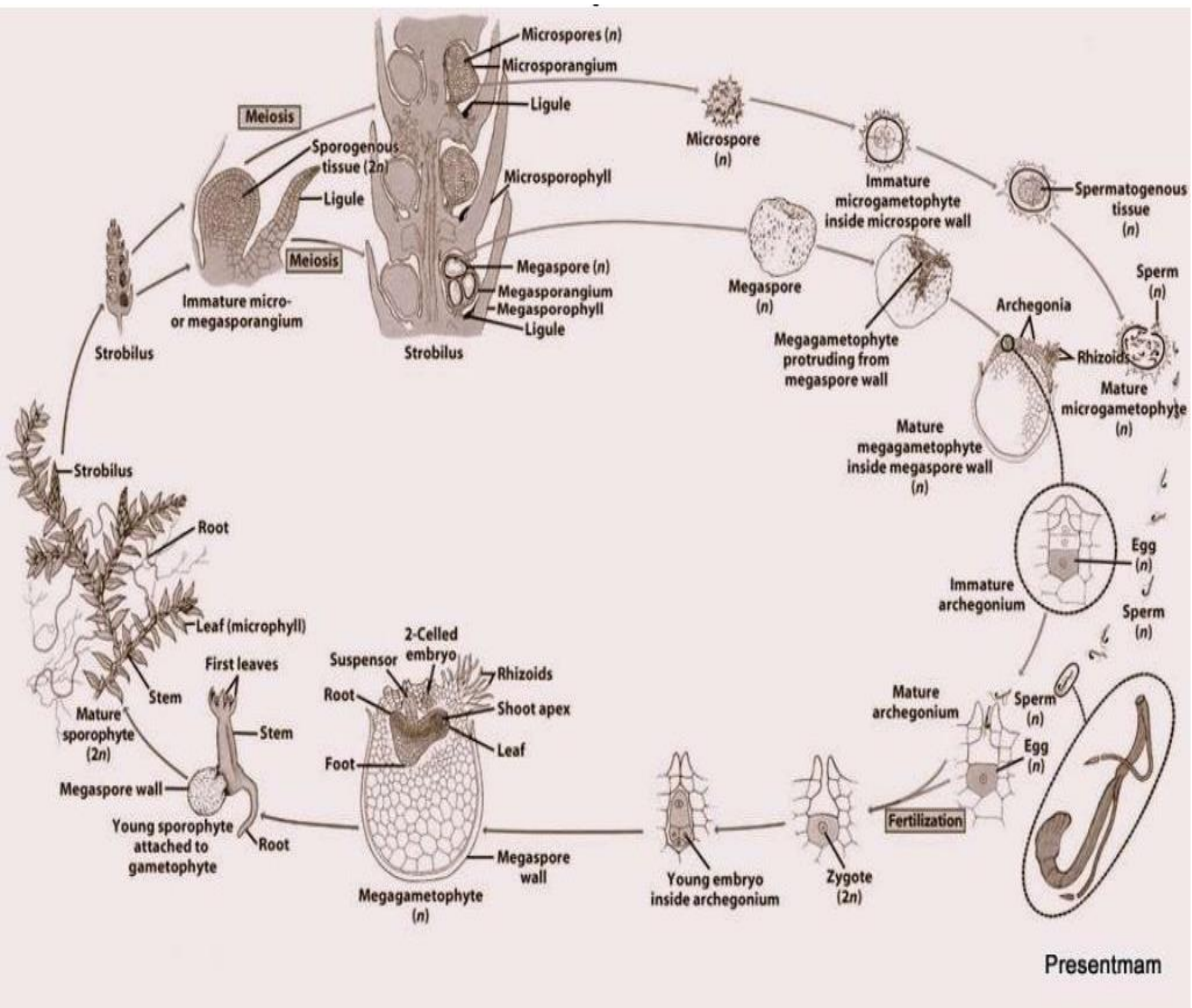


Figure 13.8: Life cycle of Sileginella

Life-cycle of Selaginella

Within Selaginella, spore is classified into two types: microspores, also known as male spores, are smaller and develop in microsporangia, while megaspores, also known as female spores, are larger and form megasporangia. Upon germination, the microspores yield the male gametophyte, which is the sole source of male gametes, or sperm. The female gametophyte is produced by the megaspore, and when fertilization takes place in the presence of water, a diploid cell called a zygote is formed. This zygote then matures into a sporophytic generation. Selaginella life cycle is thus comprised of a sporophytic and gemetophytic generation that rotate in succession.

13.4 Equisetum

The genera Equisetum, which are commonly referred to as horsetails, are the extant progeny of enormous ancient trees that formerly dominated the planet. Coal is how these extinct behemoths are still present in our world today. The extant Equisetum species provide scientists with a window into the past and present of vascular land plants. The only surviving genus in a class of long-extinct land plants is Equisetum. The world's forests were ruled by the calamites, enormous horsetails that grew up to 18 meters tall, during the late Devonian and Carboniferous periods. Fossils of the ancient giants can be found dating back to this time. The woods of the past were very different from those of the present day since many large land animals had not emerged. The world's vast coal resources were finally produced by the lush calamite forests. The huge calamites finally went extinct during the Permian, leaving only the herbaceous genus Equisetum in contemporary times, as the temperature became progressively drier and colder along with a shift in the atmospheric oxygen level. It has been proposed that John Napier's discovery of logarithms was motivated by the pattern of node spacing in horsetails, wherein nodes at the apex of the shoot are progressively closer together. With almost 200 species, the second genus Adiantum is extensively found throughout the world's tropical and temperate zones. Although Adiantum species can be found in many different types of environments, they are most prevalent in damp, shaded areas.

Figure 13.9: Equisitum in its natural habitat

Habitat

There are 15 species; Equisetum is nearly exclusively found in North Temperate zones, while several are also found in Tropic areas, with the exception of Australia. There are four species of E. arvense, E. diffusum, E. palustre, and E. ramosissimum known to come from India. Equisetum species are commonly referred to as "scouring rushes," "pipes," or "horse tails."

Terrestrial plants range in size from tiny to enormous, and they typically thrive in open, sunny sandbanks near rivers and lakeshores, as well as in damp or marshy areas.

The genus Equisetum is widely distributed; it is only known to be extinct in Antarctica. However, it is also not known to be endemic to Australia, New Zealand, or the Pacific islands. These plants are perennials; like other temperate species, they may be either herbaceous and die back in the winter. The four types of horsetails are dwarf (*E. scirpoides*), branching (*E. ramosissimum*), rough (*E. hyemale*), and variegated (*E. variegatum*). The "giant horsetails" can reach heights of up to 2.5 m (Northern giant horsetail, *E. telmateia*), 5 m (Southern giant horsetail, *E. giganteum*), or 8 m (Mexican giant horsetail, *E. myriochaetum*), and reportedly even higher. Generally, they grow between 0.2 and 1.5 m tall.

Although some species in this genus are semi-aquatic and others are adapted to wet clay soils, many species in this genus prefer wet sandy soils. The stalks emerge from deeply buried rhizomes that are very impossible to extract. Field horsetail (*E. arvense*) can be a bothersome weed since it spreads easily from the rhizome when removed. Additionally, several herbicides meant to destroy it have no effect on it.

Since *E. arvense* favors an acidic environment, lime can help eradicate it by raising the pH of the soil to 7 or 8. In New Zealand, all Equisetum species are categorized as "unwanted organisms" and are included in the National Pest Plant Accord.

Structure of Equisetum Equisetum's plant body is divided into a roots, stem, leaves.

Rhizome: The Equisetum sporophyte grows an extensive, underground rhizome that is often perennial. Real roots are produced by the rhizome which split into internodes and nodes, with the scales at the nodes fusing together to form a sheath. Additional axillary branching grow from nodes, generally once a year, to produce aerial shoots that follow the same structure as the rhizome. It serves as a storage organ and anchor for the plant body. Rhizomes enable a plant to thrive in hostile environments.

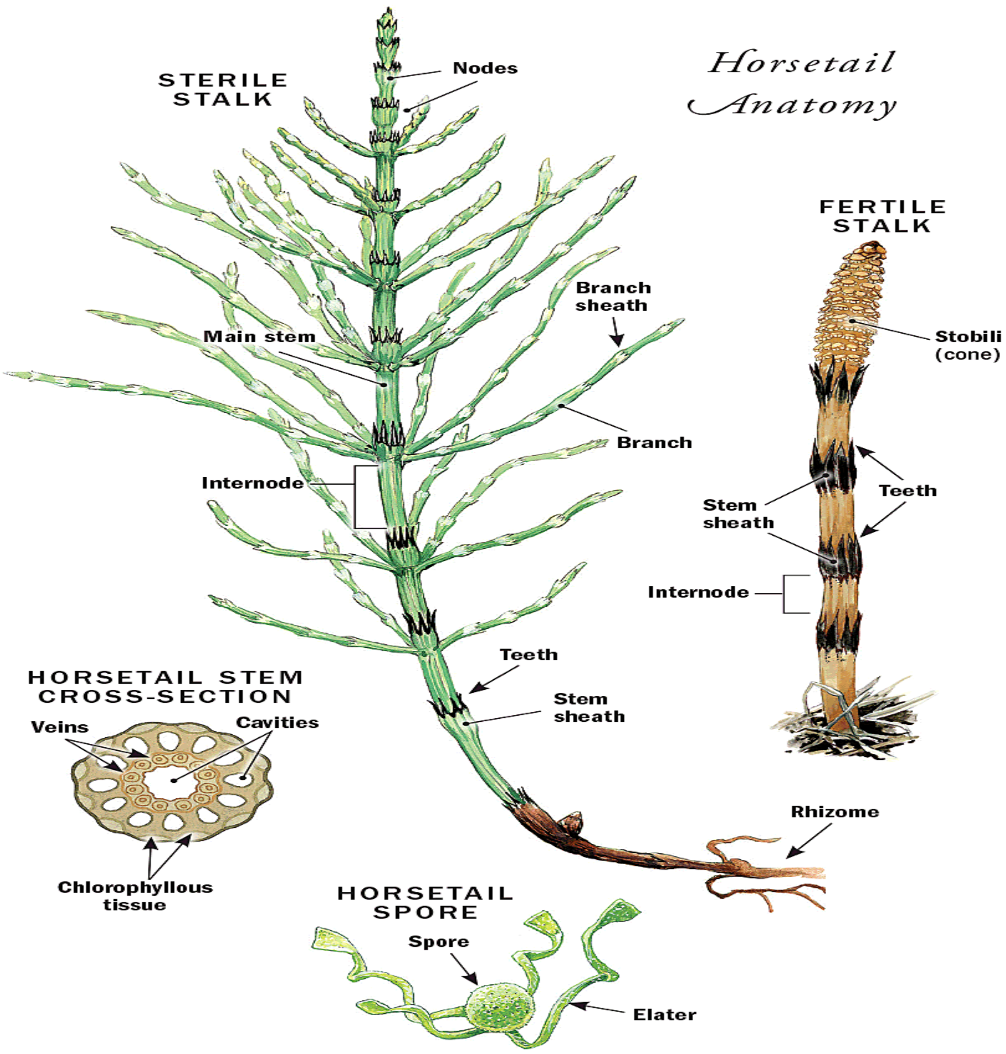


Figure 13.10: Equisetum structural features

Roots: Not all roots but the principal root is adventitious. At every rhizome node, they emerge in whorls from the base of the branch primordia. Slender and fibrous, the roots can occasionally branch (Figure 13.10).

Stems: The upright aerial stems have a single principal axis of growth and a monopodial branching pattern. The aerial stems of the plant are green, photosynthetic, joined at the nodes, and have vertical ridges or ribs on the internodes. Stems might have whorls of branches or be plain and unbranched. Since the shrunken leaves lack chlorophyll, if they are present, the stems and branches do photosynthesis. The aerial stems emerge from perennial, horizontal rhizomes and can last anywhere from one to three years. Silica is used to impregnate stems. Because of this, Equisetum has a rough texture. It also gives some Equisetums their popular name, scouring rushes. The stems are strengthened by collenchyma cells, which have main walls that are unevenly thickened, located beneath the ridges.

Branches: In certain species, the base of the leaf sheath is where whorls of photosynthetic branches emerge from each node of the jointed stems.

Horsetail leaves: Since each leaf has only one leaf trace, horsetail leaves were originally thought to be microphylls. However, more recent research has revealed that horsetail leaves are actually reduced megaphylls. At each node is a whorl of numerous tiny leaves that resemble scales. With the exception of their tips, the tiny leaf blades are connate, or fused together, and surround each node in a sheath that has teeth along the upper margin. The apical meristem gives rise to new branches and leaves in equisetum.

Anatomical features of Equisetum

Stem: The internal anatomy of the stem as well as the longitudinal and transverse sections that pass through the internodes and nodes are examined.

Internal anatomy: The aerial stem must be cut through the internode in transverse sections in order to analyze the anatomy of the node. The presence of ridges and furrows gives the stem's exterior a wavy appearance as shown in Figure 13.11.

A single layer of epidermis covering the stem is broken up by stomata that are placed in the furrows or grooves. A dense coating of silica is always injected into the epidermis. The Equisetum plants are also referred to as "scouring rushes" because of the rough look of the stem caused by the deposition of silica on the epidermal layer. The grooves of the aerial shoots contain the stomata.

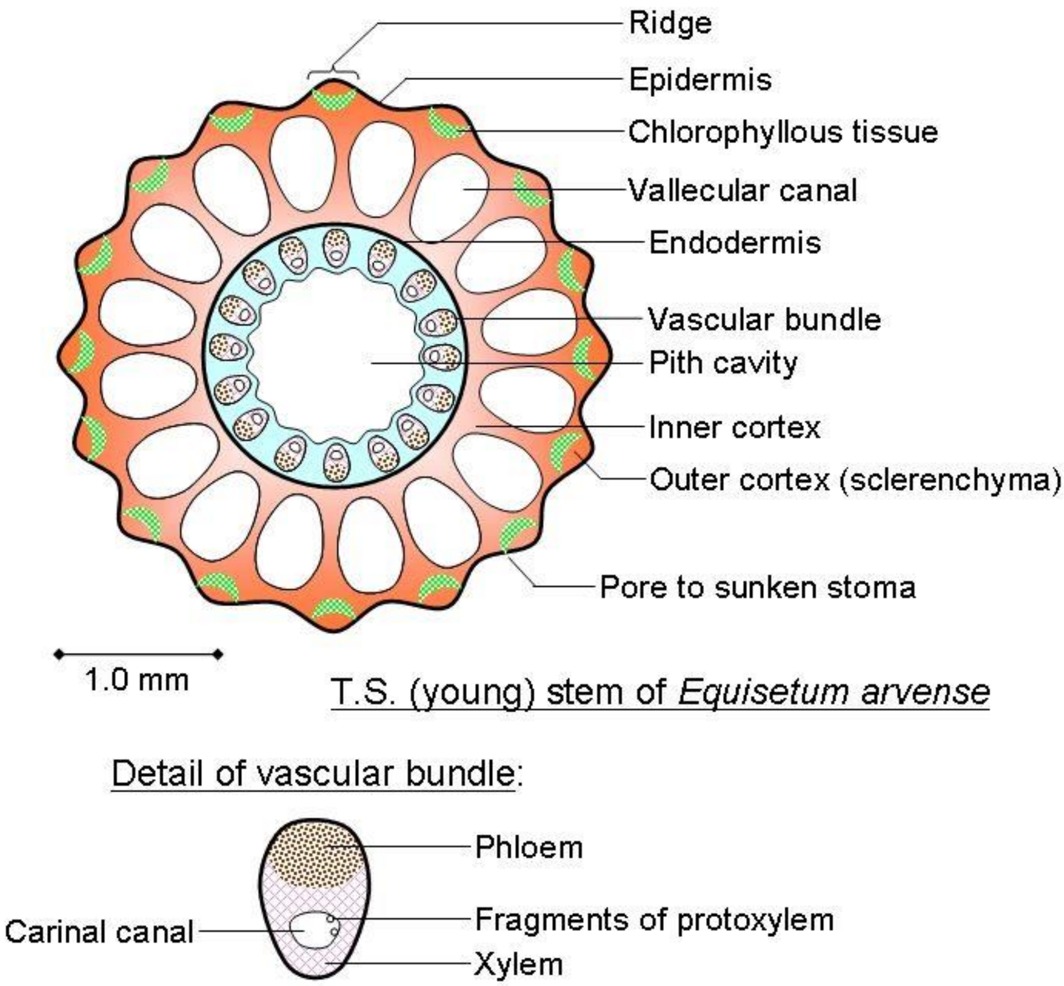


Figure 13.11: T.S of stem of Equisetum

Node: A continuous ring of the vascular cylinder is found in the node as a result of the short branches connecting the alternating vascular bundles of the consecutive internodes. According to Eames (1909), there are no carinal canals in the bundles at the nodes. In this instance, the protoxylem components are whole and fully occupy the carinal canal or lacuna. The pith is not hollow at the node, where it creates a diaphragm to divide the two succeeding internodes.

Rhizome: The aerial shoot and the rhizome have nearly the same anatomy. The rhizome lacks both the stomata and the assimilatory tissue. Comparing the mechanical tissue, or sclerenchyma, to the aerial shoot, the latter is more developed. Pith in *E. arvense* is solid but in some other species the pith and vellacular canals are little reduced.

Leaf: The leaf has a very basic anatomy. Since the leaves lack veins, they are all composed of a single vascular bundle. The leaf sheath's vascular bundles are straightforward and collateral. There are no carinal canals can be found. Diverse endodermal layers (endodermis) envelop individual bundles. Narrow sclerenchymatous bands make up the leaf sheath's outer tissues. The strips of chlorophyllous tissue connected to stomata alternate with these bands of sclerenchyma as they go up the leaf ridges.

Root: Aerial shoots and rhizome nodes are where adventitious roots are carried. A adventitious root's anatomy is rather straightforward. The root's cross sections are necessary to investigate the anatomy. The word "pilerous layer" refers to the uppermost layer which has unicellular hairs on it. The cortex is divided into two zones. The outer most is composed of 3-4 layered lignified exodermis, inner zone consists of the thin walled parenchyma with well-developed intercellular spaces (Figure 13.12)

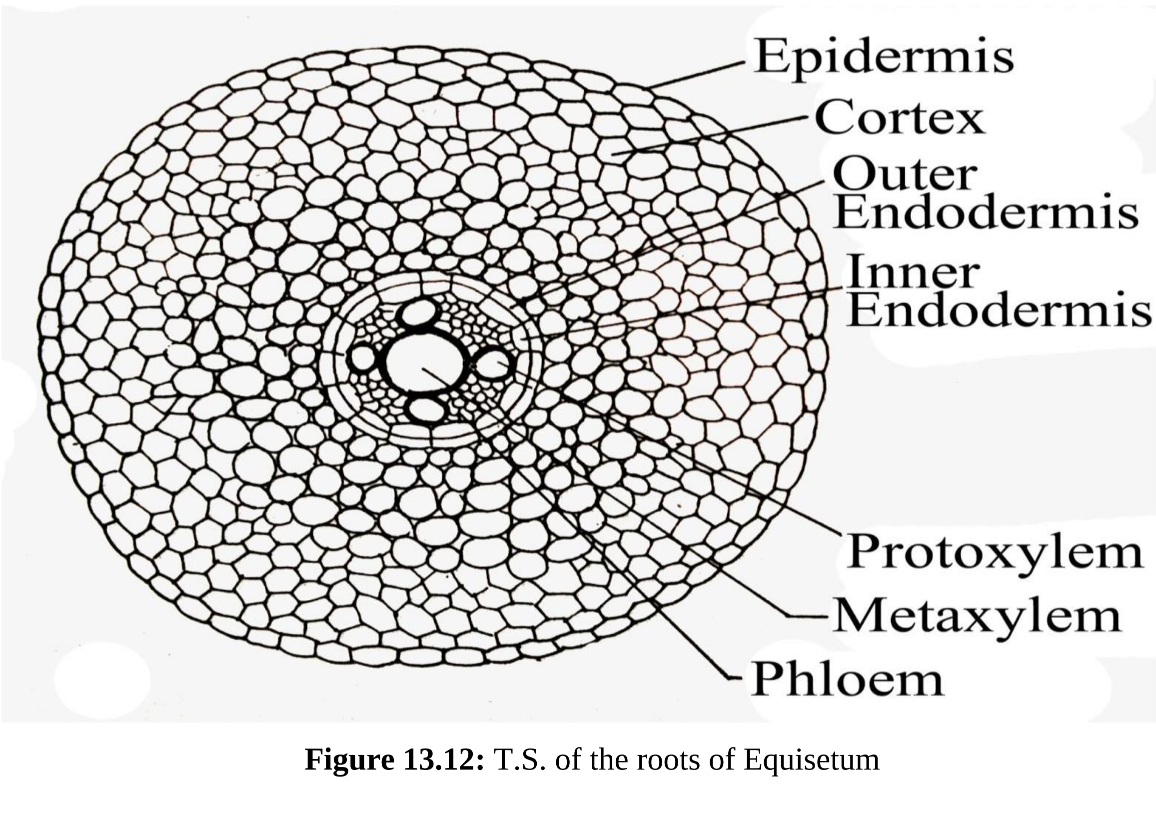


Figure 13.12: T.S. of the roots of Equisetum

Reproduction

Equisetum reproduces both sexually and vegetatively.

1. Vegetative mode of reproduction

Certain species of Equisetum (*E. arvense*, *E. telmateia*) produce tubers from their subterranean rhizomes, which aid in vegetative proliferation. At the rhizome's nodes, certain branch buds grow erratically, which leads to the development of tubers. E. arvense has an oval shape, while *E. telmateia* has a pear shape. The tuber is composed of two or three layers of sclerenchyma surrounding a core parenchymatous zone that is rich in starch granules. The central area has several collateral vascular bundles. The endodermal layer surrounds each bundle separately. The tubers stay in the soil after breaking away from the parent plant, and when favorable conditions return, they sprout into new plants.

2. Spore mediated Reproduction

Equisetum is a pteridophyte that is homosporous.Within the sporangia carried by sporangiophores, the spores develop. The sporangiophores congregate to form a strobilus, a compact cone. The strobilus's location and structure: The majority of species carry their strobili terminally on their vegetative branches. However, in certain species (*E. arvense*), they are carried on unique, fertile shoots that have a brief lifespan and immediately die after releasing spores. The strobilus is composed of several sporangiophores and a central enormous axis known as the strobilus axis. From the strobilus axis, the sporangiophores protrude in successive, alternating whorls at right angles. A hexagonal peltate disk is located at the distal end of each stalked structure that is a sporangiophore. Five to ten sac-like sporangia are carried close to the sporangiophore disc's edge on the underside in a ring like structure.The free round apex of sporangia to form strobilus (Figure 13.13).

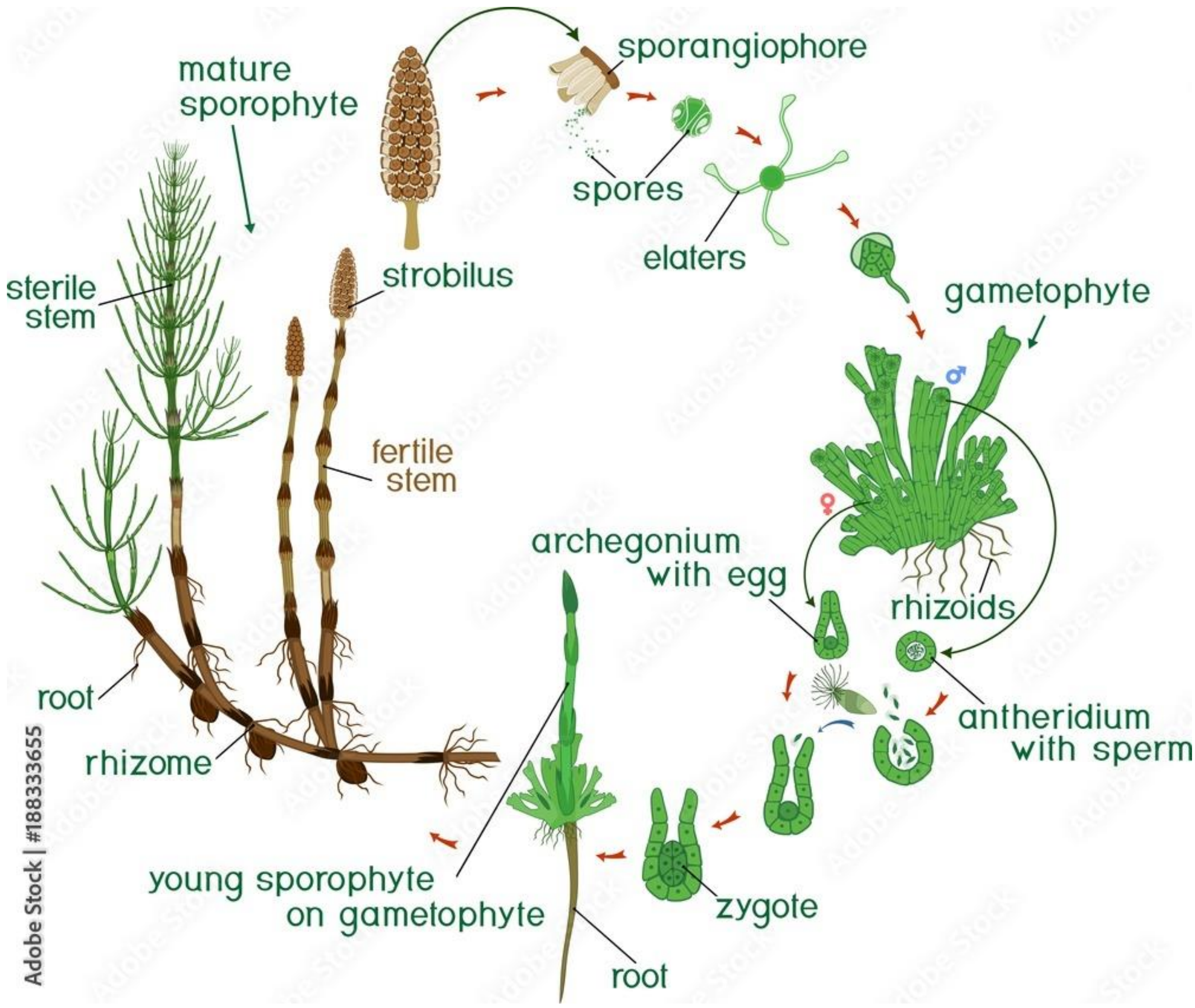


Figure 13.13: Life cycle of Equisetum

Formation of the sporangium: The branch that eventually houses the strobilus becomes conical in shape and slows down its apical expansion. The strobilus axis is now this conical apex. Sporangiophorese primordia are generated in places similar to leaf primordia on this axis in an acropetal succession. The primordium is hemispherical at first, but a constriction that forms close to its base causes it to quickly turn peltate. On the sporangiophore's apical dome, sporangia are first initiated.

Eusporangiate development is the process by which a sporangium forms from a collection of initials. Sporangia begin close to the sporangiophore's apical dome's center. However, later on, the dome spreads laterally (because the central portion of the dome is growing so quickly). The first division of the sporangial initial cells are divided by periclinal division repeatedly.

All but the two outermost wall layers crumble and create periplasmodial fluid as the sporangium ages. The sporogenous cells now split off from one another and serve as the mother cells of the spores. About 30% of the spore mother cells also break down and produce plasmodial fluid prior to meiosis. The mother cells of the remaining spores are still alive and freely float in the periplasmodial fluid. After a reduction division, each spore mother cell produces four spores. Spores quickly take on a spherical shape.

Mature sporangium: The mature sporangia are sac-like structures that are joined to the sporangiophore's peltate disc from below. The mature sporangium has only two layers in its wall. Within a sporangium, every spore is the same.

Sporangium dehiscence: As the sporangia develop, the strobilus axis elongates. The compactly arranged sporangiophore gets separated from each other resulting into exposing the sporangia. When sporangia dehydrate the helicoid thickening bands present in the outer wall layer when sporangium raptures.

13.4 Pteris

Almost 280–300 species of ferns, collectively known as Pteris or brakes, are found in tropical and subtropical climates. They belong to a terrestrial genus that lives in mountainous and damp woodlands. The Latin name Pteris is equivalent to the Greek word for fern.

The North-Western and Western Himalayan valleys and roadside habitats are home to many Pteris species. *P.vittata* grows at less than 1200 m elevations. However, *P.cretica* can grow up to 2400 m starting from 1200 m. Several species are found in India, including *P. wallichiana*, *P. stenophylla*, *P. quadriaurita*, *P. pellucida*, *P. critica*, *P. vittata*, and others.

Morphology

The sporophyte phase is the most prominent one in the Pteris life cycle. It is distinguished by its stem, roots, and leaves. The dark, thin, wiry roots emerge from the underside of the rhizome. It might also exist near the surface. Primary roots emerge from the embryo and have a brief lifespan before adventitious roots take their place.

The perennial, branched subterranean stem is rhizomatous, covered in brown scales. Some of the species have rhizomes with persistent leaf bases. The higher, long-rachis-bearing section of the rhizome is where the leaves emerge. There are two types of coverings for the petiole base: ramenta and brown scales.

The macrophyllous, unipinnately complex leaves emerge acropetally from the rhizome. Dissection rates in Pinnae are higher than in Pteridium. Certain species also exhibit digitate, decompound, and bipinnate leaves. The term "frond" refers to developing leaves. With the exception of the terminal leaflet, the rachis is made up of several sessile, coriaceous, lanceolate leaflets arranged in pairs.

The leaflets are wider toward the base and finally narrow as they approach the peak. The apical and basal portions of the rachis show a progressive reduction in leaflet size, although the central leaflets are quite large. The rough leaflets have a midrib, from which lateral veins sprout in dichotomous pattern. It has a dichotomous open venation as shown in Figure 13.15.

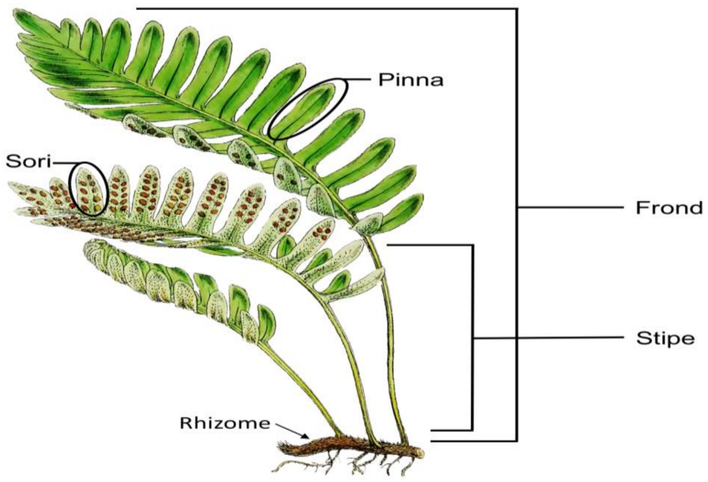


Figure 13.15: Morphology of the Pteris

Leaflet – Anatomy

Mesophyll, epidermis, and the vascular bundle make up the leaflet. The epidermis is a single layer that covers both the upper and lower surface. The only layer with stomata is the lower epidermis. There are two distinct types of mesophyll: top palisade or homogeneous and bottom spongy areas. The hypodermal areas of the midrib contain both the adaxial and abaxial sides of sclerenchymatous strips. An amphicribral vascular bundle around the endodermis and a single layer of pericycle is present in the midrib. The mesophyll is embedded with vascular strands.

Reproduction

In Pteris, vegetative and asexual reproduction occurs. Spore creation is the method used for asexual reproduction. It is homosporous because it only produces one kind of spore.

Vegetative reproduction older rhizome parts eventually die and degrade to produce new growth. The branch and main axis separate and grow into new plants as soon as the rot reaches the branching stage.

Life Cycle of Pteris

The coenosorus produces spores. The dominant phase, the sporophyte, is diploid and autonomous. After germination, the spores eventually grow into the prothallus and move on to the gametophytic stage (haploid). Prothallus is a short-lived, extremely reduced, and independent organism. It reproduces sexually with the help of antheridia and archegonia. Consequently, spermatozoid and egg formation occurs. Upon fertilization of the egg and spermatozoa, a diploid zygote, the future normal sporophyte, is formed. The life cycle is hence diplohaplontic. Because the sporophyte and gametophyte are thought to differ morphologically, the alternation of generations is considered to be heteromorphic.

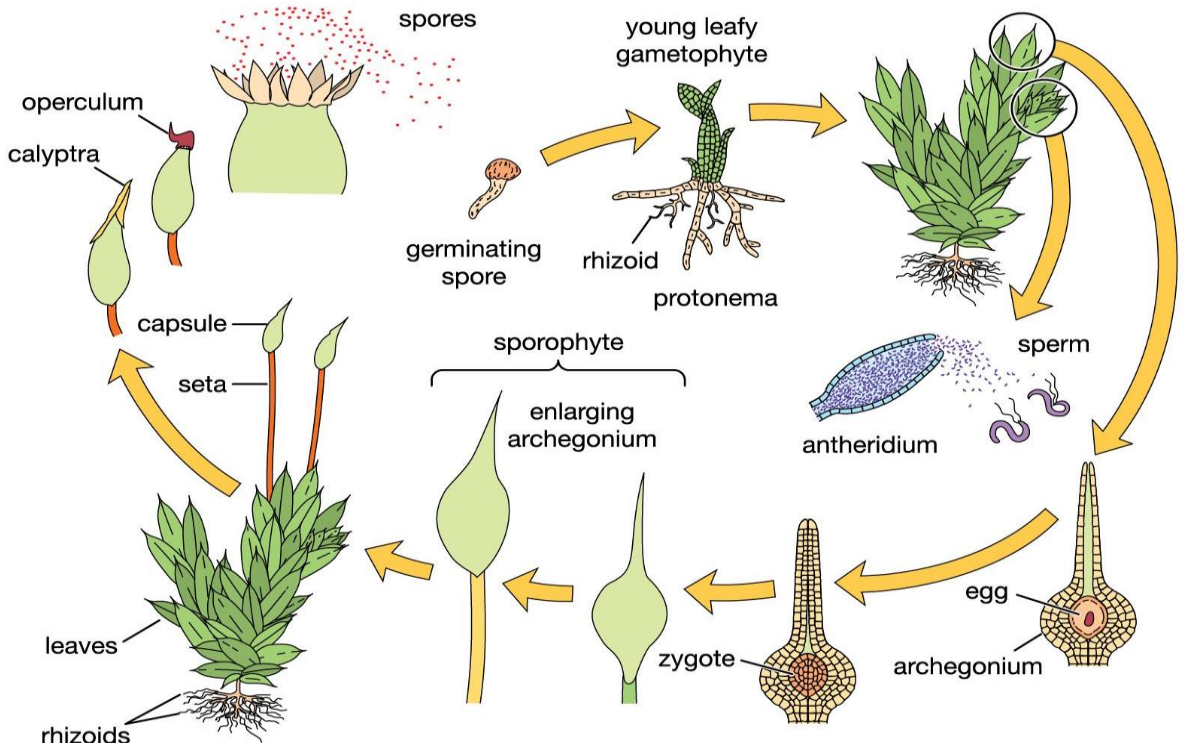


Figure 13.8: Life cycle of Pteris

13.5 Self-Assessment Question

(i) Vallecular canals are found in the stem of:
(a) Lycopodium (b) Adiantum (c) Equisetum (d) None of these

(ii) Which of the following is not correctly matched?
(a) Lycopodium ----Club moss (b) Osmunda-------Royal fern
(c) Adiantum-----Maiden hair tree (d) Equisetum-------Horse-tail

(iii) Trabeculated endodermis with casparian strips are found in:
(a) Selaginella (b) Lycopodium (c) Equisetum (d) Marsilea

(iv) The scientific name of Sanjeevani is:
(a) Selaginella kraussiana (b) S.bryopteris (c) S.radiata (d) S. lepidophylla

(v) Heterospory is found in:
(a) Lycopodium (b) Selaginella (c) Equisetum (d) Psilotum

(vi) The sorus in Pteris is:
(a) Discontinuous and circular (b) Discontinuous and reniform
(c) Discontinuous and vermiform (d) Continuous and linear

(vii) Seed habit originated in:
(a) Algae (b) Fungi (c) Bryophytes (d) Pteridophyte

(viii) Spike moss is the common name of:
(a) Lycopodium (b) Selaginella (c) Equisetum (d) Pteris

(ix) The antherozoids of Selaginella are:
(a) Aflagellate (b) Uniflagellate (c) Multiflagellate (d) Biflagellate

(x) The common name of Equisetum is:
(a) Club moss (b) Water fern (c) Quillwort (d) Horsetail

Answers: (i) c (ii) c (iii) a (iv) b (v) b (vi) d (vii) d (viii) b (ix) d (x) d

13.6 Short Question Answers

(i) Resurrection plant (ii) Elaters (iii) Bird nest moss (iv) Glossopodium (v) Ligule

CHAPTER – 14

Pteridophytes - Apogamy & Apospory

Objectives

Upon successful at the end of chapter student will be able to learn:

- Basic concept of Apogamy and apospory.
- Types of stealer evolution in Pteridophytes.
- Anatomical features of the Pteridophytes.

14.1 Apogamy & Apospory

Apospory and apogamy are two different asexual reproductive strategies found in plants. Usually, plants like liverworts and mosses (Bryophytes) have these mechanisms. One obvious distinction between these two kinds of reproduction is that, in apogamy, the embryo develops independently of fertilization. The gametophyte immediately grows from the second sporophyte during apospory.

Druery (1884) made the initial discovery of the biological process of apospory in the plant *Athyrium filixfoemia* var. clarissima. In apospory, the gametophyte is created straight from the sporophyte's cells, which are diploid by nature (2n), without going through meiosis or producing spores. These gametophytes are naturally diploid, or 2n. They are mostly found in pteridophytes. Ferns such as Dryopteris, Osmunda (*Osmunda javanica*), Pteris (*Pteris aquiline*), and others are the few plants that reproduce by apospory. When pteridophytes experience unfavourable circumstances or a shortage of nutrients, apospory takes place. For instance, some plants go through apospory to reproduce if the soil starts to lose minerals, or if there is not enough sunshine or water available.

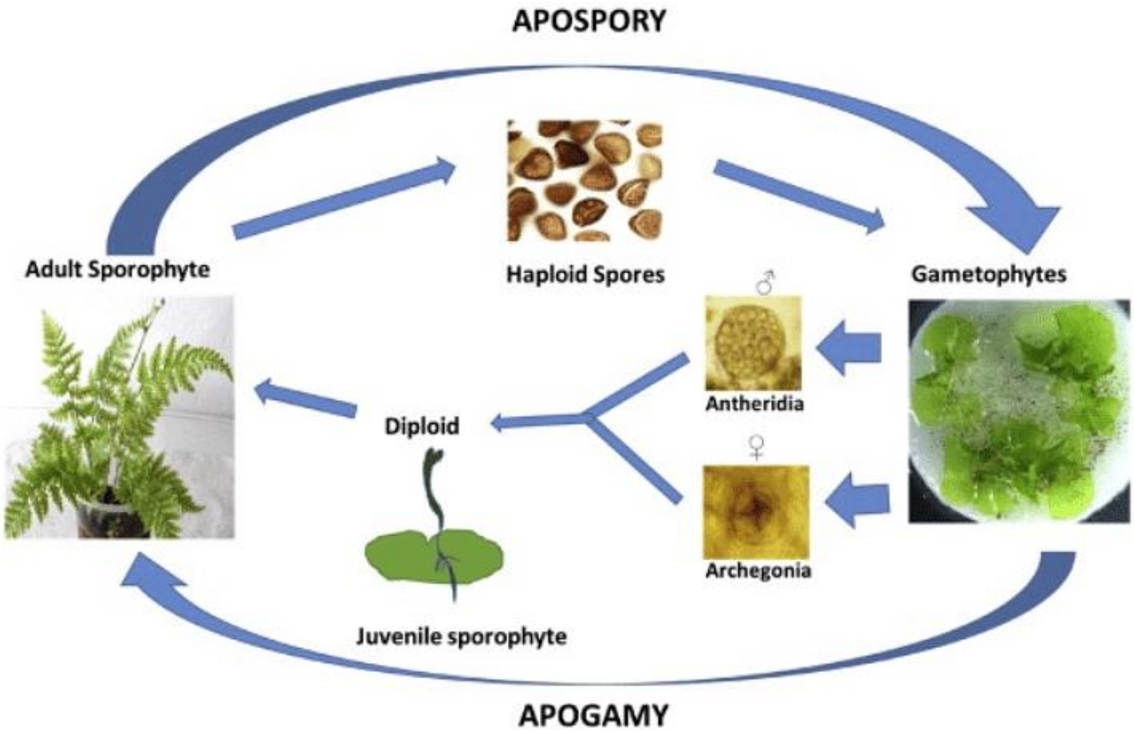


Figure 14.1: Apogamy & Apospory

Apospory in Ferns

The following describes the steps involved in fern apospory.

Step 1: The sporophytes, a diploid multicellular creature that the fern produces, are responsible for either producing diploid zygote or haploid spores (Figure 14.1,2).

Step 2: After undergoing gene activation and forming an embryo sac, these sporophytes mature and eventually give rise to gametophytes. Gene activation can result in spore production or the direct formation of gametophytes.

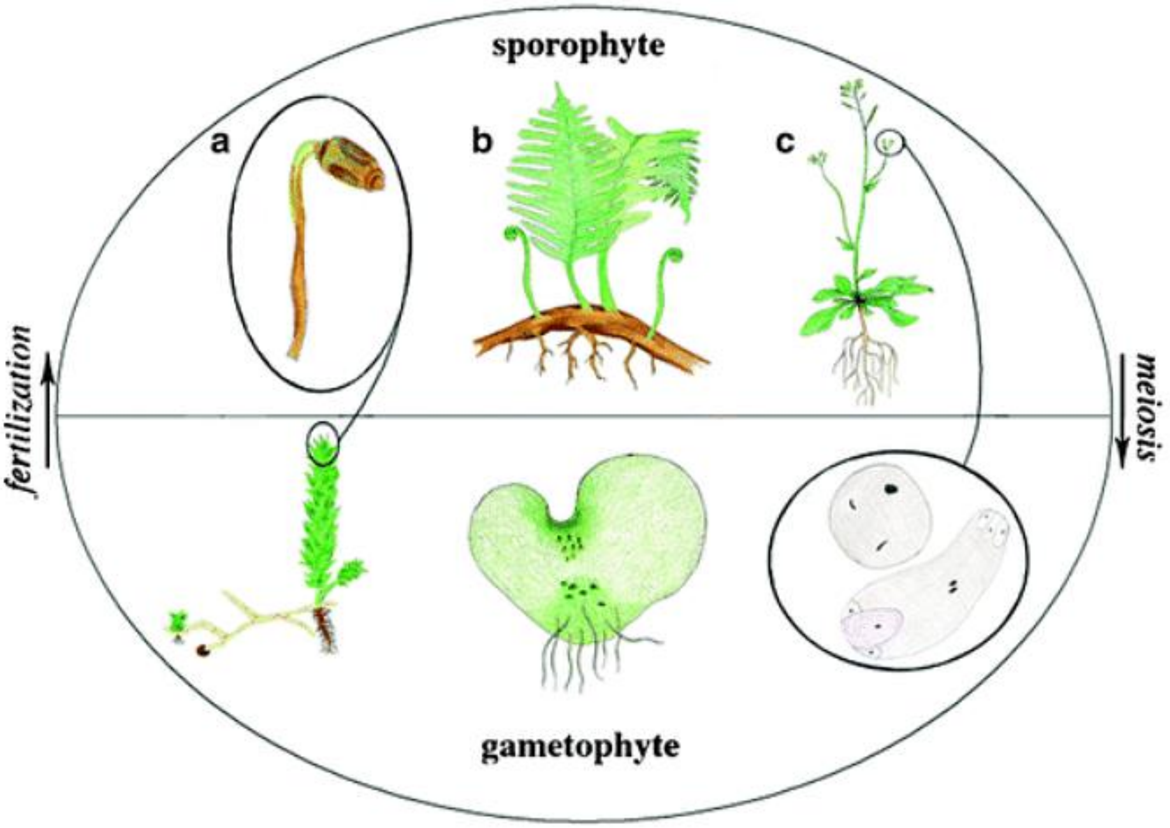


Figure 14.2: Apospory in Ferns

Types of Apospory

Two types of apospory exist, based on the cell from which the embryo sac develops. It might originate from any other cell, the nucellus, or the archesporial cell. These two types are:

Haploid or Generative Apospory

The haploid megaspore is used to form the embryo sac in this instance. These are non-regenerating and eventually create non-recurrent apomicts in the event that fertilization fails.

Diploid or Somatic Apospory

Here, the nucleus or any other diploid cell is used to create the embryo sac. In the event that fertilization is unsuccessful, they can regenerate.

What is Apogamy?

Farlow originally identified the biological mechanism of apogamy in Pteris cretica in 1874.

In apogamy, there is neither syngamy nor fertilization, and the sporophyte is descended from a gametophyte (haploid by nature, n). Since gametophytes are haploid in nature, so are these sporophytes. Adiantum, the holly fern (*Crytomium falcatum*), and other ferns are examples of apogamous species

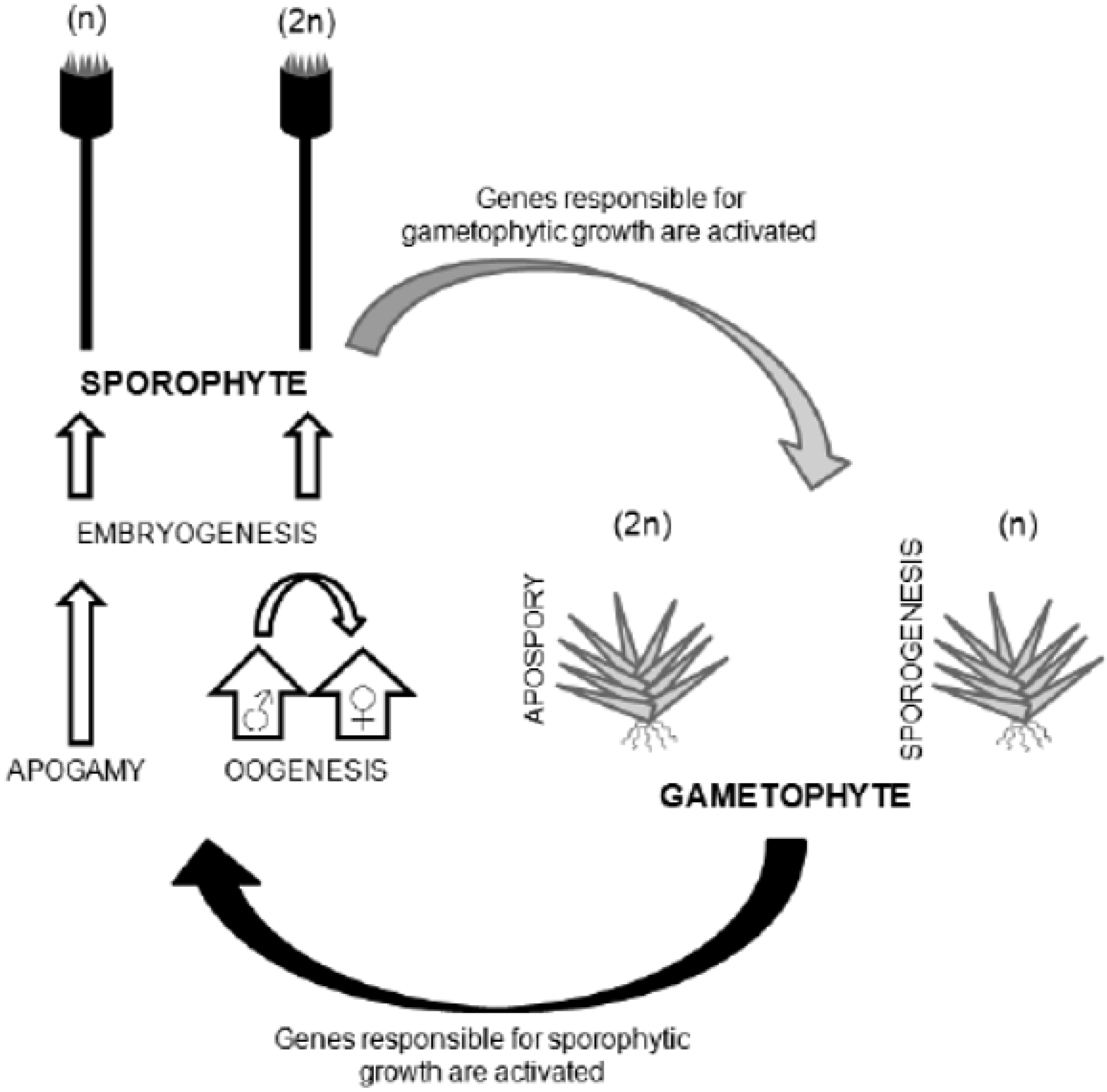


Figure 14.3: Apogamy

This mostly happens in plants, where gametes must survive the fusion period in order to develop into sporophytes. It also happens when growing circumstances aren't right and when there aren't enough nutrients. For instance, some plants reproduce via apogamy when there is a loss of minerals in the soil or when there is insufficient sunshine or water available.

Apogamy in Ferns

In Ferns, the process of apogamy takes the following form.

Step 1: In order to go through apogamy, the haploid multicellular creature known as gametophytes must activate its genes.

Step 2: Immediately upon maturity, they lead to the development of sporophytes (Figure 14.4).

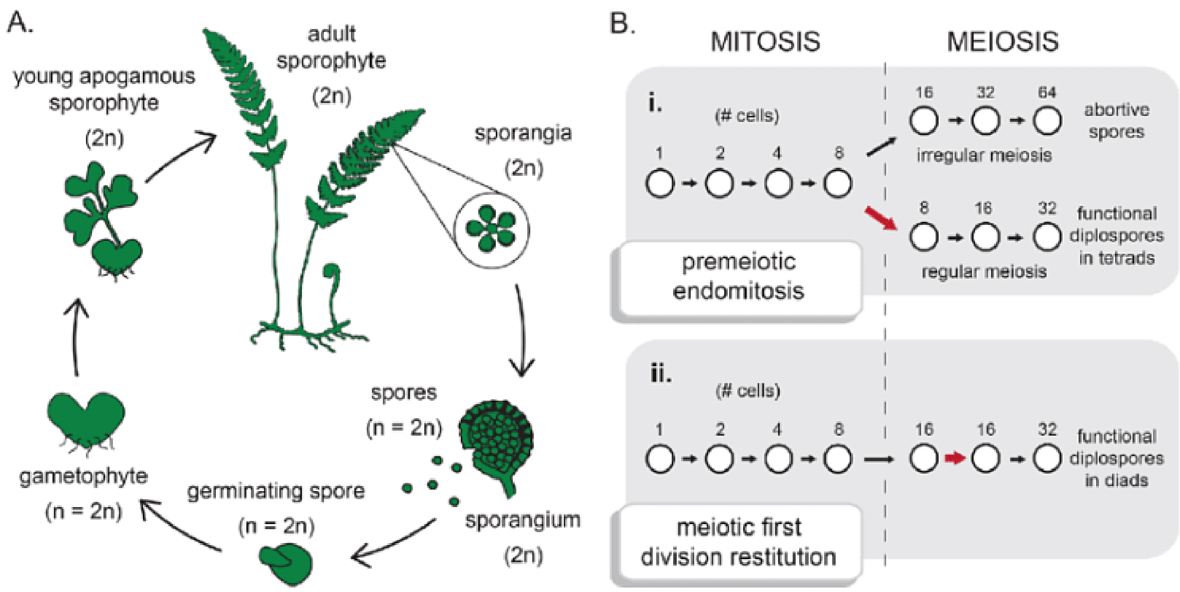


Figure 14.4: Apogamy in Ferns

14.2 Types of Apogamy

There are two types of apogamy:

Induced or facultative apogamy

Here, apogamy is induced artificially in the plants even with the presence of sexual organs in the plants. It is induced via gamma radiations, UV radiation, illumination, etc.

Obligate apogamy

Here, apogamy is the only process of reproduction. This is because of the loss of sexual organs in the gametophytes, or because of the non-functional nature.

Difference Between Apospory and Apogamy	
Apogamy	**Apospory**
Meaning	
Apogamy is an asexual method of reproduction in plants where the gametophyte develops from the sporophyte	Apospory is also an asexual method of reproduction where sporophyte develops from the gametophyte.
Ploidy	
Produces a diploid gametophyte	Produces a haploid embryo
Implication	
Gametes are formed without the formation of gametophytes	The embryo is formed without the process of fertilization

14.3 Heterospory and Seed Habit in Pteridophytes

- Heterospory is the presence of two different types of spores in the same plant. The two types of spores are formed within the microsporangia and megasporangia, respectively, with the smaller ones known as microspores and the bigger ones known as megaspores.
- Since heterosporous plants produce two different types of spores—a male gametophyte called a microspore and a female gametophyte called megaspore —the development of both spore types is unquestionably linked to sex differentiation. Therefore, the sexual differentiation of gametophytes is linked to heterospory.
- Certain characteristics of Selaginella's life cycle, such as the proliferation of spores into microspores and megaspores and their reliance on the parent sporophyte for nutrition, have been thought to be necessary preconditions for the formation of seeds, which are a hallmark of spermatophytes. Most people assume that the seed plants originated from heterosporous vascular plants that developed the habit of holding onto the megaspore inside the megasporangium rather than releasing it.
- There are two types of spores found in seed-bearing plants: megaspores and microspores, which develop into male and female gametophytes, respectively; One megaspore in these plants is held inside the megasporangium while remaining connected to the mother plant, rather than being shed from it. Inside the

megasporangium (nucellus), it germinates to produce the much smaller female gametophyte that bears the archegonia. Eventually, an integument or covering forms to shield the nucellus and the gametophyte, and the entire structure is referred to as an ovule. The female gametophyte does not need to produce on its own because it receives nourishment for growth from the parent plant. Following fertilization, the ovule's zygote develops into an embryo, the remaining gametophytic tissue produces endosperm, or nutritive tissue, and the integument thickens to create the seed coat. The term "seed" refers to this complete structure, or the integumented ovule. It separates from the parent plant and grows into a new plant during germination.

Thus, we see that the following conditions must be met in order to produce seeds:

- The development of two kinds of spores, called heterospores.
- The solitary megaspore inside the megasproangium (nucellus), which is closed off, germinates from the female gametophyte.
- An integument or covering covers the nucellus and eventually forms a seed coat. The reduction division in the functional megaspore mother cell results in the formation of a linear tetrad of four haploid megaspores within the nucleus. The lowest of these four megaspores develops into a female gametophyte, while the other three degenerate.
- The male gametophyte's tubular extension, known as the pollen tube, is how the male gametes get to the egg.
- The megasporangium serves as the site of fertilization and embryo production.
- The developing embryo goes through a period of rest.
- Selaginella demonstrates an unusual adherence to the spermatophyte seed habit due to the following characteristics:
- In the majority of Selaginella species, reduction division results in the production of a single functioning megaspore mother cell; heterospory is observed in nearly all species.
- Each megasporangium produces a single megaspore, which germinates to become the female gametophyte instead of being shed.
- As a result, it is clear that Selaginella is significantly closer to the seed habit in a few species than it is to the actual seed because of the following characteristics:
- There is no covering or integument on the megasporangum.

- It is still unclear whether the megaspore is permanently retained inside the megasporangium.
- There is no time of rest following the development of the embryo.

14.4 Economic importance:

- Because of their elegant leaves, ferns are planted as decorative plants.
- When burned, they are a valuable source of potash.
- The petiole and rhizome of Dryopteris are used to make an antihelmintic medication.
- Certain tribes utilize the sporocarps of Marsilea as food.

Stelar Evolution in Pteridophytes

Stele is the term for the central cylinder or core of vascular tissue, which is made up of xylem, phloem, pericycle, and occasionally medullary rays and pith.

The Greek word "stele" (meaning center pillar) is the source of the term. The endodermis divides the Stele, the central cylinder, from the cortex. The pericycle is the outermost part of the stela while the endodermis is the innermost layer of the cortex.

In 1886, Van Tiegam and Douliot introduced the theory of Stellarity.

According to the stellar theory, the physical architecture of the stem and the root is not fundamentally different, even though both have a stela encircled by cortex.

According to this theory, in addition to xylem and phloem, the stele is made of tissue such as pericycle, vascular rays, and pith.

14.5 Types of stele

Among vascular plants, Easu and Smith identify two main forms of stelar organization. The protostele and siphonostele are these.

1. Protostele

Jeffrey proposed the term "protostele," considering it the most basic and uncomplicated kind of stele. Protostele steel has a solid xylem core encircled by phloem pericycle and

endodermis, forming the gas cylinder. A protostele has no pith in it. It is the basic kind of steel found in vascular plants, from which the other variety descended throughout time.
Brenner classified the protostele into following types

Haplostele: Haplostele is a kind of protostele that has a homogeneous coating of phloem around a smooth xylem core. It is present in a number of extant taxa, including Selaginella kraussiana, and numerous extinct genera, including Rynia and Horneophyton.

Actinostele: An actinostele is a protostele with a stellate or star-shaped xylem core and radiating arms. Actor no longer, the phloem is found in discrete clusters that alternate with the xylem's star-shaped arms rather than continuously. Lycopodium serratum, for example, and Psilotum.

Actinostele variants can occasionally occur as a result of xylem tissue separating into two distinct forms (Figure 14.5).

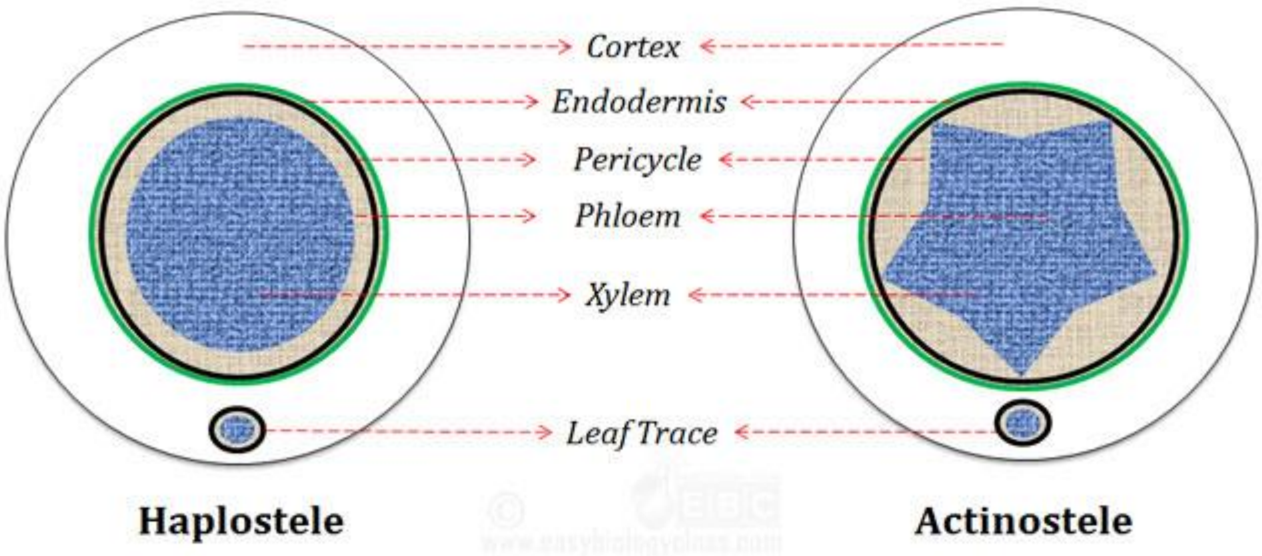


Figure 14.5: Haplostele and actinostele

Plectostele: The most sophisticated kind of protostele is this one. Here, the xylem's central core is split into many parallel-to-one-another plates. The xylem and phloem alternate (in *Lycopodium clavatum*, for example). Zimmerman gave it a name in year 1930.

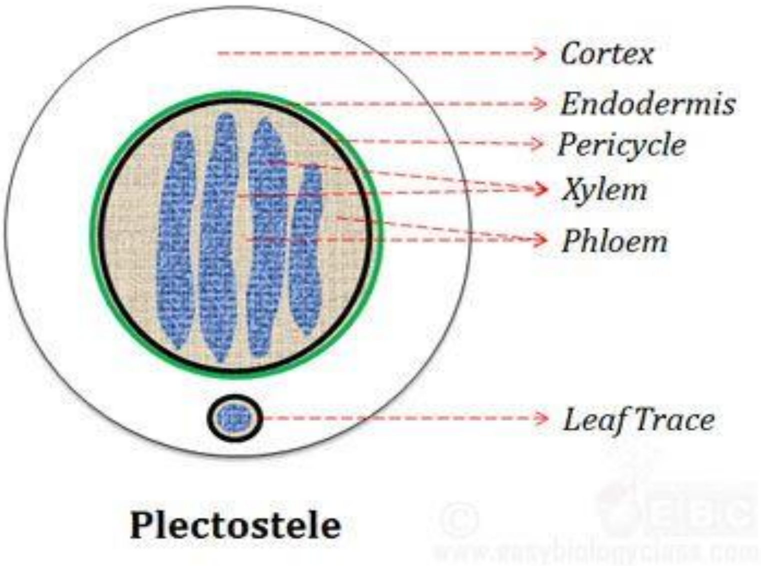


Figure 14.6: Plectostele

Mixed protostele: The xylem is separated into many groups or components. Every xylem unit is dispersed and grouped inside the phloem's groundmass. Lycopodium cernuum is one example.

Mixed protostele with pith: Here, the tiny patches of parenchymatous cells of the pith are combined with the xylem components, or tracheids. Both extinct ferns and early fossils belong to this class. They are considered to be the intermediate forms that lie between siphonosteles and real protosteles (found, for example, in *Hymenophyllum demissum* and *Lepidodendron selaginoides*).

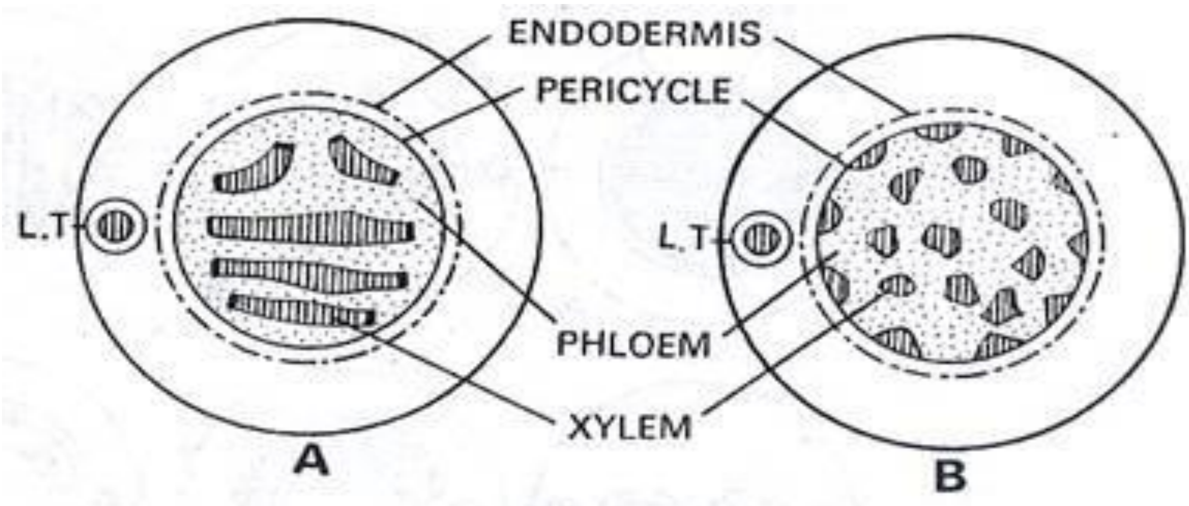


Figure 14.7: Plectostele and mixed Plectostele

2. Siphonostele: It is a modified protostele in which the pith is located in the stele's center. Siphonostele is the term for a medulated protostele. The parenchymatous pith of the xylem replaces the core during siphonostele formation. A cylinder of xylem and phloem encircles the central pith in a siphonostele. Pteropsida members have this kind of stele. It is more advanced than protostele.

Origin of siphonostele

Regarding the genesis of siphonostele, experts hold varying opinions. However, they all agreed that the pith production in the middle of the protostele is how the siphonostele arose. Here, parenchymatous pith takes the role of the centrally located xylem core.

The T.S. exhibits several phases of protostele to siphonostele conversion at varying degrees in Gleichenia, Osmunda, and Anemia.

Regarding the genesis of pith in the siphonostele, there are two schools of thought.

Jeffrey's hypothesis

The theory states that the invasion of cortical parenchymatous cells into the stele results in the formation of the pith. Through the branch or leaf gap, the pith invades the plant.

This hypothesis thus holds that the cortex and pith are homogenous entities.

The majority of writers disagree with this idea since siphonosteles without leaf gaps are seen in several pteridophytes.

Boodle's hypothesis

The notion put out by Boodle (1901) and Gwynne Vaughan states that the inner vascular tissue changed into the parenchyma, allowing the siphonostele to develop from the protostele. There are several varieties of siphonosteles.

(a) Ectophloic

This kind of siphonostele has a concentric xylem cylinder surrounding the pith and a concentric phloem cylinder adjacent to the xylem.

(b) Amphiphillic

Vascular tissue encircles the pith in this kind of siphonostele. The center pith is surrounded by the concentric inner phloem cylinder. The concentric xylem cylinder (e.g., in the Marsilea rhizome) is located next to the inner phloem and is immediately encircled by the outer phloem cylinder.

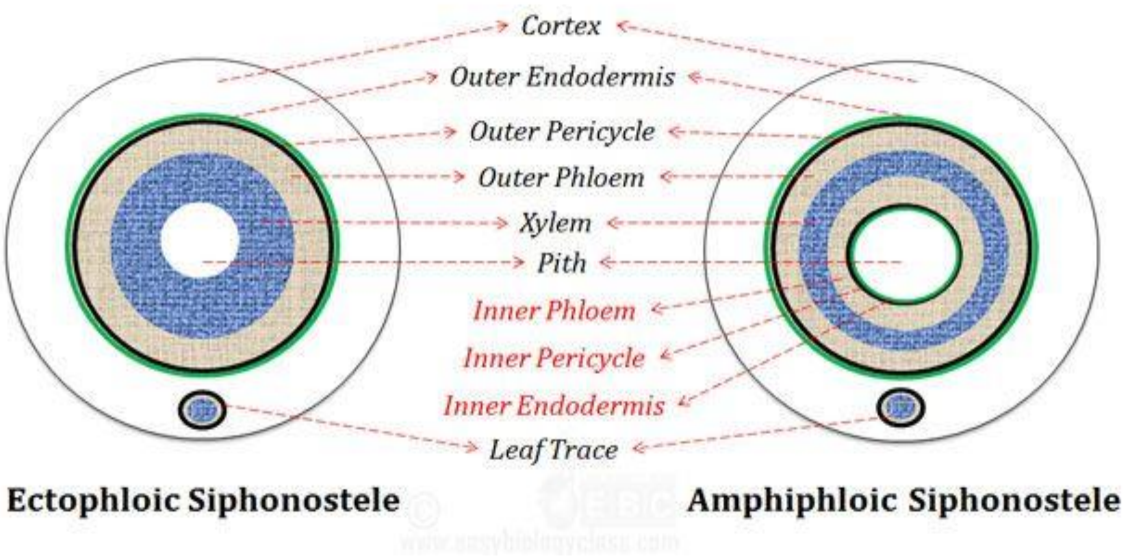


Figure 14.8: Siphonostele

Other modifications of siphonostele

Cladosiphonostele: There are no leaf gaps. It's the most basic kind of siphonostele. and discovered in several Selaginella species.

Phyllosiphonic siphonostele: Siphonostele that is nevertheless punctured by leaf traces, whether the gaps are minor or vast. the Filicophyta members.

3. Solenostele

A pith with a single leaf gap can be found in solenostele. Ectophloic or amphiphloic solenostele might be the kind.

(a) Ectophloic: Phloem solely encircles the xylem on its outside. For instance Osmunda.

(b) Amphiphloic: A pith is located in the middle. Phloem encircles the xylem on both sides. like the rhizome of Marsilea.

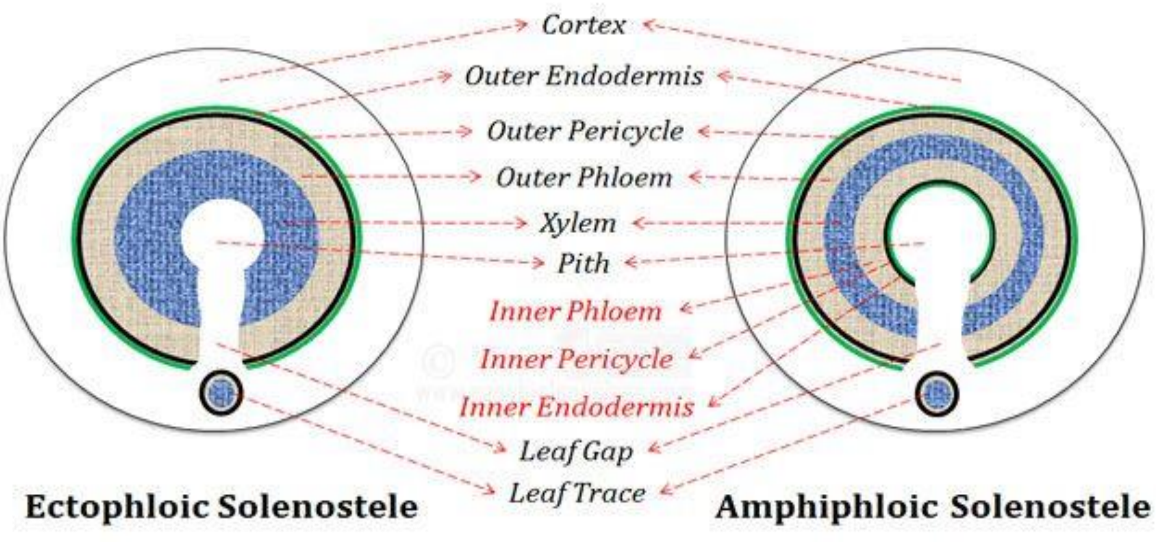


Figure 14.9: Solenostele

4. The Dictyostele

Dictyostele is the term for solanostele that is divided into a network of distinct vascular strands. The many leaf gaps are the cause of the stelar core's disintegration.

A meristele is a single vascular thread of this kind. Each protostelic type meristele exists. With several meristeles, the dictyostele resembles a cylindrical meshwork. Examples: Pteris, *Adiantum capillusveneris* (Figure 14.10).

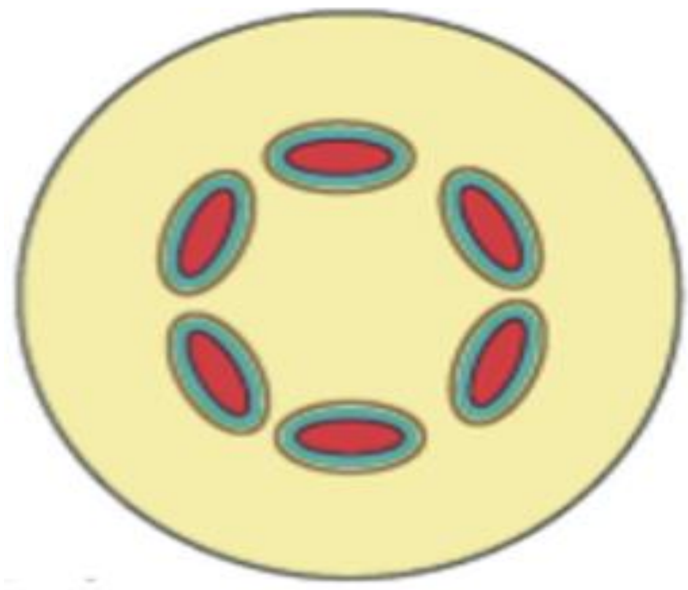


Figure 14.10: Dictyostele

5. Polycyclic Stele

The most intricate stelar arrangement found in all vascular cryptogams (pteridophytes) is this one. The structure of these steles is invariably siphonostelic.

Two or more concentric rings of vascular tissue are characteristic of a polycyclic stele. This might be either a dictyostele or a solenostele. Pteridium aquilinum has two concentric rings of vascular tissue, whereas Matonia pectinata has three (Figure 14.11).

(a) Polycyclic solenostele

(b) Polycyclic dictyostele

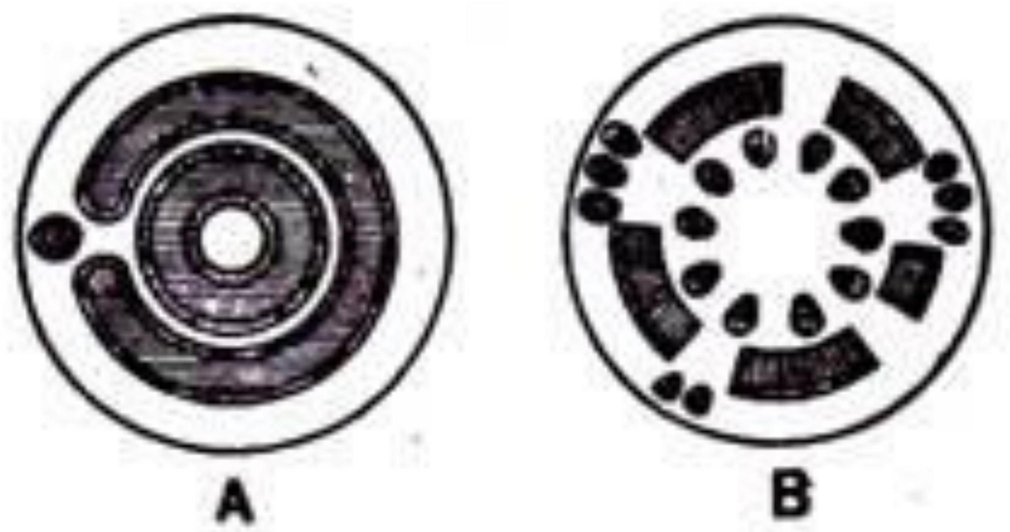


Figure 14.11: (a) Polycyclic solenostele (b) Polycyclic dictyostele

6. The Eustele

Brebner (1902) states that there is an additional siphonostele variant called eustele. The circulatory system in this instance is made up of a ring of collateral or collateral vascular bundles that are positioned around the pith's perimeter. Equisetum's internode is an illustration of this kind (Figure 14.12).

This is the ectophloic siphonostele modified.

The overlapping leaf gaps cause splitting to occur.

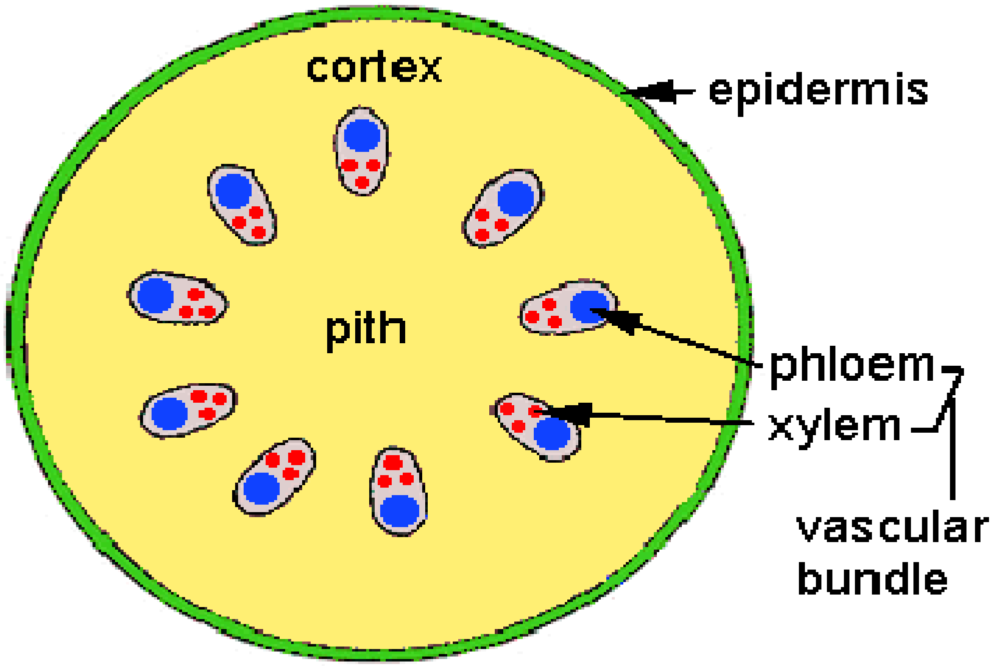


Figure 14.12: Eustele

7. Polystele

Currently, a playstyle is defined as more than one stele in the pteridophytes axis. Given that every one of these stele exhibits protostelic conditions, it is a kind that has to have originated from protostele. Generally, *Selaginella kraussiana* has two steles. However, *Selaginella laevigata* has up to 16 steles (Figure 14.13).

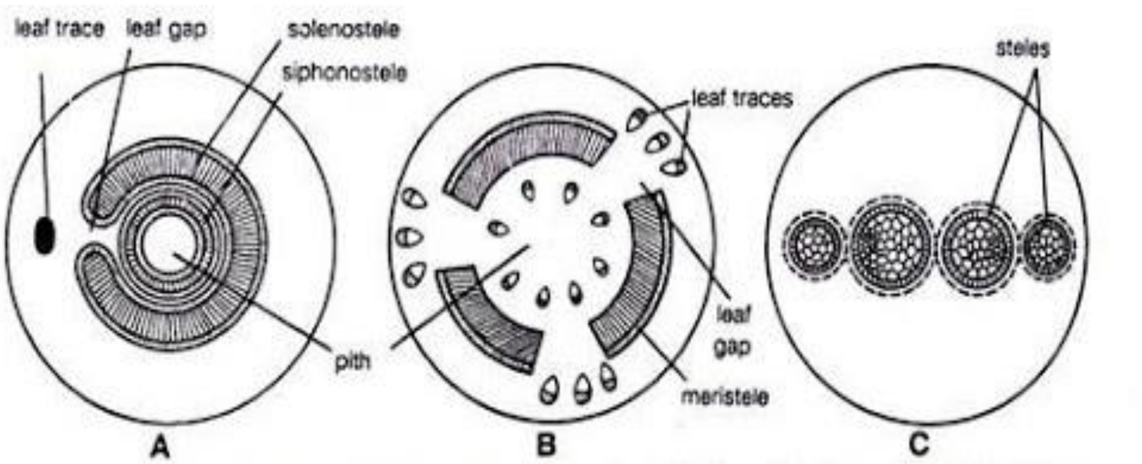


Figure 14.13: Different type of steller

14.7 Summary

A class of vascular plants known as pteridophytes has distinct reproductive and anatomical traits. Two types of asexual reproduction are apogamy and apospory. In apogamy, a sporophyte develops from a gametophyte without fertilization, whereas in apospory, a gametophyte grows straight from sporophytic tissue, avoiding the spore stage. An important evolutionary adaptation that increases genetic variety and is a prerequisite for seed development is heterospory, or the generation of two different types of spores (megaspores and microspores). The development of seeds, which result from ovule fertilization, represents a significant evolutionary improvement by offering the growing embryo more protection and nutrition. Pteridophytes exhibit a range of morphologies, which can be attributed to their diverse range of skeletal morphologies. Their skeletal evolution, from simple protosteles to more complex siphonosteles and eusteles, reflects the increasing complexity of vascular tissue organization.

14.8 Self-assessment Question

i) Heterospory is found in:

(a) *Lycopodium* (b) *Selaginella* (c) *Equisetum* (d) *Psilotum*

(ii) Actinostele is found in:

(a) *Lycopodium serratum* (b) *L. cernuum* (c) *L. clavatum* (d) *L. inundatum*

(iii) In which of the following examples, Heterospory is found:

(a) *Selaginella* and *Lycopodium* (b) *Selaginella* and *Equisetum*

(c) *Marsilea* and *Equisetum* (d) *Selaginella* and *Marsilea*

(iv) Who discovered Apogamy?

(a) Farlow (b) Druery (c) Winkler (d) Strasburger

(v) Who discovered Apospory?

(a) Druery (b) Farlow (c) Winkler (d) Strasburger

(vi) In Pteridophytes, what is the dominant stage?

(a) Rhizoids (b) Prothallus (c) Gametophyte (d) Sporophyte

(vii) The scientific name of Sanjeevani is:

(a) *Selaginella kraussiana* (b) *S.bryopteris* (c) *S.radiata* (d) *S. lepidophylla*

(viii) Stellar theory was proposed by:

(a) Sachs (b) Van Tieghem and Douliot (c) Foster and Gifford (d) DD Pant

(ix) Which of the following is the fossil pteridophyte of the middle Devonian period?

(a) *Lycopodium* (b) *Rhynia* (c) *Selaginella* (d) *Equisetum*

(x) A siphonstele with leaf and branch gap is called:

(a) Protostele (b)Haplostele (c) Solenostele (d) Actinostele

Answers: (i) b (ii) a (iii) d (iv) a (v) a (vi) d (vii) b (viii) b (ix) b (x) c

14.9 Short Question Answers

(i) Living fossil **(ii)** *Lyginopteris* **(iii)** Apomixix **(iv)** Dictyostele **(v)** Sanjeevni

CHAPTER - 15

Gymnosperms

Objectives

At the end of chapter student will be able to:

- Identify plant life forms characterized gymnosperms different from bryophytes.
- Differentiate the range of structural organization, reproduction, life cycles and importance of gymnosperms.

15.1 Gymnosperms Definition

Plants with naked seeds, known as gymnosperms, originated before blooming plants. Their seeds are visible on the megasporophylls, or carpels. They are most likely the earliest seed plants to survive.

The Greek terms "Gymnos" (meaning "naked") and "Sperma" (meaning "seed") were combined to create the term gymnosperm, which literally translates to "naked seed."

15.2 Ecological and economic importance of Gymnosperms

The plants that produce seeds are called gymnosperms; in contrast to angiosperms, they do not produce seeds covered like fruits. These plants grow at the tips of stalks that resemble cones, or on the surface of scales or leaves. The process by which angiosperms and gymnosperms grow their seeds is the primary distinction between them. A protective fruit envelops the developing seeds of angiosperms in the ovaries of flowers. Gymnosperm plants don't have fruits or flowers, and their seeds are typically produced in unisexual cones called strobili.

The four primary groups of gymnosperms are Cycadophyta, Ginkgophyta, Gnetophyta, and Pinophyta. Each group is occasionally treated as a separate phylum.

15.3 Gymnosperms Characteristics

Unlike angiosperms, gymnosperm plants do not bear fruits; instead, they only produce seeds. With fewer than 900 species, they are a small group of plants. The following list contains gymnosperm characteristics:

1. **Occurrence**: There are gymnosperms on every continent. The northern hemisphere's temperate and subarctic zones are habitat to the majority of them.
2. **Size**: Gymnosperms are limited to tall, evergreen trees. Sequoia sempervirens is the tallest gymnosperm, whereas *Zamia* pygmaea is the smallest. *Gnetum ula* is a climber of woods.
3. **Plant body:** The root,stem and leaves make up the sporophyte plant body.
4. **Habit:** The majority of gymnosperms are woody, evergreen plants. The majority of gymnosperms are shrubs and trees. Some of them may be climbers or lianas.
5. **Life Span**: Gymnosperms require more time for fertilization and development because they do not yield fruits or flowers. A pine tree, for instance, can live for more than a century.
6. **Roots**: They possess a taproot or fibrous root structure.
7. **Stems**: Because they are woody plants, their stems are upright. Gymnosperm stems can be heavily branched or unbranched.
8. **Leaves**: With a thick cuticle, leaves might be compound, like *Cycas*, or simple, needle-like like *Pinus, Juniper,* etc.

   There are two primary kinds of leaves:

a. Green, photosynthetic foliage. b. Scale leaves are brown in color, non-photosynthetic, and found on the nodes and short branches.

9. **Xylem:** The xylem supports and transports minerals and water to various sections of the plant. Gymnosperm xylem does not have any vessels. There are vessels in the secondary wood of *Gnetum.*
10. **Phloem:** The partner cells in the phloem are typically absent from the sieve tube. To channel food, they have sieve cells instead. Pine contains albuminous cells instead of companion cells.
11. **Flower:** No flowers are produced by them.

12. **Microsporophyll:** Hard, leafy, triangular clusters of male cones with microsporangia, which contain microspores, are known as microsporophyll in gymnosperms.
13. **Megasporophyll:** A female gamete, or megasporangia with a single megaspore, is carried by megasporophyll in gymnosperms.

    a. Either distinct plants (*Cycas*, dioecious) or the same plant (Pinus, monoecious) can have both male and female cones.
14. **Pollination:** The wind transports pollen grains from the male to the female cone (Anemophily).
15. **Gametophyte:** a. Haploid microspores give rise to male gametophytes. Pollen grains, also known as male gametophytes, are drastically reduced to a small number of cells. b. From haploid megaspores, female gametophytes are greatly reduced. The ovules are known as integumented megasporangium because they have integuments. Except for Gnetum, all gymnosperms are unitegmic.
16. **Endosperm:** The endosperms are haploid.
17. **Seeds:** In gymnosperms, the seeds are naked and borne in cones that are hidden until they reach maturity.

15.4 Classification of Gymnosprems

Kramer and Green further classified the gymnosperms into four classes (see Kubitzki, 1990). The following are the four classes of gymnosperms:

1. Cycadopsida
2. Ginkgopsida
3. Coniferopsida
4. Gnetopsida

1. **Cycadopsida**

a. Both extant and fossilized representatives of these groups are depicted. The Triassic epoch is when they first appeared. There are a lot of these in tropical regions. b. They are dioecious, woody plants with separate male and female plants. c. At the summit of the plant, they have a single, usually unbranched trunk. On top of the trunk, the leaves are produced in a group.

d. Cycads have huge cones made up of several fertile leaves, or sporophylls, grouped in a cone shape.

e. Because of their lovely shape, they are frequently utilized as decorative plants.

f. *Cycas* and *Zamia*, as examples.

2. **Ginkgopsida**

a. *Ginkgo biloba* is the only surviving member of this class—all other species have become extinct—it is frequently referred to as a living fossil.

b. Their leaves have dichotomous venation and are fashioned like a fan.

c. They have two sexes. Cones might be male or female on individual plants.

Ginkgo as member representative

3. Coniferopsida

a. These are the tallest, evergreen, most prevalent gymnosperms.

b. Their leaves resemble needles.

c. Present at higher altitudes and well adapted to drier climates.

d. Sporophylls surround a stem in an arrangement.

e. Cones are often meaty, occasionally tender, and woody.

f. They have two sexes.

Pinus, Cedrus, Spruce, and *Firs*,.

4. Gnetopsida

a. They consist of tiny trees and plants.

b. Both Gnetum's internal and exterior traits are similar to those of angiosperms.

c. Their reproductive organs resemble those of blooming plants in many ways.

d. The reproductive organs are carried in inflorescences, or whorls.

e. The xylem contains vessels.

Gnetum, Ephedra

15.5 Gymnosperms Reproduction

Plants classified as gymnosperms lack actual seeds, fruits, and flowers.

a. The primary means of reproduction for gymnosperms are both vegetative and sexual.

b. Their ethnicity is diverse.
c. On megasporophylls, megasporangia develop.
d. On microsporophylls, microsporangia develop.
e. Sporophylls gathered together to create strobili or cones.
f. Male strobili, also known as microsporangiate cones, are compactly arranged microsporophylls that carry male spores. Inside their microsporangia, these cones contain microspore mother cells. Male gametophytes are produced by haploid microspores. Male gametophytes, or pollen grains, are significantly reduced to a limited number of cells.
g. Megasporophylls are compactly organized in female cones, female strobili, or megasporangiate cones, bearing female spores. These cones contain megaspore mother cells in their megasporangia. The haploid megaspore gives rise to substantially diminished female gametophytes. The ovules are known as integumented megasporangium because they have integuments. Except for *Gnetum*, all gymnosperms are unitegmic.
h. *Gnetum* and other advanced gymnosperms are not produced with archegonia, in contrast to angiosperms that produce non-motile female gamete eggs or ovum.
i. In all gymnosperms, pollens are spread by the wind and lands on the female cone.
j. To start fertilization, a pollen tube forms the pollen grain.
k. The pollen grain undergoes mitosis to split into two sperm cells.
l. One of the sperm cells fuses with one of the egg cells inside the archegonium during fertilization.
m. Fertilization produces a diploid zygote, which grows into a seed.
n. The diploid zygote undergoes many mitotic divisions to generate the diploid embryo, which subsequently gives rise to the diploid sporophyte.
o. Pines typically exhibit polyembryony, or the production of many embryos within a single ovule.

15.6 Gymnosperm Seeds

Unlike angiosperms, gymnosperm seeds lack an exterior covering such as the ovary wall. Rather, because there is no ovary, the seeds are visible hence the name "naked seeded plants." After resting for a while, the seed spreads over a wide region. Epigeal germination occurs.

15.7 Life Cycle of Gymnosperms

(a) Gymnosperms exhibit generational alternation.

(b) The dominating stage of the life cycle is the diploid photosynthetic sporophyte generation.

(c) The haploid and sporophyte are necessary for the gametophytic generation.

(d) A diplontic life cycle is seen in them.

Examples of Gymnosperms Plants

A few examples of gymnosperms plants are:

1. *Cycas*
2. *Pinus*
3. *Ginkgo*
4. *Gnetum*
5. *Ephedra*
6. *Juniperus*
7. Spruce
8. *Abies*
9. *Cedrus*
10. *Thuja*

15.7 Gymnosperms Importance

Gymnosperms are significant from an ecological and financial standpoint.

Economic Importance

1. The main source of turpentine, resins, lumber, and paper pulp is gymnosperms. Pulp for paper is produced from *Pinus roxburghii*.
2. Gymnosperms can be used as fuel.
3. Medicines are made from gymnosperms. Bronchitis and asthma are treated with *Ephedra gerardiana.*
4. Gymnosperms yield an abundance of wood for furnishings and other building needs. Sleepers for railroads, boats, and doors are all made from *Cedrus deodar*.

5. Gymnosperm plants are also utilized as ornaments and décor.
6. *Taxus baccata* is the source of the anti-cancer medication taxol.

15.8 Cycas

A distinct genus of gymnosperms, the *Cycas* is a member of the Cycadaceae family. In this family, it is the only known genus that is still extant. *Cycas* plants, of which there are over 100 kinds, are mostly found in eastern and southeast Asia. Many *Cycas* species are also indigenous to nations like China, Australia, and India.

Cycas plants are evergreen perennials that resemble palm trees quite a bit. These plants are distinguished by their naked seeds, which have ovules that are not protected by an ovary. The diploid sporophyte is the main structure of a *Cycas* plant's body. Additionally dioecious, or having separate male and female plants.

Classification

Kingdom	**Plantae**
Subkingdom	Tracheobionta
Superdivision	Spermatophyta
Division	Cycadophyta
Class	Cycadopsida
Order	Cycadales
Family	Cycadaceae
Genus	*Cycas*

All vascular plants are members of the subkingdom Tracheobionta, which includes *cycas* plants. Spermatophyta is the superdivision that contains all seed plants.

Some of the commonly found species of *Cycas* include:

- *C. revoluta* (sago palm)
- *C. circinalis* (fern palm) – endemic to India
- *C. media* (australian nut palm)
- *C. Rumphii (queen sago palm)*

Structure

A diploid sporophyte is a *Cycas* plant's main body.The roots, stems, and leaves of this vascular plant are distinct from one another. Among *Cycas*' notable characteristics are (Figure 15.1).

(A) (B)

Figure 15.1: *Cycas circinalis* (A) and *Cycas revoluta* (B)

Morphology of *Cycas*

- *Cycas* is a perennial plant that is evergreen. Certain species have a maximum height of 60 feet.
- Because *Cycas* is a dioecious plant, its reproductive organs are borne on separate trees for the male and female.
- The tap root and coralloid root are the two types of roots found in these plants.
- The main roots, known as tap roots, are used for mineral and water absorption and anchoring.
- The coralloid roots grow from regular roots and are connected to cyanobacteria that fix nitrogen biologically.
- The caudex, or stem, is stout, woody, and primarily unbranched. Because of the persistent leaf bases, the stem's surface is rough.
- The leaves at the top of the stem form a crown. *Cycas* has two different kinds of leaves: scaly leaves and leafy leaves.

- The tiny, brown, scaly leaves are covered in scales. They serve as a shield for the shoot apex and reproductive systems. The foliage leaves switch places with the scaly leaves.
- The leaves of the green foliage are complex, pinnately. There are several leaflets on each leaf, and they are grouped on a lengthy rachis.
- The midrib of the leaves lacks lateral veins, and they exhibit circinate vernation. The foliage leaves shed and are not permanent, leaving the bases of the leaves.
- Although xylem lacks vessels, it does have tracheids and xylem parenchyma.
- Phloem is made up of parenchyma and sieve tubes. It lacks companion cells.
- There is secondary growth evident.
- They are not uniform. The megasporangia and microsporangia, respectively, are where the megaspores and microspores are formed. Megasporophylls and microsporophylls that are grouped in a spiral hold the sporangia.
- Megasporophylls and microsporophylls in *Cycas* are dioecious since they are found on separate trees.
- Neither a cone nor a strobili form on the megasporophyll.
- Phloem is made up of parenchyma and sieve tubes. It lacks companion cells.
- There is secondary growth evident.
- They are not uniform. The megasporangia and microsporangia, respectively, are where the megaspores and microspores are formed. Megasporophylls and microsporophylls that are grouped in a spiral hold the sporangia.
- Megasporophylls and microsporophylls in *Cycas* are dioecious since they are found on separate trees.
- Neither a cone nor a strobili form on the megasporophyll.

Reproduction and Life Cycle

Cycas plants can reproduce sexually as well as vegetatively. Vegetative reproduction happens through adventitious buds or bulbils. On the other hand, seeds are formed during sexual reproduction.

Vegetative Reproduction

Bulbills, or adventitious buds, develop in the axils of scaly leaves. To produce new plants, they separated from the stem. The bud of the male plant develops into a male plant, and the bud of the female plant becomes a female plant.

Sexual Reproduction

Cycas is heterosporous and generates two distinct kinds of spores. Because it is dioecious, separate plants have both the male and female reproductive components. During sexual reproduction, or oogamous reproduction, the egg is significantly bigger and non-motile than male gametes.

Development of Male Gametophyte

The microsporangia, which are carried by microsporophylls, produce the microspores. Cone-shaped or compact strobili are created by the spiral arrangement of microsporophylls along the axis in the acropetal succession. In the kingdom of plants, *Cycas*'s male cone is the biggest.

Meiosis in the microspore mother cells produces the haploid microspores. Pollen grains are the reduced male gametophytes that grow from microspores. Inside the sporangia, pollen grain formation begins. When pollen grains reach their three-celled stage—a prothallial cell, a generative cell, and a tube cell—the microsporangia break apart. Following pollination, the male gametophyte continues to develop. Wind pollinates pollen grains (Figure 15.2).

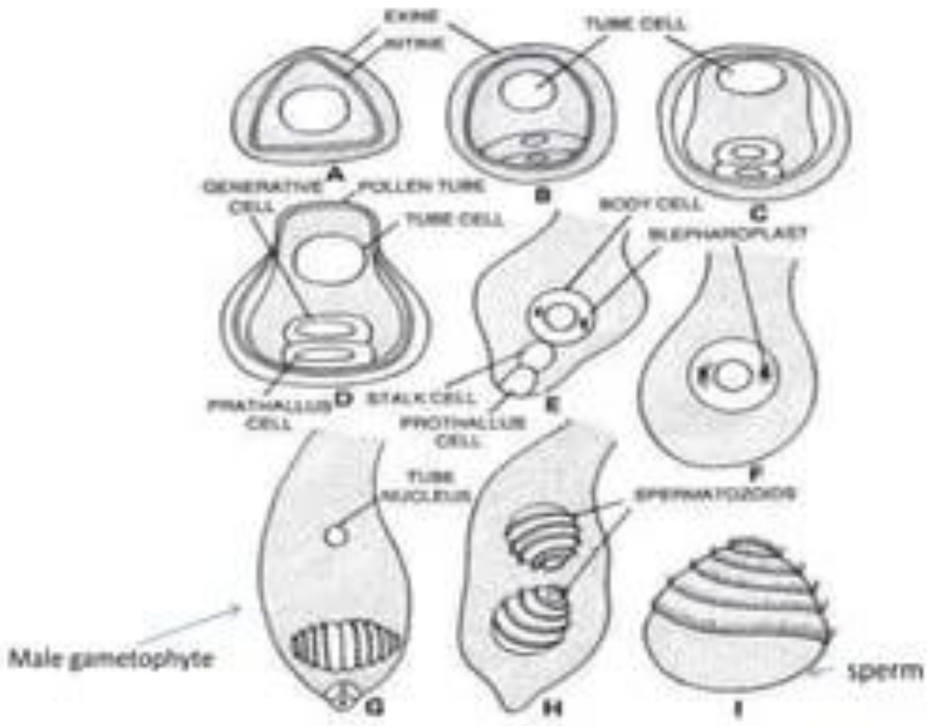


Figure 15.2: Stages of Development of Male Gametophyte of *Cycas*

Development of Female Gametophyte

Megasporangia, which are carried by megasporophylls, are where the megaspores are generated. On the leaf crown, megasporophylls are organized spirally in the acropetal succession; they do not form strobili or a cone. In the kingdom of plants, *Cycas* has the largest ovules, or megasporangia.

To generate haploid megaspores, the megaspore mother cell goes through meiosis. One of the megaspores develops into a multicellular female gametophyte inside the megasporangium. The female gametophyte carries one or more archegonia, or female sex organs. The female gametophyte is located in the megasporangium (Figure 15.3)

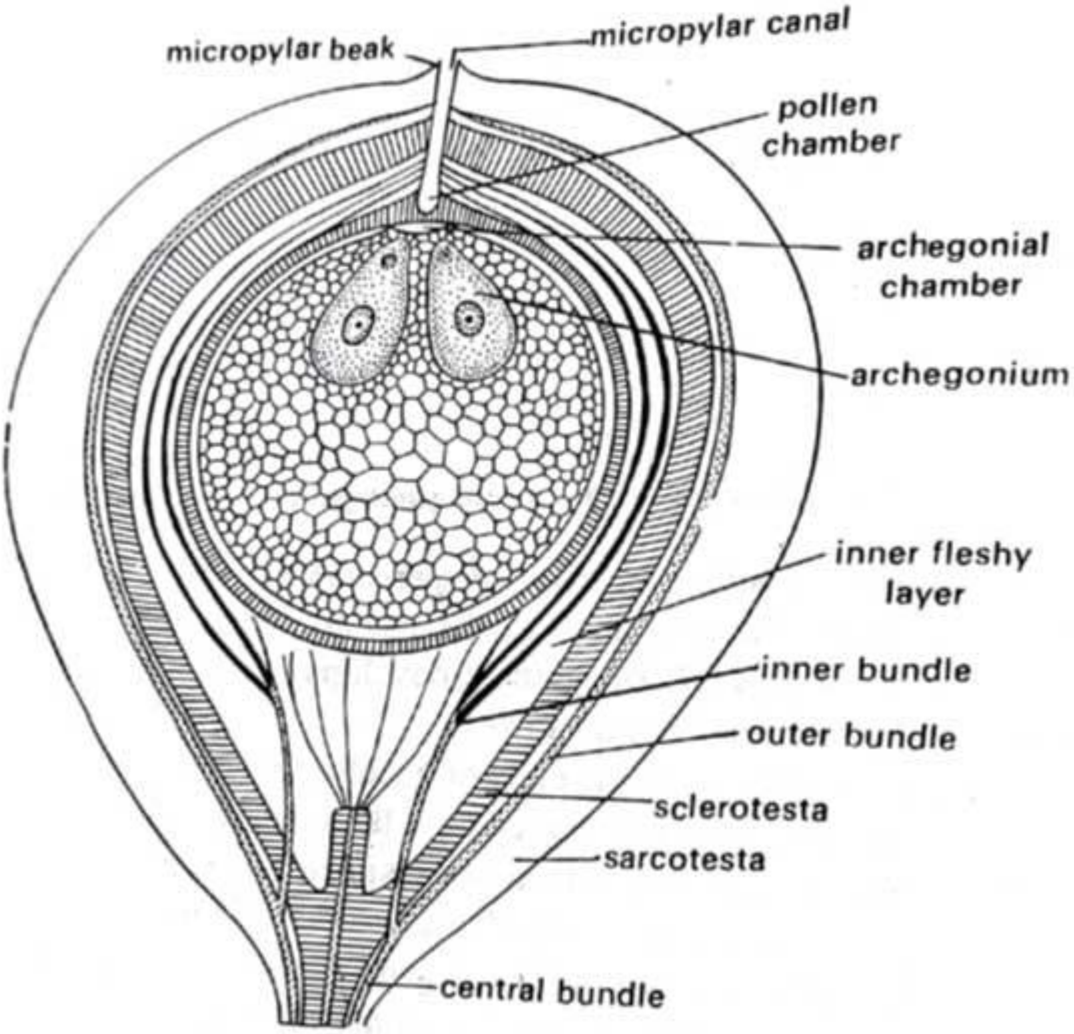


Figure 15.3: Cycus ovule

Fertilisation

The air carries pollen grains in the direction of the ovule. In the ovules, the pollen tube expands in the direction of the archegonia and releases its contents—male gametes—near the archegonia's mouth. A diploid zygote is created when the nucleus of the egg and the male gamete combine. The ovule matures into a seed, while the zygote produces the embryo. Gymnosperm seeds are distinguished by their lack of seed covering.

Economic Importance of *Cycas*

- *Cycas* plants are used for a variety of things, including food, medicine, and ornamental gardening.
- *Cycas* are utilized as attractive plants in many different species.
- *Cycas* siamensis, or the Thai sago palm, and a few other species are the source of starch.
- Certain plants belonging to the *Cycas* species are also utilized to make alcoholic beverages.
- Edible seeds are produced by certain *Cycas* species.
- Leaves are prepared for baskets, hats, and other items, as well as utilized for decoration.
- Some species' seeds and raisins are used to treat swellings, lesions, and ulcers.
- Flatulence and vomiting can be treated with young leaf juice.
- Young, succulent leaves from different plants are frequently prepared as vegetables.

15.9 Pinus

Gymnosperms belong to the subkingdom of Embryophyta under the kingdom Plantae. These are primarily plants without ovules that are protected by the ovary wall. It stays exposed both before and after fertilization, as well as before it becomes a seed. Stems of gymnosperms can be unbranched or branching. Because of their depressed stomata, thick cuticle, and needle-like leaves, these plants lose less water.

The gymnosperm family includes conifers, cycads, gnetophytes, species of the Ginkgophyta division, and *Ginkgo biloba.*

Although there are about 115 species of evergreen conifers in the pine family (Pinaceae), they are mostly native to northern temperate zones and are found all over the world. One example of how pines and conifers are crucial elements of coniferous forests, taiga (boreal forests), and mixed forests worldwide is the habitat of the longleaf pine (*Pinus palustris*) in the southern United States.

Description of *Pinus*

Evergreen pinus trees have wood that is resinous. The majority of their traits are determined by their bark, cones, and needles.

- *Pinus* Needle: Mature pine leaves are referred to as "needles" in this context. The foliage forms fascicles, or collections of leaves.
- Cone: The organs that carry seeds on gymnosperms are called cones. With several scales encircling them, female pine cones are frequently larger than male ones. The scales at the base and apex of the cone are usually sterile (void of seeds).
  The seeds themselves resemble wings that the wind can carry away.
- White pines (Strobus) have clusters of five leaves per leaf. Typically, its wood is soft, white, and features faint yearly ring patterns. *Pinus gerardiana* is one of the soft pines, commonly known as haploxylon.
- The bark of yellow pines (*Pinus*) is divided and thick. Their wood has more noticeable annual rings, is yellower and tougher. Some call them hard pines, such *P. roxburghii*, or diploxylon.The old pines known as lacebark pines (*Ducampinus*) are different in terms of their phylogeny (Figure 15.4).

Figure 15.4: Pinus morphology

Classification of *Pinus*

Kingdom	Plantae
Division	Pinophyta
Class	Pinopsida
Order	Pinales
Family	Pinaceae
Genus	*Pinus*

Pinus is divided into the following species based on their number and types of leaves:

- *Pinus insularis*
- *Pinus echinata*
- *Pinus monophylla*
- *Pinus densiflora*

Pinus Life Cycle

Sporophyte of the *Pinus*

Tall trees with excurrent branching that are distinguished by fascicles of thin, needle-like, evergreen foliage leaves are known as *Pinus* species. The main stem is thick, cylindrical, covered in scaly bark, and has multiple widely spaced branches. At the termination of the stem lies a sizable terminal bud.

It yields two different kinds of shoots: long or infinitely growing shoots, and dwarf or barely developing shoots.

Usually, the long branches' scale leaves are dwarf shoots that bear axils. A circle of scales surrounds the base of each dwarf shoot, which has an apex that is topped by a fascicle of two or more needle-like leaves. The main root system consists of a wide, deeply ingrained tap root that is robust and perennial. In certain species, the tap root may die quite quickly.

Pinus are monoecious plants, which mean that within a single plant, the male and female cones grow on separate branches.

Reproduction

Pinus reproduces sexually. It is a monoecious plant that develops male and female cones on separate branches of the same plant. Male cones sprout on the lower branches, while female cones form on the top branches. Early in the spring, groups of male cones that will eventually replace the dwarf stems start to grow at the base of the long stem.

Between 15 and 140 male cones—140 for *P. roxburghii* and 15 for *P. wallichiana*—may be found in a cluster. When the male cones begin to fall off at the beginning of spring, the young female cones are born in pairs or clusters near the top of the long stem.

*Pinus i*s wind-pollinated, or anemophilous. After pollination, a pine woodland turns yellow as a result of numerous pollen grains dispersing into the atmosphere. This phenomenon, which is also referred to as "sulphur showers," is most frequent in the spring when windy weather shakes the pine trees.

Female Cone

The female cones may continue to grow for several years at a very modest rate. When completely formed, the third-year cone is bigger (15–60 cm long), loose, woody, and brown. Consequently, female cones of varying ages can be seen in acropetal succession on the long branches.

The *Pinus* tree's female cone is an intricate structure that resembles a compound shoot. Scale leaves, which have 80–90 megasporophylls, are placed spirally along the female cone's central axis.

Ovule

The ovules of Pinus are unitegmic, anatropous, and crassinucellate. There is no nucellus in the solitary integument, save from the chalazal end.

The three layers of the integument are the stony middle layer, the rocky inner layer, and the fleshy outer layer.

Gametophytes of *Pinus*

The spore phase marks the beginning of gametophyte production. The megaspore represents the female gametophyte or its early stage, while the pollen particle or microspore represents the male gametophyte.

Development of the Male (or Micro) Gametophyte

The fundamental pattern of male gametophytic growth is comparable in ginkgo and pinus. In the pollen grains, endosporic growth happens. Pollen nuclei divide as a result of mitosis, producing a small, lens-shaped first prothallial cell at the proximal end and a big central cell at the distal end.

The central cell cuts off the antheridial initials and a second prothallial cell. Although both prothallial cells are transient, there is still a connection between the secondary and main prothallial cells.

An antheridial cell, two prothallial cells, and a tube cell make up the four-celled stage of the microsporangium, which is when the pollen grains are released.

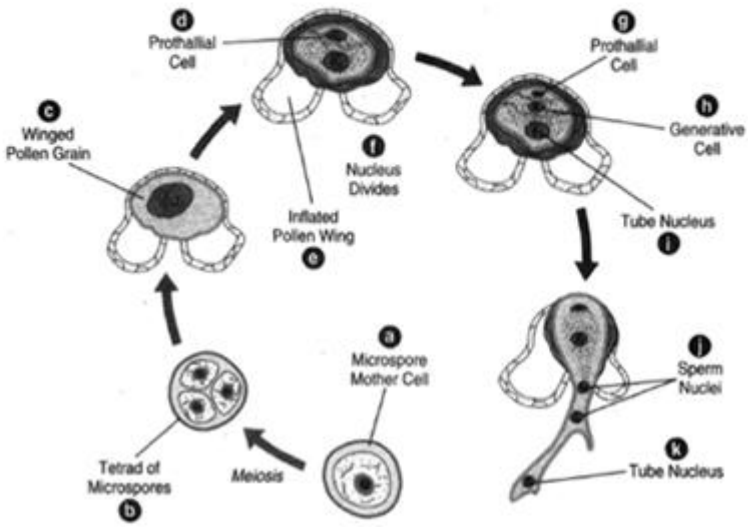


Figure 15.5: Development of the Female (or Mega) Gametophyte

The female gametophyte of *Pinus* undergoes extensive evolution from its functional megaspore. During mitosis, the megaspore's nucleus divides, creating a large number of nuclei without the assistance of wall construction.

On every alveolus, cross-walls are present in order for uninucleate cells to form. As a result, the gametophyte as a whole becomes cellular, and the resulting tissue represents the endosperm or female prothallus.

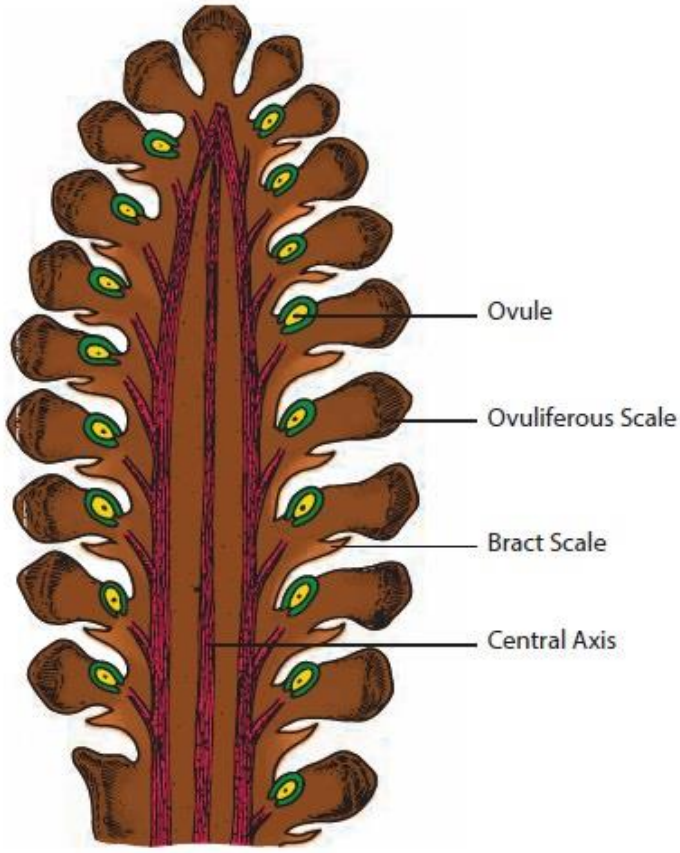


Figure 15.6: L.S. of Female cone of *Pinus*

Pollination

Pinus is either anemophilous or pollinates by wind. In the air, the pollen grains disperse and float. Simultaneously interfering nucellar beaks of the ovule generate a viscous, sweet liquid that contains fructose, sucrose, and glucose. This fluid emerges in the form of pollination droplets through the micropyle, depending on the time of day.

The pollen grains are collected inside the pollen chamber and are collected by the pollination drop as the fluid dries. Next, the micropyle mouth is sealed off from the outside world.

Fertilisation

The process of fertilisation starts after the year of pollination. Through the cells of the nucellus, the pollen tube moves toward the tip of the archegonium. The pollen tube wall is finally broken down by the enzymes the egg produces, allowing two male nuclei to emerge. One male nucleus fuses with an egg cell to generate a zygote.

A layer of cells known as the jacket layer surrounds the big cavity that holds the egg and provides support for the developing embryo. The archegonia develop and are ready for fertilization around a year after pollination.

The pollen tube tip ruptures the neck cells and releases its constituents into the cytoplasm of the egg when it comes into touch with an archegonium on the surface of the female gametophyte. The nucleus of one male cell approaches the nucleus of the egg and fertilizes it. The other male nucleus rapidly splits apart from the stalk and tube nuclei. The fertilized egg becomes an oospore by enclosing itself in a wall.

New *Pinus* Sporophyte

After reaching the oospore's base, the fusion nucleus divides four times, producing nuclei that are angled with respect to the long axis of the oospore. Two more divisions result in four tiers with four nuclei in each tier after that.

Exception of those on the top layer, all of the nuclei develop partition walls that divide them. The complete structure is known as the pro-embryo, and the three bottom layers are named the embryo, suspensor, and rosette tiers. The top levels are only used for feeding; the lowest tier, often known as the embryo tier, is where the embryos grow.

The placenta has dispersed food ingredients into the tissue of the female gametophyte, causing the suspensors to rapidly stretch and diverge, forcing the embryos deep into the tissue. At the tip of each suspensor is one of the four embryo cells.

Four potential embryos are formed by the fast division of each embryo cell. It should be highlighted that many possible embryos may be formed in addition to the possibility of fertilizing multiple oospheres. This is a highly distinctive feature of conifers and is known as polyembryony. Only one, nevertheless, reaches maturity; the others disappear while the others develop.

A completely developed embryo consists of a radicle, three or more cotyledons, a hypocotyl, and a little plumule. Normally, as the endosperm swells, the nucellus is crushed out, but on rare occasions, it survives as a thin layer and produces perisperm. The integument gradually converts into the seed coat, transforming the ovule into a seed.

15.9 Gnetum (Gnetales)

A gymnospermic plant is *Gnetum*. They resemble dicot plants in similar ways. 40 different species can be found worldwide. There are five species of *Gnetum* in India. *Gnetum* is home to a variety of woody and climber-type plants, shrubs, one or two three-type plants, and one species of plant that is parasitic. They can be found in humid, tropical regions of the globe. Tropical refers to those warm climates. It is found in the Western Ghats of India, close to the Andaman and Nicobar Islands, Tamil Nadu, Orissa, Assam, Andhra Pradesh, and Nilgiris (Figure 15.7).

Species of *Gnetum* which are found in India are-

- *Gnetum ula*
- *Gnetum contractum*
- *Gnetum gnemon*
- *Gnetum mentanum*
- *Gnetum latifalium*

These 5 species are found in India.

Figure 15.7**:** *Gnetum*

Two types of branches found in plants of *Gnetum.*

(1) Limited growth of branches (2) Unlimited growth of branches

Although the plants resemble dicot species, they are actually evolved species. Nodes and internodes are the divisions of plants; tiny petioles are also present.

Anatomy of stem:

There is a rough circular construction. Thick cuticle layer is the outermost layer. Which coated the epidermis solitary layer the top epidermis also has sunken stomata. Lower surface have sunken stomata, there is less transpiration. The epidermis contains the cortex layer. It has three sections:

(a) The 5-7 layer outer cortex is composed of chlorenchymatous cells. It has chlorophyll.

(b) Parenchymatous cells comprise the middle cortex. An excessive number of fiber cells were discovered in the middle cortex, which stores food.

(c) The ring-shaped, 2-3 layer inner cortex is composed of sclerenchymatous cells.

Xylems are found in vessels in *Gnetum.* There are other traces, which are composed of lignin. There is cellulose in the parenchyma of the xylem. Xylems are found in vessels in *Gnetum.* There are other traces, which are composed of lignin. There is cellulose in the parenchyma of the xylem.

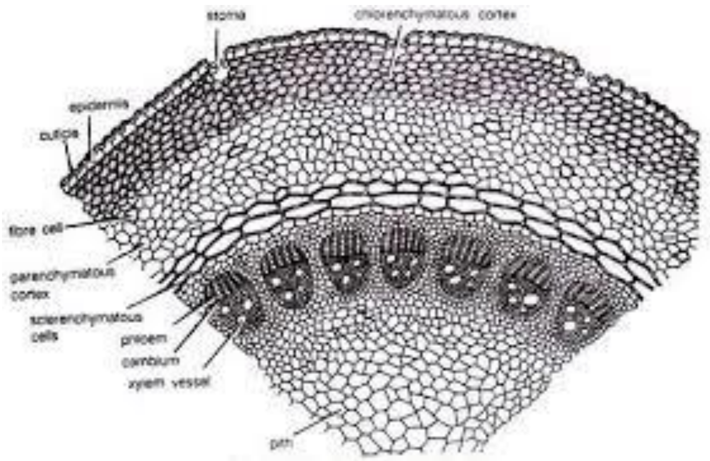


Figure 15.8: *Gnetum stem*

<u>Secondary growth in Stem</u>:

- The Cambium is separated into two sections: (a) Secondary xylem and (b) Secondary phloem.
- The Periderm is thin.
- The phloem's outermost layer is where the cambium forms. Eccentric refers to a side that is wide and woody on one side. There was a ring of sclerotic cells. There were uniseriate and multiseriate medullary rays. Medullary rays are comprised of carbohydrates.

Internal structure of roots:

- A single layer of epidermis with a thick layer of cuticle covering it.
- A cortex region identified, containing a high concentration of starch.
- Endodermis contains casparian strips.
- Six pericycle layers were found.
- Protoxylem and metaxylem are prominently visible.
- The upper and inner epidermis was identified.

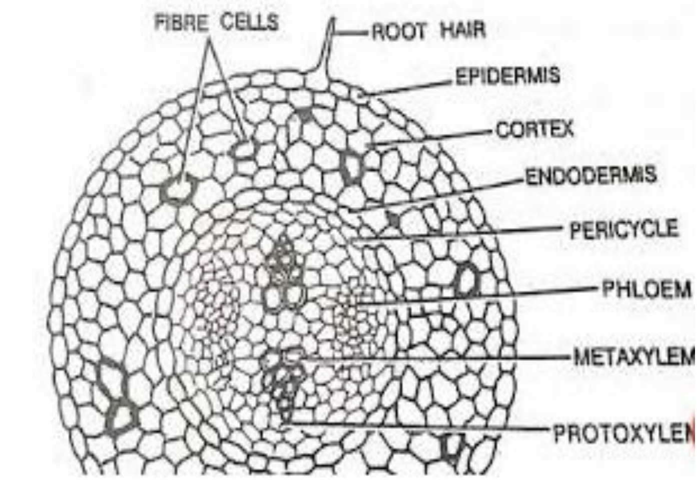


Figure 15.9: *Gnetum root*

Anatomy of leaf:

- Thick cuticle layers cover the upper and lower epidermis. The upper leaf structure contains xylem, whereas the lower leaf structure contains phloem.
- There is cambium in the center section.
- Sclerenchyma cells cover the xylem.

- The stomata are submerged.

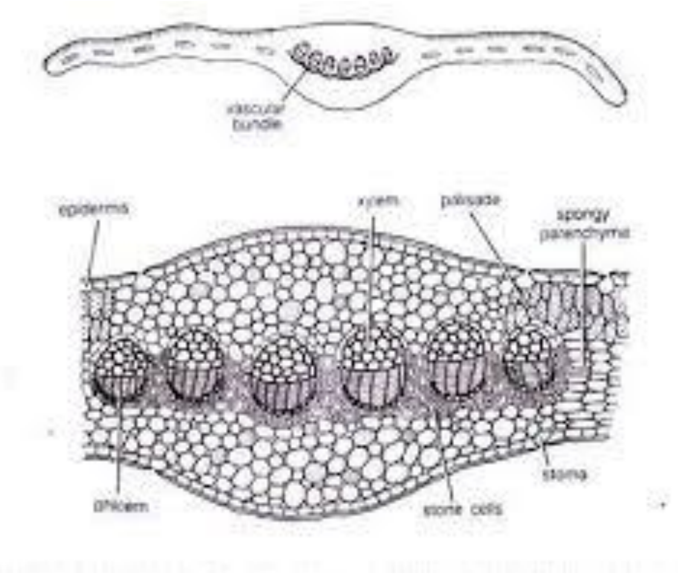


Figure 15.10: *Gnetum leaf*

Reproduction of Gnetum:

Even though *Gnetum* is a dioecious plant, there are also infrequent bisexual strobili. *Gnetum* has sexual reproduction. The strobili of the male and female *Gnetum* are complex, and the plant is dioecious. The inflorescence is made up of a series of cup-shaped bracts called cupules or collars that are arranged one above the other and connate bracts at the base. At an early stage, the strobilus becomes compact. A juvenile strobilus's collars seem to be continuous. The axis lengthens and the collars split apart as the animal reaches maturity.

Male strobilus:

The male strobilus is complex, with 10–25 whorls of bracts (collars) on its long, slender axis. Above each collar, about 12–25 male flowers are grouped in rings of three to six. Just above the male flowers is a single ring with seven to fifteen incomplete female flowers.

Figure 15.11: Male strobilus

Male flower:

A tiny sheathing perianth encloses the two unilocular anthers of a male flower. The term "antherophore" refers to its stalk, which grows longer as it ages. As a result, the anther appears through a slit in the perianth, outside of the collar. A male flower's anther count can also differ.

Female strobilus: In its juvenile stage, the female strobilus resembles the male strobilus in many ways.

The female strobilus is made up of an axis with multiple whorls of collars arranged one above the other, just like the male strobilus. Above each collar, a ring of four to ten female flowers is seen. In the female strobilus, the male flowers are absent (Figure 15.12).

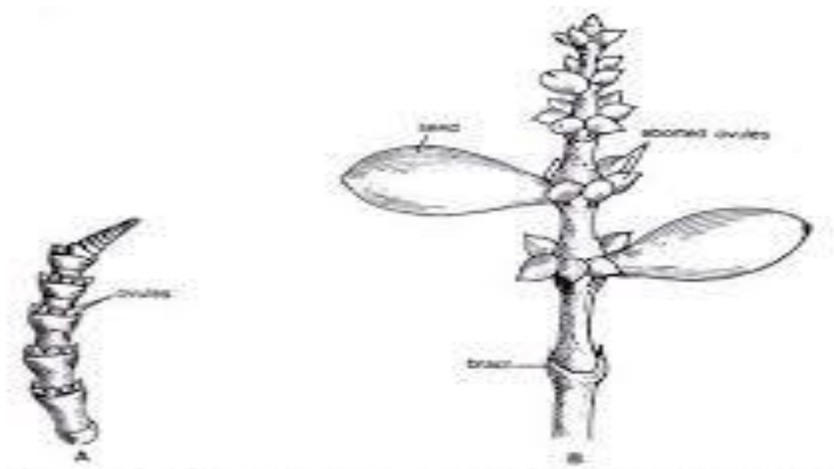


Figure 15.12*:* Female strobilus of Gnetum

Microsporangium:

Through repeated divisions, a multicellular archesporium is formed by two sets of hypodermal archesporial cells.The primary parietal and sporogenous cells are formed by the division of the outermost layer of the archesporial cells.Through periclinal division, the parietal layer gives rise to the wall layer on the outside and the tapetum on the interior.The tapetal cells often become binucleate (occasionally multinucleate) and become highly cytoplasmic. Nuclei may unite to form polyploidy. Following meiosis, the tapetalcells begin to deteriorate. The sporogenous cells proliferate and divide, with the last cell generation dividing into microspore mother cells (2n).

Megasporangium:

- Ovule is the name for the integumented megasporangium.
- In *G. ula*, the ovule is stalked, although it can also be sessile or subsessile.
- The ovules are crassinucellate, orthotropous, and enveloped in three layers of protection.
- At maturity, the outer envelope is thick and succulent. According to some, it is the perianth.
- The integuments are actually the inner and middle envelopes. The middle envelope, which resembles the outer envelope physically, is referred to as the outer integument. mother cells (2n).

Fertilization: The male and female nuclei are released into the egg cell. One grows larger than the others and advances in the direction of the egg nucleus. The other, non-functioning male nucleus degenerates and stays on the cytoplasmic periphery. The sheath of the male gamete remains outside and only its nucleus penetrates the egg.

Economic and ecological significance.

For a number of reasons, including Copal, gymnosperms are significant economically. *Agathis australis* is the source of this green gum, sometimes known as candle gum. Fibers Romantic hairs taken from Macrozamia leaf bases are used to make stuffing fibers. Ropes and fishing nets are made from high-tensile strength fibers found in gelatinumgnemon bark.

Industrial Origin

Gymnosperm plants have a variety of industrial uses, such as the following:

1. *Cycas* gum is used as a treatment for dangerous lesions, adjuvant, and snake bites.
2. The leather industry uses tannins from the bark of various trees, including *Sequoia, Pinus*, and *Araucaria*.
3. *Abies balsamea* is used to extract tannin, which is then utilized as a balm in organic products.
4. Fossil resin is seen in *Pinus succinifera*.
5. Pine wood is utilized for wagon floors, pillars, beams, doors, and other things.
6. Podiacarpus plywood.
7. *Pinus, Picea, Abies, Gnetum*, and other species' wood pulp is used to make papers like newsletters, stationery, and prints.

Ornamental Uses

Gymnosperms are used in the industry as:

1. A number of *Cycas* species are commonly grown as garden plants and for ornamental purposes. Gymnosperms also have decorative value.
2. The 'virgin' tree, ginkgo, is revered in Chinese and Japanese temples where it is grown as a beautiful plant.

Resins

It is plant exudate that is discharged through designated pathways. The majority of these come from tapping conifers. They are frequently employed in the manufacturing of paints, varnishes, lacquers, medicines, and paper products. They are soluble in organic solvents but insoluble in water.

Rosin

Pine oleoresin or turpentine distillation yields rosin, often known as colophony. The principal suppliers of Indian turpentine are *Pinus roxburghii, P. wallichianus, P. insularis, and P. merkusii*. Distilling them yields turpentine oil and rosin. The manufacturing of varnish, enamel, paper sizing, plasters, and ointments all require rosin. Excellent quality rosin is needed to make many different industrial items, including furniture, sealing wax, oilcloth, adhesives, insulators, disinfectants, insecticides, yellow laundry detergent, grease and oil, and plastics.

Food Sources

1. Gymnosperms are important to the economy since they are a great source of food and are frequently utilized to make staple foods that may be eaten.
2. This group of plants includes *cycas*, pinus, and ginkgo.
3. Gymnosperms are utilized to manufacture sago and are important suppliers of starch.
4. In many parts of America and the surrounding regions, the leaves of these species are dipped and consumed like green leafy vegetables.
5. A wide range of non-flowering plants are used to make wine and other food products.

Medical Sources

1. A wide range of pharmaceutical products, including those used to treat allergies and infectious diseases like colds, coughs, asthma, and respiratory congestion, commonly contain gymnosperms.
2. The coniferous tree *Taxus* is the source of the medication Taxol.
3. A range of hair care products, including shampoo, oil, lotion, and other items, are made from several varieties of *Cycas* plants, which are also used to treat a number of different illnesses.

Oil Sources

1. Gymnosperm seeds, including those of *C. revoluta, Macrozamia riedlei, Pinus cembra,* and *Cephalotaxus drupaceous,* are used to make edible oils.
2. To clean microscopic objects and lenses soiled with oil, use red cedar oil, which is extracted from the heart skin of *Juniperus virginiana*.
3. *Serum-Peruvians, Cupressus, Japonica*, *Cedrus deodara*, and Cryptomeria oils are used in perfumery.

Sources of Wood

1. Gymnosperm plants are important to the economy because they are a good source of lumber, which is often used to make furniture and other building supplies.
2. These species have long lifespans because of the softness of their wood.

3. The largest gymnosperm tree in the world that produces lumber is *Agathis australis*.

15.10 Summary

Plants with cones and naked seeds are called gymnosperms. There are both trees and shrubs in this group. 280 million years ago, a forest of ferns, horsetails, and mosses gave rise to the first seed-bearing plant.

1. Plants needed to produce seeds in order to reproduce sexually and not rely on outside resources like water supply. Furthermore, the seed that had formed was well-protected, allowing it to withstand adverse weather conditions.
2. Seed-bearing plants have the ability to establish their offspring at great distances from their parents.
3. The different seed distribution mechanisms—including people, wind, and animals—make this possible.
4. Conifers, which include cone-bearing trees like pine, yew, cedars, redwood, and spruce, make up the biggest group of gymnosperms.

15.11 Self Assessment Question

Choose the correct option:

(i) Girdling leaf traces are the characteristic of the stem of:

(a) *Gnetum* (b) *Ephedra* (c) *Cycas* (d) *Pinus*

(ii) Which of the following species of *Pinus* has trifoliar spur?

(a) *P.sylvestris* (b) *P. merkusii* (c) *P. gerardiana* (d) *P. wallichiana*

(iii) *Gnetum trinerve* is a:

(a) parasite (b) saprophyte (c) tree (d) shrub

(iv) All gymnosperms are without vessels except the members of …….

(a) Gnetales (b) Cycadales (c) Ginkgoales (d) Coniferales

(v) An anticancerus drug is obtained from …

(a) *Taxus* (b) *Thuja* (c) *Pinus* (d) *Cupressus*

(vi) Which of the following is not a true fossil?

(a) impression (b) compactation (c) amber (d) pseudofossil

(vii) In plant kingdom, the largest ovules occur in ....

(a) *Cycas* (b) *Pinus* (c) *Ephedra* (d) *Gnetum*

(viii) Inspite of several angiospermic features, *Gnetum* is a gymnosperm because :

(a) polyembryony is a common feature

(b) prothallial cell is present in the male gametophyte

(c) seed is naked

(d) stem exhibits anomalous secondary growth.

(ix) Endosperm in gymnosperm is:

(a) haploid (b) diploid (c) triploid (d) tetraploid

(x) Stalked ovules were seen in:

(a) Bennettitales (b) Cycadales (c) Cycadofilicales (d) Coniferales

Answers: (i) c (ii) c (iii) a (iv) a (v) a (vi) d (vii) a (viii) c (ix) a (x) a

GLOSSARY

Phycology:The study of algae.

Anisogamous-Differentiate gametes.

Aplanospore- Non-motile spore.

Aseptate- Septa absent.

Asexual-Sexual organ absent

Auxospore-After sexual reproduction in diatoms spore are produced

Carpospore- A spore formed from carpogonium in Rhodophyceae.

Carposporophyte- In red algae diploid generation found.

Cellulose- Form of carbohydrate .

Cell wall- Outer portion of cell.

Chlorophyll- The green colour pigment found in plants for photosynthesis

Chloroplast- A minute granule or plastid containing chlorophylls.

Coenobium-Definite number and shape colony of unicells

Cyanin- A blue color pigment.

Dendroid- Extremely branched.

Epiphyte- Plant which live on surface of another plants.

Fertilization- Fusion of male and female gamete.

Fission-Breakage of cells.

Flagella- More than one flagellum.

Heterocysts- Huge cells found in BGA.

Hyaline- Dull

Isogamous- Having similar gametes

Oogamy- The fusion of a motile male gamete with non motile female gamete or egg.

Palmella- stage of certain algae, the cells dividing within a jelly-like mass and producing motile gamete.

Perrenating bodie-s bodies that have sufficient reserves of nutrients to last in adverse circumstances.

Phycocyanin- Algae blue colour pigment

Phycoerythrin- red coloured pigment of red algae.

Plankton- organisms found in marine as well as freshwater,free floating plants.

Tetrasporangium-Ttetraspores found in sporangium

Tetraspore- Non motile spore that are found in tetrasporophyte of red algae.

Agar- A mucilaginous material obtained by red algae.

Algin- A mucilaginous material found in the middle lamella of cell wall of brown algae.

Algal bloom- a quick development of small algae that leaves a colored scum on the water's surface.

BGA- Blue Green Algae

Biofertilizer- Used as fertilizers.

Coral reef- A sea-level ridge of rock created by coral growth and deposits.

Coccoid- Spherical shape body

Cyanophage- Viruses infecting BGA

Fossil- Preserved remains of plants or animals

Fossilization- Process of fossil formation.

Fragmentation: Breaking in multicellular/colonial organisms is an example of an asexual reproductive process.

Endophytes: Endosymbiont that lives within a plant for at least some part of its life cycle.

Rhizoids: Branched root like structure

Bi-stipulate: Each node contain two stipulodes such species called bi-stipulate.

Dimorphic: Two forms found , e.g. leaves, male and female plants.

Dorsiventral: flattened with distinct upper and lower surfaces.

Endothecium: The inner embryonic tissue of a capsule in the majority of mosses, which gives birth to all tissues inside the outer spore sac. It also generates the columella in Sphagnum.

Epiphyllous: Which plant grows on the living leaves of another plant.

Epiphyte: a plant grow on another plant

Elater – elongate sterile cells, usually hygroscopic, admixed among spores of most hepatics and hornworts.

Embryo –First stage of a sporophyte.

Embryophyta –In which plant embyo found

Filamentous: thread-like structure

Foot: the basal part of bryophyte sporophyte, embedded in the gametophyte.

Habit: general morphology

Heteroicous: In which plants many forms of gamentagia found .

Hornwort: Class of Anthocerotopsida member called Hornwort

Apophysis -At the base of the capsule swollen Sterile tissue present where it joins the seta

Bryophyte--Green plant with a gametophyte generation that is free-living and a comparatively ephemeral sporophytel; a collective name for mosses, liverworts and hornworts, Non-vascular plant.

Endothecium: The inner embryonic tissue of a capsule in the majority of mosses, gives rise to all tissues inside the outer spore sac. It also generates the columella in Sphagnum.
Foliose: covered in leaves; leafy or leaflike.

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