FUNARIA

- This genus has **117** species with wide distribution throughout the world.
- **15** species occur in our country. The best known species is *F. hygrometrica*.
- This genus grows as dense green mats or patches in moist, shady soils, banks, rocks, burnt grounds and tree trunks.

Habit

- The dominant stage in the life cycle is gametophyte. It has two stages known as **protonema** and **gametophore**.
- **Protonema** is prostrate, branched filamentous and multicellular and develops from spore.
- **Gametophore** is the dominant stage in the life cycle. It is erect, leafy structure that reaches upto **3 cm** height.
- It has slender, cylindrical upright central axis known as **cauloid** on which the flat, green, lateral expansions **phylloids** are present.
- Cauloid and phylloids are structurally not similar to **stem** and **leaves** because these are without vascular tissues and gametophytic in origin. But these are analogous to stem and leaves.

External morphology of Gametophore

- It has stem, leaves and rhizoids.
- Growth is carried by a **single pyramidal apical cell** with **three** cutting faces present at the apex and branch.
- Stem or cauloid is upright, slender, green and branched. A single lateral branch arises extraaxillary manner below the leaf.
- Leaves are small, ovate, sessile, green, entire, acute, with a single midrib.
- leaves are arranged alternately in **3/8** (Octastichous) phyllotaxy.
- Rhizoids arise from the base of the stem.
- These are slender, multicellular, uniseriate, branched and consists of **oblique** septa.
- Rhizoids are colourless when young and become **red** or **brown** at maturity.
- They fix the plant to soil and absorb water and minerals from the soil.

Anatomy of Gametophore

1. Stem

- In T.S., the stem is differentiated into epidermis, cortex and central cylinder.
- **Epidermis** is single layered with thin walled smaller cells with chloroplasts in younger stages. At maturity it is thick walled and **without chloroplasts**. **Stomata** are absent.
- Cortex is multilayered and parenchymatous.
- In younger stems, it has **peripheral thin walled green** outer cortex and colourless inner cortex.
- In older stems the **outer cortex is colourless and thick walled**.
- Central cylinder forms the core of the stem.
- It has vertically elongated, thin walled, narrow and compactly arranged dead cells with non – lignified cells called as **hydroids**.
- Hydroids are useful for conduction of water and salts.
- In **Funaria**, water is conducted both externally and internally. Externally, the water is conducted through the capillary channels in between the axes of gametophores. Hence **Funaria** is called as **Myxohydric moss**.

Leaf

- In T.S., leaf is single celled in thickness in the wing region and multicellular in the midrib.
- Midrib has both upper epidermis and lower epidermis. A group of thin walled cells followed by a group of thick walled smaller cells with **narrow lumen**.
- The cells of the lamina and some outer cells of the midrib contain **chloroplasts**.
- Mesophyll and stomata are absent.

Reproduction

- Gametophyte reproduces vegetatively and sexually.

1. Vegetative reproduction

- It vegetatively reproduces by **secondary protonema**, **gemmae** and **tubers**.

i. Secondary protonema

- It is formed from the detached injured portions of leaf, stem and rhizoids of gametophore when surrounded by **moist air**.
- The buds of secondary protonema develop into leafy gametophores.

ii. Gemmae

- These are multicellular, small structures that develop from rhizoids, broken leaves or from stem tips.
- Upon detachment they develop into leafy gametophores.

iii. Tubers

- These are subterranean resting buds developed from rhizoids. These produce protonema. From these **protonema**, the leafy gametophores are developed.

2. Sexual Reproduction

- *Funaria* is monoecious, **autoicous, protandrous**.
- Sex organs are developed in groups at the apex of stem (Male branch) and branch (Female branch).
- The sex organs of male branch are called as **Antheridia** and that of female branch are **Archegonia**.
- The lateral female branch eventually grows taller than the male branch.

i) Antheridial branch or Antheridiophore or Male shoot

- It is the main axis of the gametophore. It has an expanded slightly convex tip.
- It has a group of antheridia intermingled with paraphyses and surrounded by outwardly spread perichaetial leaves (previously known as perigonial leaves). This arrangement resembles a flower
- Antheridia are of different developmental stages.
- **Paraphyses** are multicellular uniseriate green structures with terminal **subspherical cap** like cell.
- These take part in photosynthesis and protect the antheridia from dessication by holding a water drop above the antheridium.
- They also secrete mucilage that helps in reducing the water loss in the liberation of male gametes.
- Antheridia, paraphyses and perichaetial leaves together known as **Perichaetium**.

Antheridium

- It is the male sex organ of **Funaria**. It is club shaped and has a stalk and body.
- The stalk is short, slender, multicellular and biseriate.
- Body of the antheridium is multicellular and surrounded by a single layered jacket.
- 1 or 2 or more than 2 cells of the antheridial jacket of the distal end are larger and known as **cover cells** or **lid cells** or **opercular cells**.
- The cells present interior to jacket are called as **androgonial cells**. These cells divide and redivide and form **androcyte mother cells**.
- Each androcyte mother cell undergoes an oblique division and forms **2** androcytes.
- Each androcyte protoplast undergoes metamorphoses and forms **sickle** shaped biflagellate **male gamete** or **antherozoid**.
- Each antherozoid has a proximal **nuclear part** and distal **blepharoplast part**.
- At maturity the cover cells are ruptured and the male gametes are liberated enmasse.
- Male gametes are spread in the water and swim towards the archegonial branch.

ii) Archegonial branch or Archegoniophore

- It is the lateral branch on whose apex archegonia of different developmental stages are formed in clusters.
- This cluster is surrounded by pericheatial leaves that bent inwards to protect the archegonia.
- Multicellular, uniseriate, green photosynthetic structures known as paraphyses are present in between the **archegonia**. These provide protection, maintain moisture around the archegonia besides performing photosynthesis.

Archegonium

- It is the female sex organ of *Funaria*. It is flask shaped with a short stalk and broad body.
- Stalk is multicellular and multiseriate.
- Body has a basal swollen venter and a projected neck.
- Venter is surrounded by **double layered jacket**. Interior to it, it has a basal egg and above it a **venter canal cell** are **present**.
- Neck has a **single layered jacket**. Jacket has **6** vertical rows of cells.
- At the tip of the archegonium **4** cover cells arranged in diagonal pairs are present.
- Neck has **6** or more than **6** neck canal cells.
- At maturity both **VCC** and **NCC** degenerate, form mucilaginous substance rich in **Sucrose**. It is secreted out as droplet. It helps in attracting the male gametes. The terminal cells of the operculum are separated apart to leave a passage.

Fertilisation

- It takes place in the presence of water.
- The antherozoids move towards the **archegonium** in response to the sugars of archegonial secretion. This phenomenon is known as **Chemotaxy**.
- One of the male gametes that enter into the archegonial venter unites with the egg cell to form diploid zygote.

Sporophyte (Sporogonium)

- Zygote is the first cell of sporophytic generation.

- It divides in the archegonial venter and forms multicellular embryo. It develops into sporophyte or sporogonium.
- It is the diploid stage in the life cycle of Funaria and partial parasite on gametophore.
- It reproduces asexually by producing spores.
- Due to fertilisation stimulus, the jacket of archegonial venter divides and forms the protective structure known as **Calyptra**.
- During the growth of sporophyte, the calyptra is ruptured transversely and the upper part remains as a hood like structure over the **capsule**.
- **Calyptra** functions as a transpiring shield around the immature capsule.
- Developed sporophyte of *Funaria* is differentiated into Foot, Seta and Capsule.

i. Foot

- It is the basal sterile portion of sporophyte embedded in the female branch of gametophore.
- It is small, dagger shaped conical structure.
- It absorbs water and minerals from the gametophore and supplies them to the capsule through seta.

ii. Seta

- It is long, slender, tough, **reddish brown** stalk like structure present between the **foot** and **capsule**.
- It helps in projecting the capsule out of the archegonial **ventre** or **calyptra**.
- It conducts mineral water obtained from the foot to the capsule.
- It is hygroscopic, twists and curls during dry conditions and helps in scattering spores from the **capsule**.

iii. Capsule

- It is the highly organised structure of sporophyte.
- It is pear shaped and green at the beginning. It later becomes dark brown when the calyptra falls off.
- It is involved in the production and dispersal of spores.
- It has **3** regions known as **Apophysis, Theca** and **Operculum**.

a) Apophysis

- it is solid, swollen, basal, sterile, green photosynthetic region of capsule.
- It has single layered epidermis with stomata.
- Multilayered green photosynthetic tissue with prominent intercellular spaces known as **spongy parenchyma** is present below the epidermis. It forms the main photosynthetic region of capsule.
- A group of narrow elongated thin walled colourless cells that form the conducting strand is present at the centre of the apophysis.
- Conducting strand is continuous with the central strand of seta.

b) Theca

- It is **Urn-shaped** middle fertile region of the capsule. It forms the bulk of capsule.
- It is the spore forming region of the capsule.
- It has capsule wall with a single layered epidermis with few stomata which is continuous with the epidermis of apophysis; **2**-layered, compact, parenchymatous hypodermis with colourless cells; and **1** or **2** layered chlorenchymatous spongy parenchyma.
- Capsule wall surrounds a wide air space. It is traversed by multicellular, narrow, uniseriate, green, elongated filamentous strands known as **trabeculae**.
- **Trabeculae** connect the chlorenchymatous layer of wall with the spore sac.
- Spore sac has an outer spore sac with **3-4** celled thick, **2-4** celled thick spore sac proper with sporogenous cells and a single celled thick inner spore sac.
- Sporogenous cells divide and redivide mitotically and form spore mother cells. These mother cells divide meiotically and form haploid spores in tetrad.
- The **4** spores of a tetrad are separated from each other, rounded off and liberated individually.
- Spore sac surrounds the central cylindrical parenchymtous compact region known as **Columella**.

c) Operculum

- It is obliquely placed cap-like structure present on the **theca**. It is also known as **Lid**.
- It is separated from theca by two rings. The lower ring is **rim** or **diaphragm** and the upper one is known as **Annulus**.
- Rim consists of **2 – 3** layers of special radially elongated thick-walled cells.
- Annulus consists of **5 – 6** superimposed layers of cells. The upper cells are thick walled and small. The lower tier cells are thin walled and larger.
- Peristome with **32 teeth** arranged in **2 rings** is present in the operculum. Each ring has **16 triangular** teeth.
- The outer ring of teeth are larger, with thick **transverse bands** and **hygroscopic**. The inner teeth are small and without transverse bands.

- Both outer and inner rings of teeth are **articulated** at the edge of rim.
- Opening of spore sac is closed by these teeth.

Dehiscence of capsule

- At maturity the lower tier of cells of **annulus degenerate** and the operculum proper is removed in the form of **cap**. This exposes the peristome.
- The thin walled cells of **columella dry off**.
- The capsule is inverted due to downward twisting of seta.
- In dry weather, the outer peristomial teeth loose water, curl, bend backwards and promote the easy liberation of spores.
- The jerking movements of peristomial teeth also aid in the removal of operculum.
- The inner peristomial teeth do not exhibit **hygroscopic movements** but act as a further check over the spore sac.
- The mechanical jerk of the capsule caused by twisting and untwisting of seta also aid in the dispersal of spores.

Apospory

- Formation of green protonemal filaments from the diploid cells of sporophyte without the involvement of spores is called as apospory. From these protonemal filament buds, the leafy gametophores are formed.
- Gametophores are diploid.

Spore

- It is spherical with **12 – 20** μ in diameter.
- It has a wall with thick outer **exosporium** and thin **endosporium**.
- It has several **oil droplets** and **chloroplasts**.
- Spores are viable for **2 – 11** years.
- Spore germinates to form a leafy gametophore.

Germination of spore

- Spore absorbs water and **imbibes**. Its exospore is ruptured and the inner endospore comes out as a tube like structure at one or both ends.
- The germ tube elongates and foms protonema.
- Protonemal filaments on the substratum have transverse walls. These are known as **chloronemal branches**.
- Some colourless branches that grow towards the soil have oblique cross walls and known as rhizoidal branches. These become green upon exposure to light.
- After certain extent of development, buds are differentiated on the protonemal branches and later they develop into leafy gametophores.
- Differentiation of buds on the protonema is promoted by a type of cytokinin known as **Bryokenin**.
- Since several adventitious buds are developed on each protonema, gametophores grow and develop in tufts.
- As the protonema dies, the gametophore becomes independent.

Life cycle

- It is **haplontic** and diplontic life cycle. Both gametophyte and sporophyte are morphologically different. Hence the alternation of generations is heteromorphy.