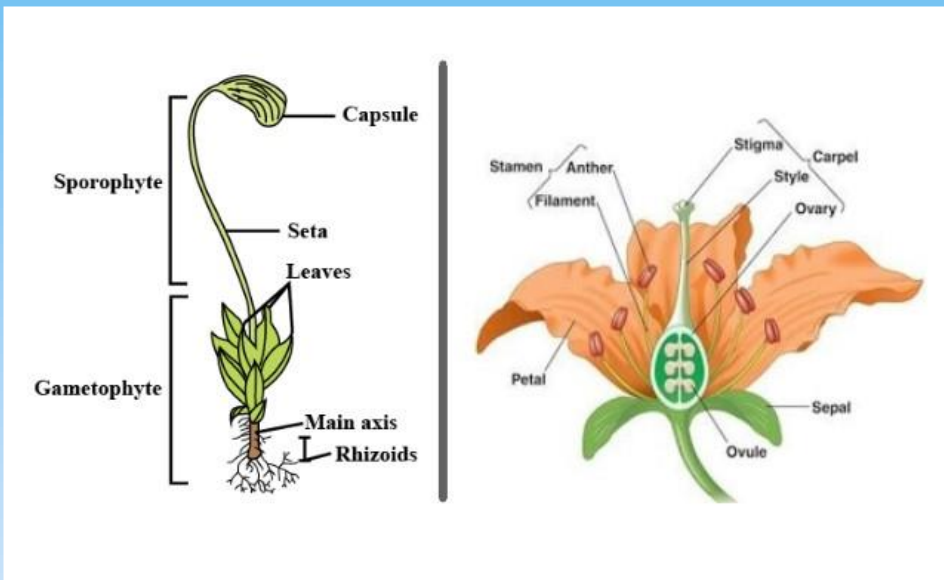
course

Botany 6

Third year students of the Faculty of Education



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Archegoniate

The name of this group has been derived from the name of this organ (**archegonium**). It comprises three divisions: Bryophyta, Pteridophyta & Gymnospermae (within Spermatophyta).

General Characters of Group Archegoniate

It characterized by the following:

1- It includes both Living and fossil plants

2- The presence of a female (♀) sexual organ known as archegonium that found almost in all group members (except few Gymnosperms).

3- The presence of a male (♂) sexual organ called antheridium.

4- The members of these group–under normal conditions– have a regular alternation of heteromorphic generations throughout their life cycles in which gametophytic generation (carries archegonium and / or antheridium) alternates with sporophytic generation that produces spores.

Archegonium:

It is a flask – shaped that consists of two main parts: (1) a basic swollen fertile part known as **venter** that includes two unequal cells ; the larger fertile cell (egg) and a smaller elongated sterile cell (venter canal cell). (2) an upper elongated slender part known as **neck** that usually contains a row of cells (4-6) known as neck canal cells .The whole structure is protected by a sterile wall formed of one or more layers of cells which extend to cover the neck and venter. This archegonium may be stalked or sessile and its tip is usually covered by four special cells known as **cover cells.**

Antheridium:

It is a stalked club– shaped structure consists of spermatogenous tissue that develops into several cubic sperm–mother cells .These cells produce slightly twisted sperms that may be bi-flagellated or multi-flagellated. After being release from the antheridium, they swim in water and are attracted to the opened channel of archegonial neck (this phenomenon known as **chemotaxis**) for fertilization of the egg cell.

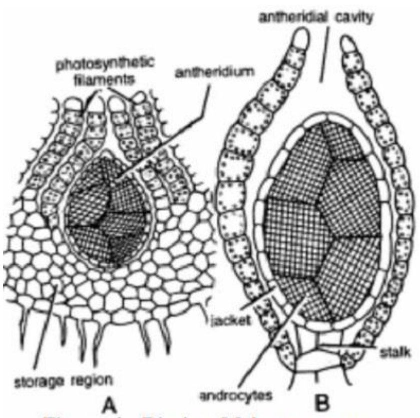


Fig. Riccia - Male sex organs.
A, Vertical section of the thallus showing position of antheridium B, An antheridium

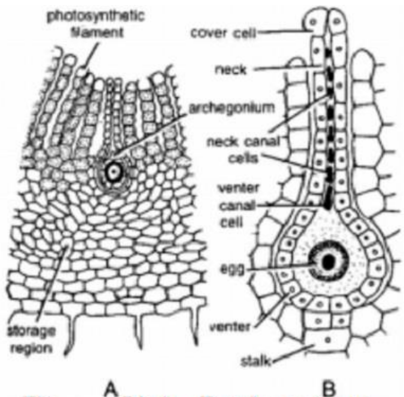


Fig. Riccia - Female sex organs.
A, Vertical section of the thallus showing position of archegonium B, An archegonium

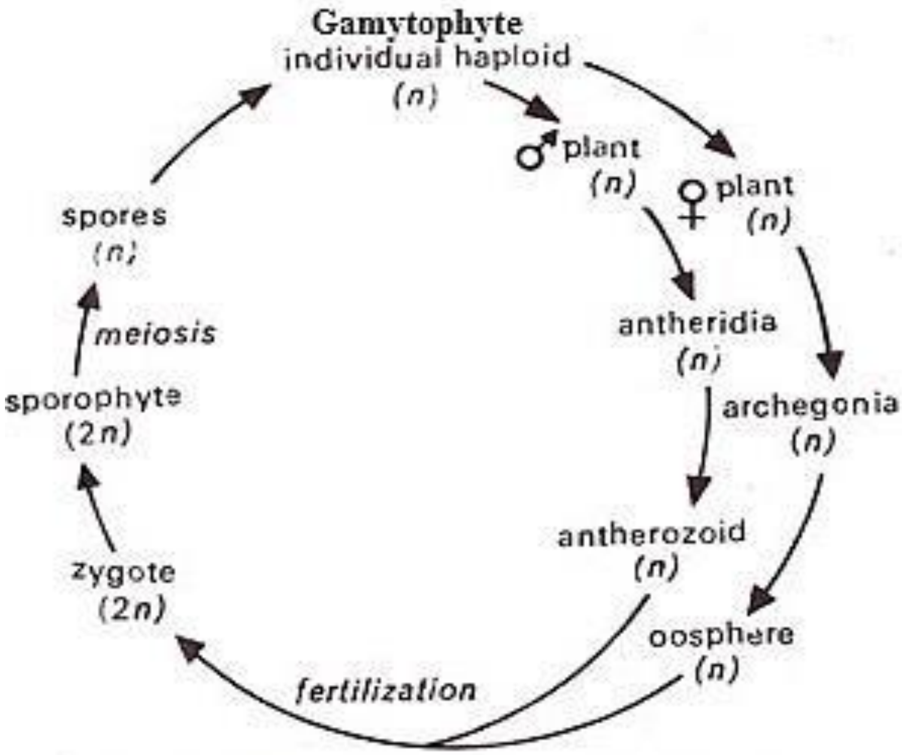
Life cycle and alternation of generations:

There is a regular alternation between the gamete–producing generation or gametophyte and the sporophytic generation or sporophyte. The male gametes or **antherozoids** swim in water searching for female gametes or egg cells where they are non-motile and borne singly in the venter of the archegonium.

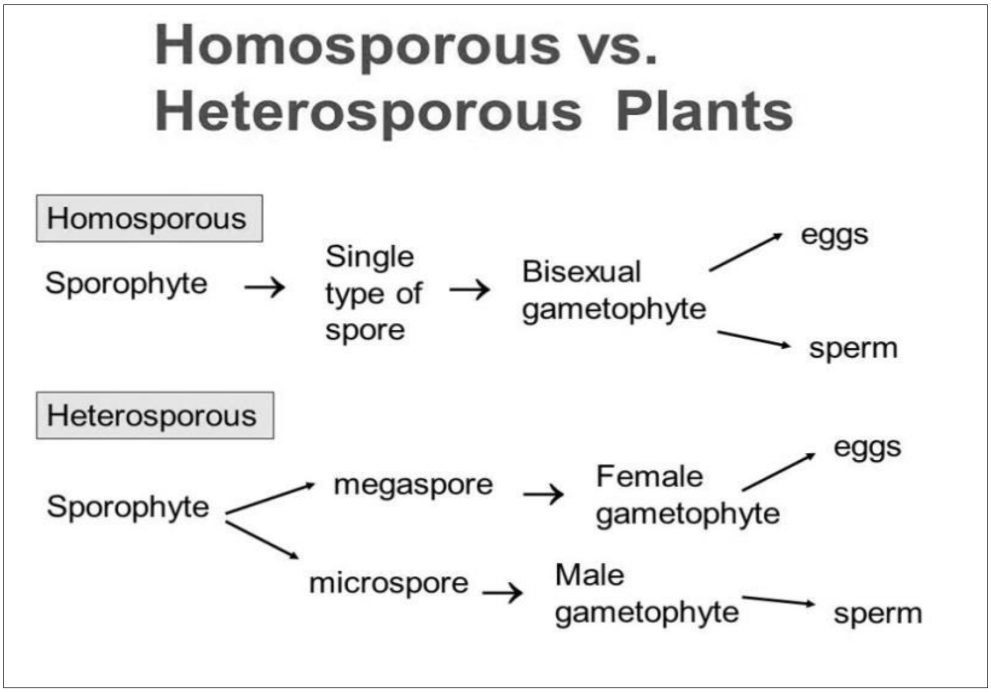
At maturity of archegonium and shortly before fertilization, the neck-canal cells and venter canal cells degenerate usually from top to downwards forming a mucilaginous mass which imbibes water and swells causing separation of cover cells from one another by breaking the middle lamella of these cells. Thus narrow passage (the neck canal) is formed from the apex of the archegonium to the egg. The fusion between the two gametes results in the formation of a **zygote** (2n) where its nucleus contains double the number of chromosomes present in the nucleus of both antherozoid and egg. The zygote develops directly by mitotic divisions into the sporophyte which is also diploid (2n). Finally, and after meiosis, a number of non - motile spores are produced from the sporophyte. The spores germinate to give rise to haploid gametophytes. These spores may be of similar or different sizes. In the first case the plant is known as "**homosporous**" and "**heterosporous**" in the second one. In Heterosporous type the larger spore (**megaspore** or **macrospore**) gives rise to female gametophyte and the smaller one (**microspore**) gives rise to male gametophyte. One can mentioned that there are two patterns as follows:

1) **Homosporous** (all Bryophyta and a part of Pteridophyta) and

2 **Heterosporous** (a part of Pteridophytes and all Gymnospermae)



Life cycle and alternation of generations



It is worthy to mention that usually one of the two generations is dominating the other as follows:

1-In members of division Bryophyta, the gametophyte is dominant while the sporophyte is dependent upon the gametophyte through its life.

2-In members of division Pteridophyta, the mature sporophyte and the gametphyte are two independent plants. The young sporophyte (zygote) depends on the gametophytic generation and the dominant generations.

3-In members of subdivision Gymnosperms, gametophyte is very much reduced and depends upon the sporophyte.

A comparison between the three divisions of Archegoniate group is summarized in the following table:

Features	Bryophyta	Pteridophyta	Gymnosperms
Dominnant phase	Gametophyte	Sporophyte	Sporophyte
Ploidy of main plant body	Haploid	Diploid	Diploid
Differentiation of body	Thallus and rhizoids	Roots, stem and leaves	Roots , stem and leaves
Vascular bundles	Absent	Present	Present
Nature of spores	Homospores	Homospores or heterospores	Heterospores
Seed and its coverings	Seed absent	Seed absent	Seed naked without covering
Flower	Absent	Absent	Absent

Division: Bryophyta

The term “Bryophyta “ is a Greek word (Bryon) = moss , phyton = plant, represents a group of plants including liverwort and mosses This group of plants varies in sizes ranging from inconspicuous to seldom exceeding 70 cm in length e.g. *Dawsonia*.

The bryophytes include three groups of green plants, mosses, liverworts and hornworts. These plants are generally small, do not produce flowers, and lack a vascular system and roots. As with all land plants, bryophytes possess a regular alternation between two morphologically distinct generations, the haploid gametophyte (n) and the diploid sporophyte (2n). However, in bryophytes, the gametophyte, rather than the sporophyte, is the larger, long lived generation. Bryophytes inhabit many ecosystems from tundra to tropical regions and are mainly found in moist, shaded environments (on rotten trunks, on rocks, forming carpets over soil, or as epiphytes), but also inhabit deserts, live under water, and a few even grow under saline conditions. This group is one of the largest groups of land plants in the contemporary flora. It comprises some 18000 species as species as estimated by Schofield (1985), a figure exceeded only by the angiosperms, and of these around 10000 are mosses. It is also an ancient group, the fossil record for mosses dating bake at least to the Carboniferous and for hepatics to the Devonian.

The main characters:

1- Bryophytes are similar with seed – plants, Pteridophytes and green algae, in processing chloroplasts that carry a mixture of chlorophylls and carotenoid pigments closely similar that found in the other green land plants and in the green algae, but differ from those found in other groups of photosynthetic organisms.
2- Bryophytes share with a few green algae, the Pteridophytes and primitive gymnosperms, in the spiral form of the motile spermatozoids, that possess anteriorly located flagella (whether 2,as in bryophytes, *selaginella*, *Lycopodium* and *chara*, or 25,000 as in cycads) and posteriorly placed nuclei.
3- Bryophytes also resemble land plants and green algae in their metabolism, such as their food reserves, which consists mainly of starches built of amylose and amylopection units.
4- The cell wall of bryophytes comprises a structural framework of cellulose micro-fibrils embedded in a matrix of polygalacturonic acid residues and hemi-cellules, Lack true Lignins.
5- Bryophytes are usually attached to their substratum by means of rhizoids. They have no cuticle and turn they can absorb water and nutrients over most of their surfaces.
6- Conducting system, except in a few of the most highly organized mosses, is simple in structure and relatively inefficient.

7- Bryophytes are poikilohydric plants, i.e. their tissues have a variable water content which is always near equilibrium with the surrounding atmosphere.

8- Most bryophytes are autotrophic but a few are more or less saprophytic and grow upon organic matter especially rotten wood, e.g. the moss *Buxbaumia aphylla* and the liverwort *Cryptothallus mirabilis*, in coniferous woods under *Hylocomium* in swampy forests with covering Sphagnum, in dry soil in forest. The latter is only the bryophyte that completely devoid of chlorophyll and it lives as the expense of its mycorrhizal fungus.

9- Though the part played by bryophytes in the worlds' vegetation is relatively minor, their importance in modifying their environment and affecting the life of other organisms should not be forgotten, even it is usually inconspicuous and difficult to account.

10- Although all bryophytes are morphologically distinct from the thallophytes, they are difficult to separate them from the algae. Perhaps the greatest differences between algae and bryophytes are the general structure of the plant body and gametangia.

- **Other differences are listed in the following table:**

THALOPHYTES	BRYOPHYTES
-Mostly aquatic.	-Mostly terrestrial.
-A few of the most advanced have sieve- like elements.	-Some mosses have cells suggesting sieve cells otherwise food conducted in relatively undifferentiated cells.
-None have water- conducting elements.	-Simple water – conducting cells.
-In general, no specialized water & nutrient absorbing tissue, rhizoids & haustoria may occur in some fungi.	-Rhizoid anchor and absorb water & minarets.
-Mostly filamentous or intertwining filaments parenchymatous in a few.	-Only one stage of mosses is filamentous (protonema) all other are formed of parenchyma.
-Both sporphytes& gametophytes are independent.	-Gametophyte is independent , sporophyte is dependent,
-Sporophyte is frequently large and complex.	- Sporophyte is small & relatively simple.
-Gametangia are either single or groups of single cell not accompanied by a jacket of sterile vegetative cells.	-Gametangia always composed of the gamete- producing cells protected by a jacket of sterile vegetative cells.

Taxonomy and phylogeny

Eichler (1883) divided bryophyte into two classes, The Hepaticae and the Musci, and **Engler** (1892) divided each class into three orders,

Class I: **Hepaticae**

Marchantiales   Jungermanniales   Anthocerotales

Class II: **Musci**

Sphagnales   Andeaeales   Bryales

In 1965, the international code for botanical nomenclature suggested that bryophytes include three classes: Hepaticopsida, Anthoceropsida and Bryopsida. Bryophyte have divided, on the basis of the gametophores number of rows of leaves, growth habit of the gametophores (erect-, or prostrate), longevity of the gametophores (annual, biennial or perennial), and position as well as structure of sporophyte and capsule especially the peristome into two divisions structure of sporophyte and capsule especially the peristome into two divisions:

Division1: Bryophyta

Class 1	Class 2	Class 3
Sphagnopsida	**Andreaeopsida**	**Mnionopsida**
(Peat mosses)	(Granite mosses)	(True mosses)

Order	Order	Order	Order	Order
Sphagnales	Andreaeales	Funariales	Eubryales	Polytrichales
Spagnaceae	Andreaeaceae	Funariaceae	Mniaceae	polytrlchaceae
Sphagnum	***Andreaea***	***Funaria***	***Mnium***	***Polytrichum***

Division 2: Hepatophyta

Class 1	Class 2
Anthocerotopsida	Hepatopsida

Order	Order	Order	Order
Anthocerotales	Jungermanniales	Sphaerocarpales	Marchantiales
Anthocerotaceae		Sphaerocarpaceas	Ricciaceae
Anthoceros		***Sphaerocarpos***	***Riccia***
		Riellaceae	Marchantiaceae
		Riella	***Marchantia***

In many cases the gametophyte is a thallus, .e. a plant body without differentiation into root, stem and leaf. In those cases where it is externally differentiated into stem and leaves there are never any roots, only rhizoids. Internally bryophytic plants lack xylem and phloem tissues.

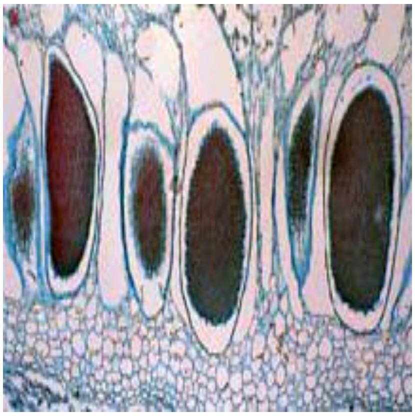
Classification

Bryophyte is subdivided into two main classes according to the habit of the gametophyte whether prostrate or erect. These two main classes are Hepaticae and Musci. In Hepaticae: The gametophyte is thalloid or leafy with dorsiventral stems. The spore germinates directly into a gametophyte.

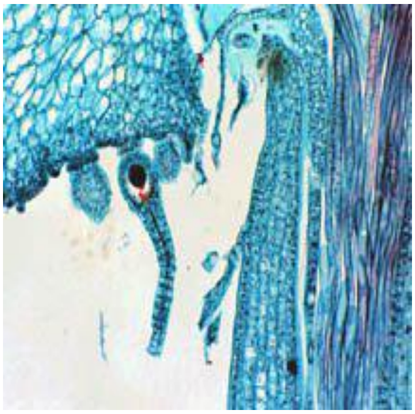
In Musci: The gametophyte has an erect stem with spirally arranged leaves. The spore germinates to give first a protonema and this produces erect leafy gametophytes.

Class: Hepaticae (liverworts)

The external morphology of liverworts is quite different from that of mosses. Instead of a small, "leafy" plant body, many liverworts have an undifferentiated body known as a thallus. As in the mosses, it is anchored to the substrate by small, root-like appendages termed rhizoids. The general morphology of liverworts is illustrated below:



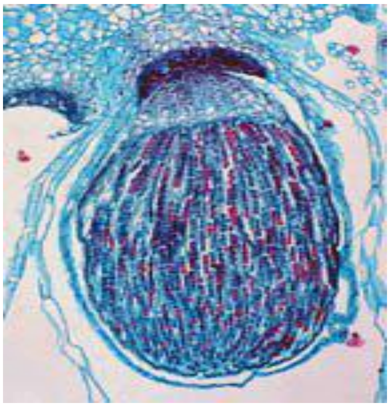
Liverwort antheridia are elongate, sausage-shaped structures that produce large numbers of flagellated sperm cells.



Liverwort archegonia are small, flask-like structures borne on the lower surface of the archegoniophores; each contains a single haploid egg cell.

The liverwort thallus represents the haploid, gamete-producing (gametophyte) phase of the life cycle. The multicellular sex organs, known as antheridia and archegonia, are often produced on erect, umbrella-like structures termed antheridiophores and archegoniophores, with the different sexes occurring on separate plants. The structure of the antheridia, or sperm-producing structures, and archegonia, or egg-producing structures, can be seen by examining longitudinal sections through the antheridiophores and archegoniophores:

Once they have been released from the antheridia, the flagellated sperm cells swim through a thin film of water covering the moss to an archegonium, where fertilization occurs. The fertilized egg, or zygote, then develops into the sporophyte, or spore-producing, generation of the life cycle. In mosses, the sporophyte is usually an elongate, brownish-colored structure that consists of a foot, stalk, and capsule. The capsule contains a sporangium, or spore-producing structure, where meiosis occurs and haploid spores are produced. When these spores are released from the sporangium they germinate and develop into new gametophytes. A typical liverwort sporophyte is illustrated below:



The liverwort sporophyte consists of small foot and stalk regions and a large capsule.

Fossil Hepatics:

The oldest known fossil liverwort is *Hepaticites devonicus*. It is of Upper Devonian age. It is considered to be a member of the Jungermanniales, however, definite conclusions are not to be made until reproductive organs are found. A small number of fossil hepatics are discovered. The reproductive organs of them were not found.

Habit and General Characters:

Hepaticae include some 8800 species. Most hepatics live in shady terrestrial habitats where the substratum is moist. A few hepatics are aquatic either floating or sub-merged.

Gametophytes are dorsoventrally differentiated and are either thalloid or with leafy stems. Leaves usually lack a midrib. The interior part of a gametophyte may be homogenous or composed of various tissues.

Family: Ricciaceae

Genus: *Riccia*

The genus *Riccia* includes more than 130 species. *Riccia* can be found on the Nile bank in winter. The gametophyte is rosette – like in shape because of several dichotomous branching close to one another. Each branch of the thallus has a median longitudinal furrow on the dorsal side. On the ventral surface of each branch and near its growing apex there is a transverse row of scales which are one cell in thickness. The thallus is attached to the underlying substratum by unicellular rhizoids together with the multicellular scales.

Internal structure of the thallus. A vertical section shows that the lower portion of the thallus is a colorless parenchymatous tissue the cells of which is devoid of chloroplasts and bears long tubular rhizoids and multicellular scales. Above this storage tissue there is one layer of air chambers in the air form of vertical canals. The cells of the walls of the air chambers contain many chloroplasts and are known as the assimilating filaments. Above the air chambers there is the upper epidermis. It is a layer one cell in thickness the cells are devoid of chloroplasts. The air pores, which allow an interchange of gases between the plant tissues and the atmosphere, are simple intercellular spaces. Each pore or intercellular space is bounded by 4 to 6 epidermal cells.

Vegetative reproduction:

When death of older parts a thallus reaches a point of dichotomy two branches become separated and each of the two branches becomes separated and each of the two surviving branches grows into a separate plant. Several species of *Riccia* produce adventitious branches from the ventral surface of the gametophyte. When these branches become separated they grow to give new gametophytes.

Sexual reproduction:

Most species of *Riccia* are homothallic or monoecious, i.e.; they bear both antheridia and archegonia on the same plant. A few species are heterothallic or dioecious, i.e., there is a female gametophyte bearing only archegonia and a male gametophyte bearing only antheridia. Sex organs (antheridia & archegonia) are Located in the median longitudinal formed from superficial cells on the dorsal side of the thallus. The superficial dorsal cell from which an antheridium is formed is called the antheridial initial. This cell divides many times in different plants to form the antheridium. The vegetative tissue round the antheridium grows upwards forming the antheridial chamber. The antheridium at maturity is composed of a stalk and a sterile wall one cell in thickness enclosing the antherzoids.

The archegonium as well develops from a superficial dorsal cell known as the archegonial initial. This cell divides repeatedly planes to form the archegonium, which is composed of a stalk, a sterile wall one cell in thickness, an egg, a ventral canal, a row of neck – canal cells, and the cover cells.

Antherozoids are biflagellate. They swim into an archegonium neck down the canal to the egg and of them penetrates the egg a diploid zygote is formed. The zygote develops a wall and increases in volume until it fills the venter. The developing zygote gives the sporephytic generation. The entire sporophyte of *Riccia* is a capsule (no foot or seta) which is known as the sporogonium, the sporogenous tissue differentiates into spore mother cells. A spore mother cell by two successive divisions, the first of which being reduction division (meiosis) gives a tetrad of haploid spores. The spores become liberated after the death and decay of the gametophytic tissues which usually takes about one year after spore formation spores germinate giving new haploid gametophytes.

Family: Marchantiaceae

Marchantia

The gametophyte is a prostrate thallus with conspicuous dichotomous branching and the thallus is light green in color.

Internal structure.

Air chambers are found just beneath the upper epidermis. Simple and branched photosynthetic filaments arise from the floor of these chambers. All chambers have well defined air pores. Every air pore is surrounded by several cells which form a barrel-like structure. The outlines of the air chambers as well as the pores can be seen on the dorsel side of the thallus with the naked eye or by the use of a simple lens. Below the chambers there is a parenchymetcus tissue several layers in thickness except near the lateral margins. Some cells contain. The ventral surface bears smooth-walled and tuberculate rhizoids between the scales.

Vegetative reproduction:

1- When death of the thallus reaches a dichotomy, the separated branches grow to give new gametophytes.

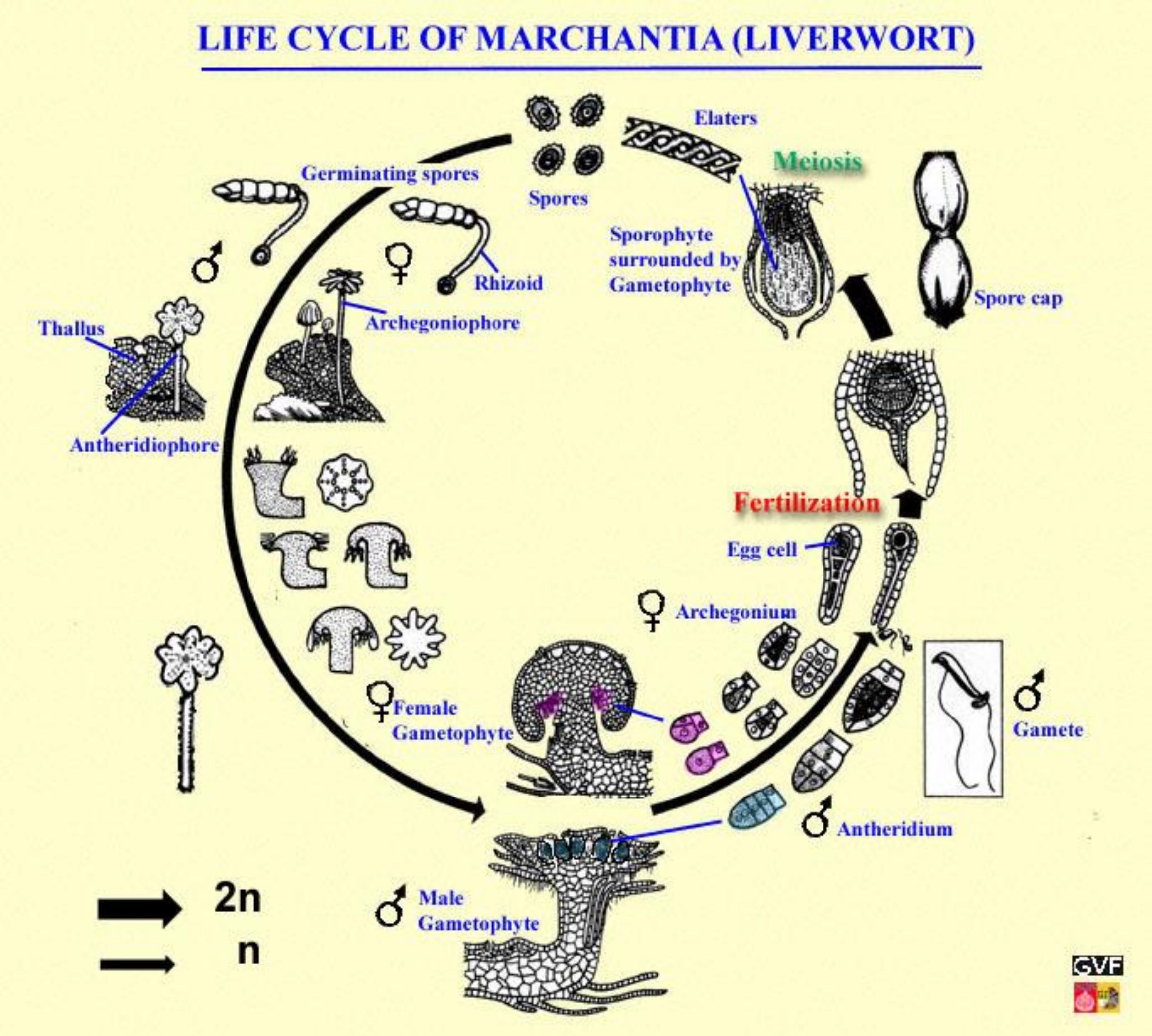
2- By **Gemmae**. Gemmae are asexual reproductive bodies. They are produced in crescent-shaped cupules on the dorsal surface of the gametophyte, close to the midrib. Each gemma is developed from single superficial cell on the floor of the cupule. A mature gemma is attached to the floor of the cupule by a stalk which is formed of one cell. The gemma is shaped like a disc. It is several cells in thickness in its center. It has either lateral margin. Most of the cells contain chloroplasts. Some both surfaces of the gemma are colorless. There are also isolated cells which contain oil bodes instead of chloroplasts. Intermingled with the gemmae are (club–shaped mucilage calls) growing up from the floor of the cupule. The mucilage comes out from the cells and imbibes water and swells thus causing the separation of the gemma settling on soil develop rhizoids from the colorless cells on the face in touch with the soil. The two growing points start growth. Each gives a dichotomously branched gametophyte. The two formed gematophytes grow in two opposite directions.

Sexual reproduction

Archegonia are borne on archegoinophores (or carpocephala) special stalked erect branches. They are modified prostrate branches. Their internal structure is like that of the thallus. An archegoniophore begins development by an upward bending of an ordinary vegetative prostrate branch. Thus in *Marchantia* the archegoniophore is a terminal structure. The apex of a young archegchore is a disc with eight lobes. Archegonia are formed in acropetal succession on the dorsal side of each lobe. The portion of lobe in which archegonia develop is a receptacle. Hence the number of receptacles on a disc is the same as the number of lobes. The stalk of the archegniophore is very short. After fertilization it, becomes very much elongated and at the same time the central area of the disc swells up and this swelling inverts the marginal portion of the disc so that the archegonia lie with their necks pointing downwards. The oldest archegonia are now the nearest to the periphery of the disc the youngest are the nearest to the stalk. Each group of archegonia becomes surrounded by a two parted curtain – like involucre. Nine stout cylindrical rays develop from the margin of the disc alternating with the eight lobes.

Antheridia are also formed in acropetalous succession. They are borne on special branches or antheridiophores. Fertilization stimulates division of the cells of the wall of the venter of the archegonium and this tissue develops into a calyptra two or more cells in thickness. Fertilization also stimulates division of cells immediately below the archegonium and these results in the formation of the pseudoperianth which is one cell in thickness. Thus there are 3 protecting sheaths around a sporophyte, the calyptra, the pseudoperianth and the involucre. The sporophyte differentiates into a foot, seta and a capsule. The foot serves for fixation and absorption. Chloroplasts are present in the cells of the foot, the seta and the capsule; this shows that the sporophyte is not wholly dependent upon the gametophyte, for the products of photosynthesis. The capsule wall or jacket is one cell in thickness. At maturity the seta elongates and pushes the capsule outside the calyptra, the pseudoperianth and the involucre. The Jacket splits longitudinally from the apex to about its middle into an indefinite number of segments. Sporogenous tissues give sporocytes and elaters with spiral thickening on their walls.

Liberation of spores after dehiscence is assisted by coiling and uncoiling of elaters as a result of hygroscopic changes in their walls. Spores give gametophytes.



Order: JUNGERMANNIALES

This order includes three forms: Thalloid, transitional (or transformed) and leafy forms. According to the position of the archegonium on the thallus, this order divided into two main groups: Acrogynae (with apical archegonium) and Anacrogynae (with lateral archegonium).

General characters of the order

1- Gametophytes may be thallose or foliose, but there is little internal differentiation of tissues. Some genera are intermediate between thallose and foliose.

2- Archegonial neck is nearly as broad as the venter.

3-The Jacket layer of the capsule of the sporophyte is more than one cell in thickness: The capsule usually dehisces longitudinally into four parts.

4- Foot, seta, and capsule are always present.

5- The sporogenous tissue usually differentiates into elaters and spore-mother cells. An elaterophore may be present or lacking.

<u>Comparisons between these groups were made as follows:</u>

Anacrogynae Jungermanniales	Acrogynae Jungermanniales
1- Gametophyte thalloid if leafy it carries only two lateral rows of leaves.	Gametophyte is leafy form with stems carry three rows of leaves
2- The apical cell of the stem does not produce archegonium	The apical cell of the stem or the branch terminates its growth by giving an archegonium.
3- Indefinite growth e.g. ***Pellia, Metzgeria, Blasia***	Definite growth e.g. ***plagiochila, lejeunea, Frullania*.**

Suborder 1: Anacrogynae

This group includes thalloid, transitional, and leafy forms. Examples belonging here are *Pellia*, *Metzgeria*, *Blasia*, and *Fossombronia*. *Pellia* gametophyte is thalloid with a wavy margin. There is a broad midrib which is not well defined; it extends laterally forming a blade one cell in thickness. *Metzgeria* gametophyte is dichotomously branched; it has a narrow, well defined midrib, some species have no midrib. *Blasia* gametophyte is transitional between thalloid forms and leafy forms. There is a distinct midrib and since they are not completely separated. *Fossombronia* gametophyte is very similar to the leafy forms of the second group “Acrogynae”. The midrib forms a stem and each lateral wing becomes divided into leaf- like portions. Anacrogynae Jungermanniales include both thalloid and transitional forms four examples to this group. Comparison between these plants was made as follows:

Pellia	***Metzgeria***	***Blasia***	***Fossombronia***
Thalloid form	Traditional form	Little advanced transitional	Very close to the leafy forms
Gametophyte is a thin green thallus with wavy outline	Gametophyte is flattened dorsoventrally dichotomously branched	Sides have lobed wings (not detached from the rest of the thallus)	Each wing is dissected completely into separate leaf-like.
Undefined broad midrib	Narrow distinct midrib	Distinct midrib	Midrib formed the stem.

Suborder 2: Acrogynae

All members of this group are foliose. The stem bears three rows of leaves; two dorsal or lateral rows and a single ventral row. The ventral leaves are usually small in size and are termed amphigastria. In some genera the ventral leaves are minute or even completely absent. In many genera the dorsal leaves consist of two lobes; a large upper lobe and smaller lower lobe (e.g. *Frullania sp*.).

Plagiochila gametophyte has a stem and two rows of lateral leaves. Leaves have tiny teeth around their edges. Under leaves are either very small or entirely absent. Some species of *Jungermannia* and *Lejeunea* have only two rows of dorsal leaves. Rhizoids are found on the ventral surface of the stem. In certain species of *Jungermannia* the dorsal leaves are bi-lobed. The gametophyte of certain species of *Lejeunea* has amphigastria and lateral leaves. Every lateral leaf consists of two lobes; an upper large lobe and a lower smaller lope in the form of an auricle. Water is held between the two lobes of the dorsal leaf. In *Frullania* the lower lobe of the dorsal leaves forms a water- sac. The water held in the auricle of *Lejeunia* and in the sac of *Frullania* is used by the plant in different vitai processes. In this water spermatozoids may swim until they reach the archegonium. Of all these examples only *Pellia* will be described in some detail.

Pellia

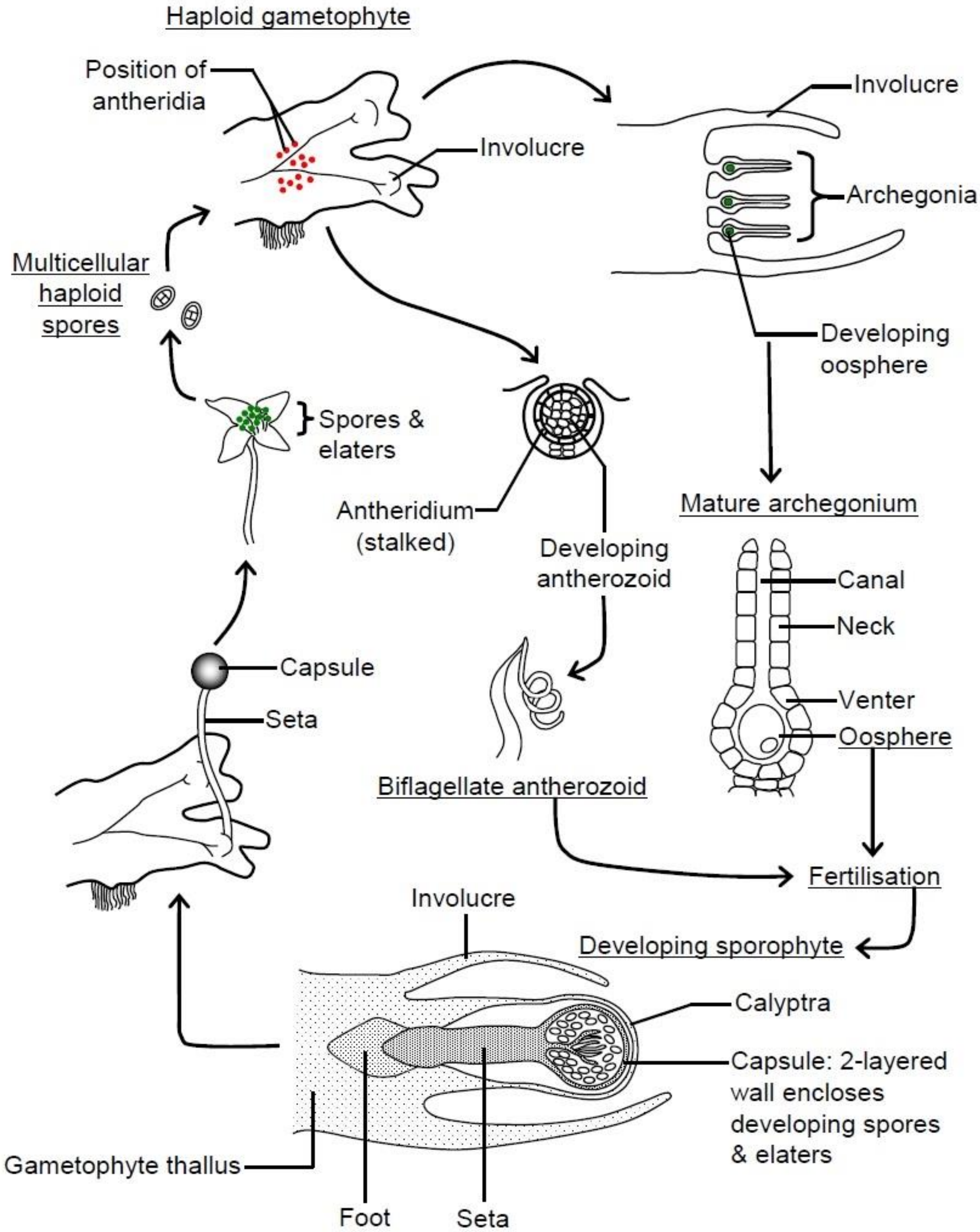
The gametophyte of *Pellia* is a branched, thin, flat thallus bearing rhizoids on the ventral surface. There is a broad midrib. The archegonia originate behind the apical. The archegonia originate behind the apical cell. The archegonia and sporophytes are always dorsal surface of the gametophyte could be seen on the dorsal surface of the gametophyte as a long seta ending in a spherical, dark-colored capsule. The thallus consists internally of a homogenous tissue. The only differentiation is that the cells of the midrib are somewhat longer, in the longitudinal direction, than the neighboring cells. Antheridia appear on the dorsal surface as small raised parts close to the midrib (refer to your drawings). Archegonia are borne on the same plant, i.e., *Pellia* is a monoecious plant. Archegonia are situated on a raised part of the thallus just behind the growing point of the stem or branch.

The archegonia are covered by an involucre which is a pocket-like structure in which water is kept.

Antherozoids released from the antheridia swim in water and one of them fertilizes the ovum. The resulting zygote divides directly to give the sporophyte. The latter soon becomes differentiated into a foot, seta, and a capsule. The foot serves fixation and absorption. The seta carries the capsule and transfers to it water and food materials absorbed by the foot. The capsule has a jacket of two layers. This encloses the spores and elaters an elaterophore is present at the base of the capsule. The elaterophore consists of sterile cells. At maturity the seta elongates greatly pushing the capsule outside the remains of the archegonial wall (or calyptra) and the involucre. The capsule is a dark brown sphere which dehisces by opining into 4 valves.

The elaters have spirally thickened walls and are hygroscopic, i.e., sensitive to humidity; they help in the dispersal of the spores. Spores are of a brown color they are usually seen to divide, each giving from 6-9 cells before dehiscence. After dissemination they continue their growth and development forming new gametophytes.

Life-cycle of *Pellia epiphylla*



Acrogynae Jungermanniales is mainly leafy forms. It includes three examples. Comparison between these plants was as follows:

Plagiochila	***Lejeunia***	***Frullania***
The gametophyte leaf-like carries two rows of lateral leaf-like.	The gametophyte is a stem-like carries two rows of dorsal leaf-like and a ventral row	A common epiphyte on tree trunk with obvious ventral leaf-like and dorsal lobed leaf-like.
The ventral leaf-like are highly reduced or absent.	Each dorsal leaf-like is bi-lobed into equal auricles.	The lower lobe of the dorsal leaf- like is developed into a bladder like
Margin of the leaf-like is usually teethed is usually teethed.		

Order: Anthocerotales

Plants here differ from other bryophytes in the following characters:

1- The cells contain large chloroplasts and each chloroplast has a pyrenoid.

2- Antheridia develop from hypodermal cells the dorsal side of the gametophyte.

3- Archegonia almost completely embedded in the gametophytic tissue.

4- The growth of the sporophyte is indeterminate because of a meristematic region continually adding to the base of the capsule.

5- Stomata with typical pair of guard cells (similar to higher plant).

These distinguishing characters led some botanists to divide Bryophytes into 3 classes (Hepaticae, Anthocrotae, and Musci) instead of 2 (Hepaticae and Musci).

Anthoceros

The gametophyte of *Anthoceros* is a prostate thallus of a dark green color it is fixed to the soil by means of numerous smooth walled rhizoids arising on its ventral surface. There are no scales. There is no internal differentiation of tissues. Almost every cell contains one large chloroplast, which has a pyrenoid. Some species of *Anthoceros* have mucilage cavities in the ventral portion of the thallus. These cavities open on the ventral surface of the thallus by narrow slits. Often colonies of the blue-green alga *Nostoc* are found in these mucilage cavities.

Vegetative reproduction takes place by the formation of “tubers” or as usual in other hepatics, i.e., by progressive death of older parts reaching a dichotomy.

Sexal reproduction:

Most species of the genus *Anthoceros* are homothallic. However, certain species are heterothallic where sex determination is genotypic; two spores of each tetrad develop into male gametophytes and the other two into female gametophytes. A superficial cell on the dorsal surface of the thallus divides to give two cells; an outer cell and an inner or hypodermal cell. The antheridium develops from the inner or hypodermal cell. The antheridial chamber usually contains two antheridia; however, the number of antheridia in one chamber may reach 20 or even more.

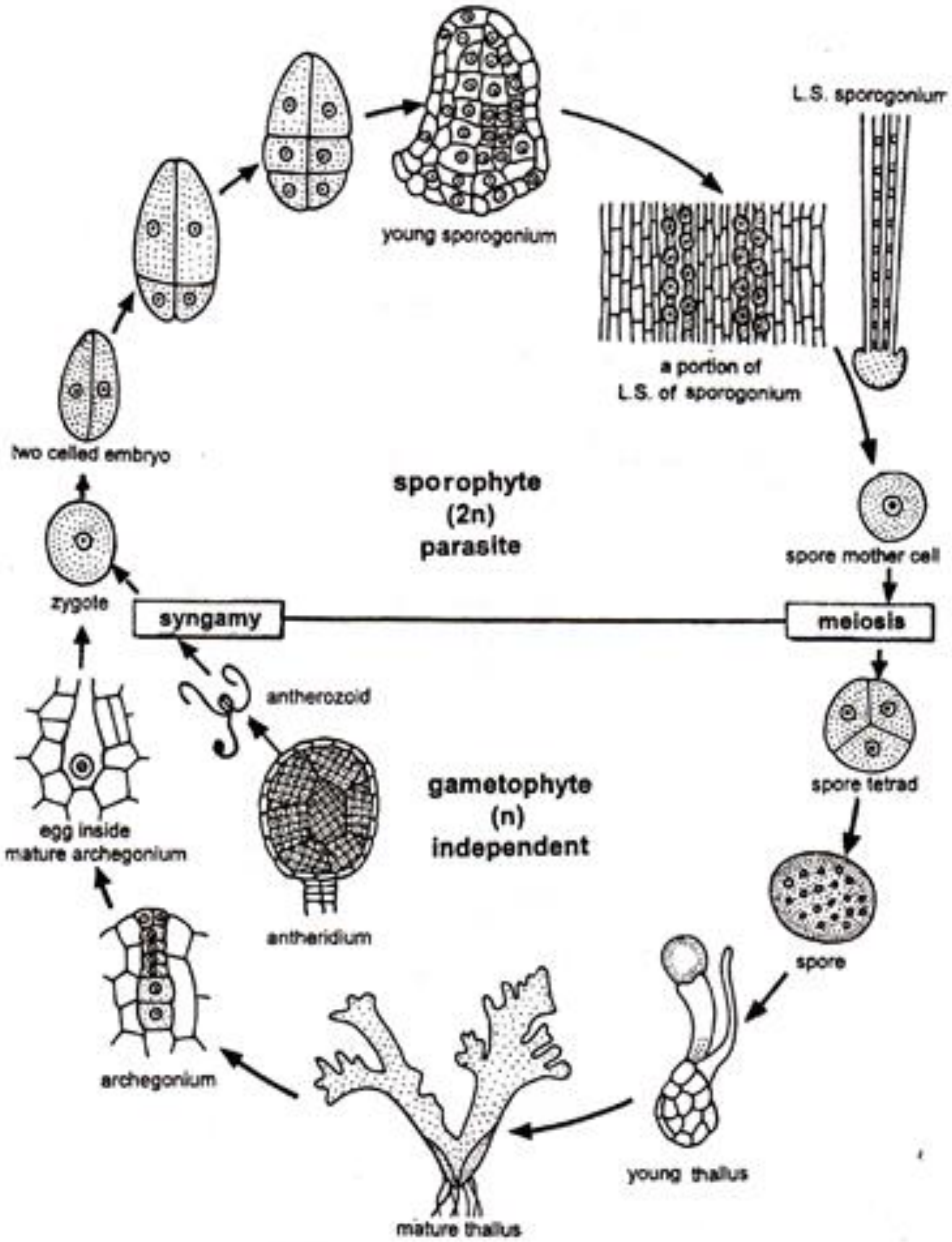
The archegonia are embedded in the tissues of the gametophyte. Every archegonium is in direct contact with the vegetative cells surrounding it. Fertilization takes place in the presence of water and the resulting zygote develops into a sporophyte. The latter differentiates into a foot and a capsule, the basal portion of which remains meristematic.

The calyptra and the adjoining

The calyptra and adjoining vegetative tissues grow upwards forming involucre which protects the young sporophyte but later it becomes ruptured by the elongating capsule. The jacket of the capsule is 4-6 cells in thickness. The outermost layer is the epidermal cells are strongly cutinized. Stomata with a typical pair of gourd cells (similar to higher plants) are present in the epidermis the capsule. Cells beneath epidermis are parenchymatous with intercellular spaces. There are a number of chloroplasts in the cells of the sporophyte. The center of the capsule is occupied by a sterile columella which consists of 16 vertical rows of cells forming a solid square. The sporogenous tissue coveraches the columella and may extend to its base. Sporogenous cells give spore mother cells and sterile cells. The letter become joined and to end to give filaments, called

pseudoelaters. Mature pseudoelaters may have smooth walls. Spore mother cells give **spore tetrads**. Spores at the upper region of the capsule mature first. The meristematic region adds, continuously, new tissues to the foot and to the capsule, but mainly to the latter. The capsule splits vertically into two or more portions or valves. Pseudoelaters help in spore discharge. Mature spores at the top of the capsule become the discharge when the capsule splits open whereas young immature and newly formed spores just above the meristematic zone remain inside the capsule until they become mature and pushed upwards by new ones formed by the meristematic zone. In other words, the tip of the capsule is mature while its base is still in an embryonic condition and thus the growth of the sporophyte is indefinite. Spores on germination give new gametophytes, and the life-cycle is repeated.

It is important to state that sporophyte of *Anthoceros* may be considered more advanced then the sporophytes of other hepatics. It has a thick jacket, stomata, large numerous chloroplasts, a sterile columella, and grows continuously as a result of the activity of the meristematic zone. Although the sporophyte has all these tissues together with the absorbing foot yet it cannot grow away from the gametophyte. In an experiment the sporophyte was supplied with food materials, it (the sporophyte lived days and days but it almost did not grow. This shows that in Bryophytes the sporophyte generation is always dependophytes that the sporophyte depends upon the gametophyte only for a short period of time after which it become an independent free-living plant whereas the gametophyte withers and away.



Anthoceros. **Diagrammatic life cycle.**

Note that concerning the gametophyte, one may notice that:

1- In *Pellia* and *Anthoceros*, the gametophyte is a simple thallus which is undifferentiated externally as well as internally.

2- In *Riccia* and *Marchantia*, the gametophyte is differentiated only internally into a stem and leaves but there is no internal differential of tissues.

Concerning the sporophyte one notices that:

1- In *Riccia* the sporophyte consists of a capsule only.

2- In *Marchantia* the sporophyte consists of a foot, a seta, and a capsule with elaters.

3- In *Pellia* the sporoohyte consists of a foot, a seat and a capsule with elates and an elaterophore.

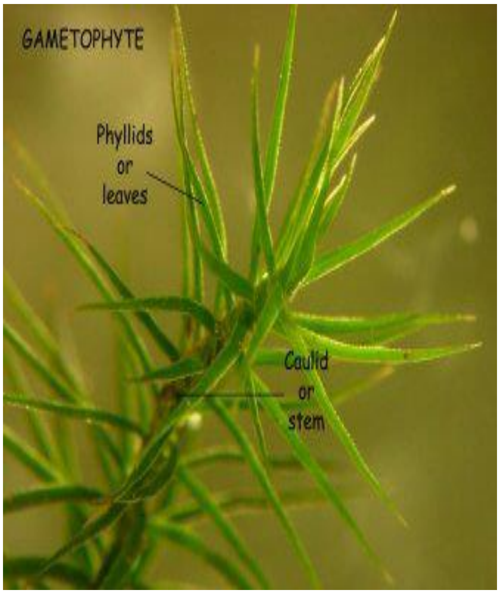
4- In *Anthoceros* the sporophyte consists of a foot and a capsule the basal part of which is meristematic. The capsule contains pseudoelaters, and a sterile columella is present and stomata are found in the epidermis. In *Anthoceros* the growth of the sporophyte is not limited. The presence of chloroplasts and stomata in the capsule is considered as a step towards the independence of the sporophyte generation.

Although the sporophyte of *Anthceros* is more complex and advanced than the sporophytes of other hepatics yet its gametophyte is a thallus of a simple internal and external structure. In *Riccia* we almost have a reverse condition; thus the gametophyte (though thalloid) is differentiated internally into a simple capsule. From the anatomical point of view the gametophytes of *Riccia* and *Marchantia* are more advanced than most of the Jungermanniales, whereas from the morphological point of view the reverse is true, tuse, the gamstophytes of *Riccia* and *Marchantia* are externally simple thalloid but most Jungermanniales, have stems and leaves. Internal and external differentiation of gamtophytes takes place in Musci. As will come soon, we will notice that the gamtophytes are more advanced and complex than those of Hapaticae. They possess stems and leaves and are internally differentiated into various tissues.

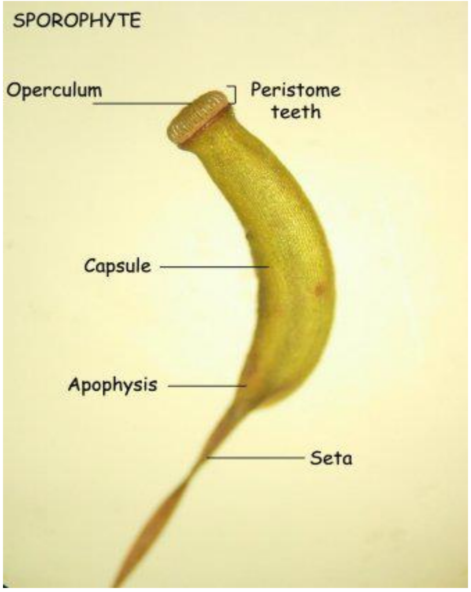
Class 2: Musci

Order Sphagnales	Order Andreaeales	Order Bryales		
Sphagnum	*Andreaea*	*Funaria*	*Minium*	*Polytrichum*

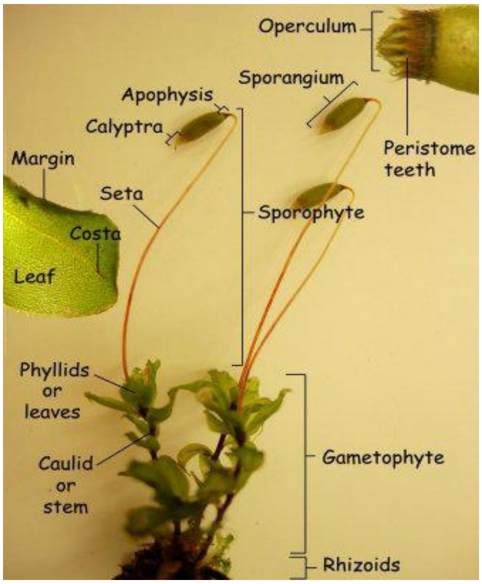
Mosses are the most diverse of the bryophytes; the group is comprised of approximately 14,300 species grouped in about 700 genera. A moss consists of two parts, the **gametophyte** and the **sporophyte**. The gametophyte is the part that you would mainly associate with a moss; it is the free-living, green, leafy stage characterized by leaf-like structures called **phyllidia** or **phyllids** (but commonly referred to as leaves) that are located around a stem-like structure termed the **caulid**. Mosses stay attached to the substratum by root-like structures called **rhizoids**. The sporophyte is diploid (two copies of the chromosome) and is the equivalent to the main body that you observe in vascular plants such as trees. The sporophyte grows partly as a parasite on the gametophyte. In most of the mosses, the sporophyte consists of an unbranched stalk termed the **seta** with a **sporangium** inside the **capsule** at the apex. The sporangium is usually covered by a cap known as the **calyptra** and often has a swollen base, the **apophysis**, and a lid known as the **operculum**. If you are curious, and you take off the calyptra and separate the operculum from the capsule, you will see the **peristome**, which is made of a ring of **peristome teeth** surrounding the mouth of the capsule. These teeth respond to changes of moisture in the environment and are involved in **spore** dispersal.



Gametophyte of *Polytrichium commune*



Sporophyte morphology of *Atrichum selwynii*



Sporophyte and gametophyte of *Rhizomnium glabrescens*

Sporophyte and gametophyte of *Leucolepis acanthoneuron*

The main characters of the mosses are:

1- Spores on germination give rise to a filamentous or thalloid protonema. This has oblique transverse walls and protonema. This has oblique transverse walls and produces upwright branches which bear the sex organs.

2- The gametophyte is differentiated into a stem & leaves & carries multicellular rhizoids.

3- Sporophytes have capsules with a greater proportion of sterile tissues.

4- No elaters in mosses.

Order 1: Sphagnales

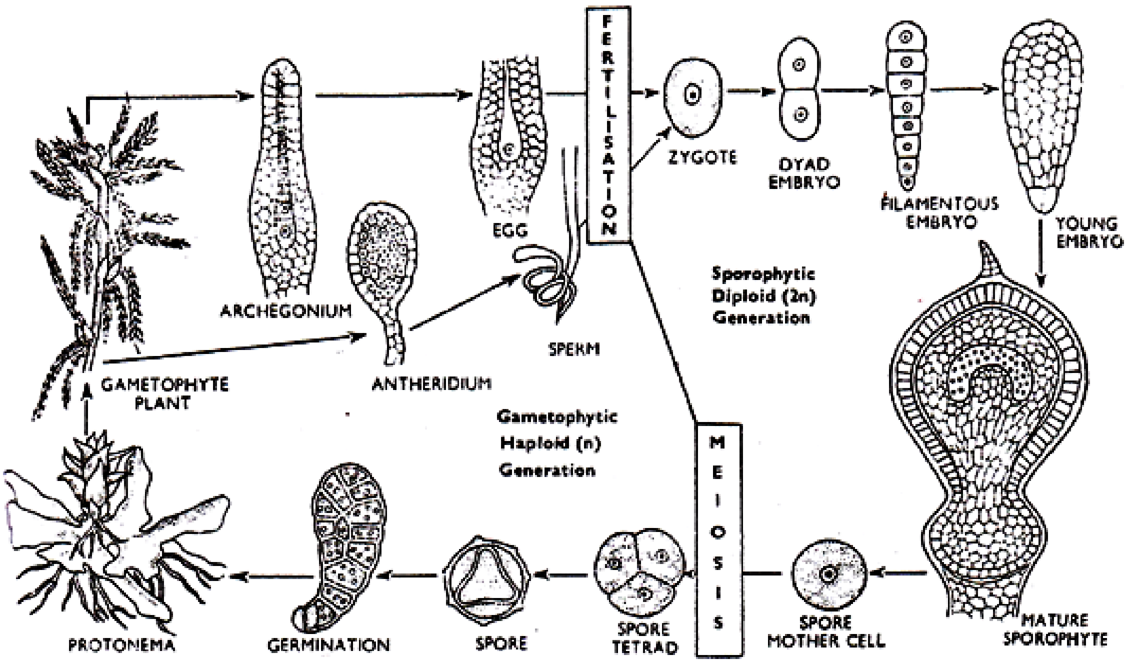
Genus *Sphagnum*

The gametophyte is differentiated into a stem carrying leaves. In young leaves all the cells are alike, in most leaves, however, there are two kinds of calls; long narrow cells which remain alive and contain chloroplasts; and large cells with spiral thickening in their walls. The narrow cells are green photosynthetic cells. The large cells lose their protoplast become hyaline and photosynthetic cells have a regular reticulate arrangement with respect to one another. Hyaline cells play an important role in the (absorption and retention of water.) Branching is lateral and there is usually a group of 3-8 lateral branches in the axils of some leaves. Near the apex of the stem the branches are densely crowded in a compact head. The stem is internally differentiated into a central medulla followed by a cylinder of hadrome and a cortex. The latter is at first one cell in thickness but later it becomes 4-5 cells in thickness. Cortical cells may develop spirally thickened walls similar to those in the hyaline cells of the leaf. The cortex of lateral branches is always one cell in thickness. The cells of the cylinder (hadrome) are thickwalled and apparently form a supporting tissue. Mature gametophytes have no rhizoids and all intake of water is by direct absorption by plant surface.

Sphagnum is homothallic or heterothallic according to species. Sex organs are borne on short lateral branches inserted near the apex of the stem. Antheridia are produced in acropetal succession in the axils of the leaves of the antheridial branch. Archegonia are borne at the apex of an archegonial branch. There are usually three archegonia at the apex of the branch. A mature archegonium does not have a well-marked differentiation into venter and neck. The venter and lower portion of neck are 2 or 3 cells in thickness. The upper part of the neck is but one cell in thickness.

Fertilization takes place and the resulting zygote gives a sporophyte which consists of a foot with haustoria, short seta and capsule. The jacket and the archespoium of the capsule are developed by the amphithecium. The endothecium gives the columella and in this respect is 3-4 cells in thickness. Guard cells are present but are without stomatal openings. All cells are jacket contain chloroplasts, this means partial independence of the sporophyte. There is an operculum (or a lid) at the top of the capsule. A transverse ring of cells delimist the lid from other superficial cells of the jacket which possess thick walls.

When the sporophyte matures the tissues of the gametophyte just beneath the foot develop into a leafless stalk known as the pseudopodium. This elongates rapidly pushing the sporophyte above the leaves at the summit of a gametophyte. Air develops in the cavity containing the spores. The pressure of this air results spores are blown many centimeters upwards. A spore on germination gives a protonema which, unlike other mosses forms only one gametophyte.



Sphagnum. Diagrammatic life cycle.

Order 2: Andreaeales

Andreaeales have some features characteristic of Bryales and others of Sphagnales. Andreaealea are similar to Bryales in vegetative form and in the endothecium gives the columella and the archesporium (sporogenous tissue). Andreaeales are similar to Sphagnales in that the sporogenous tisues overarches the columella and in the presence of a pseudopodium. Andreaeales differ from other musci in that the capsule dehisces longitudinally into 4 valaes (as in Jungermanniales).

Order 3: Bryales

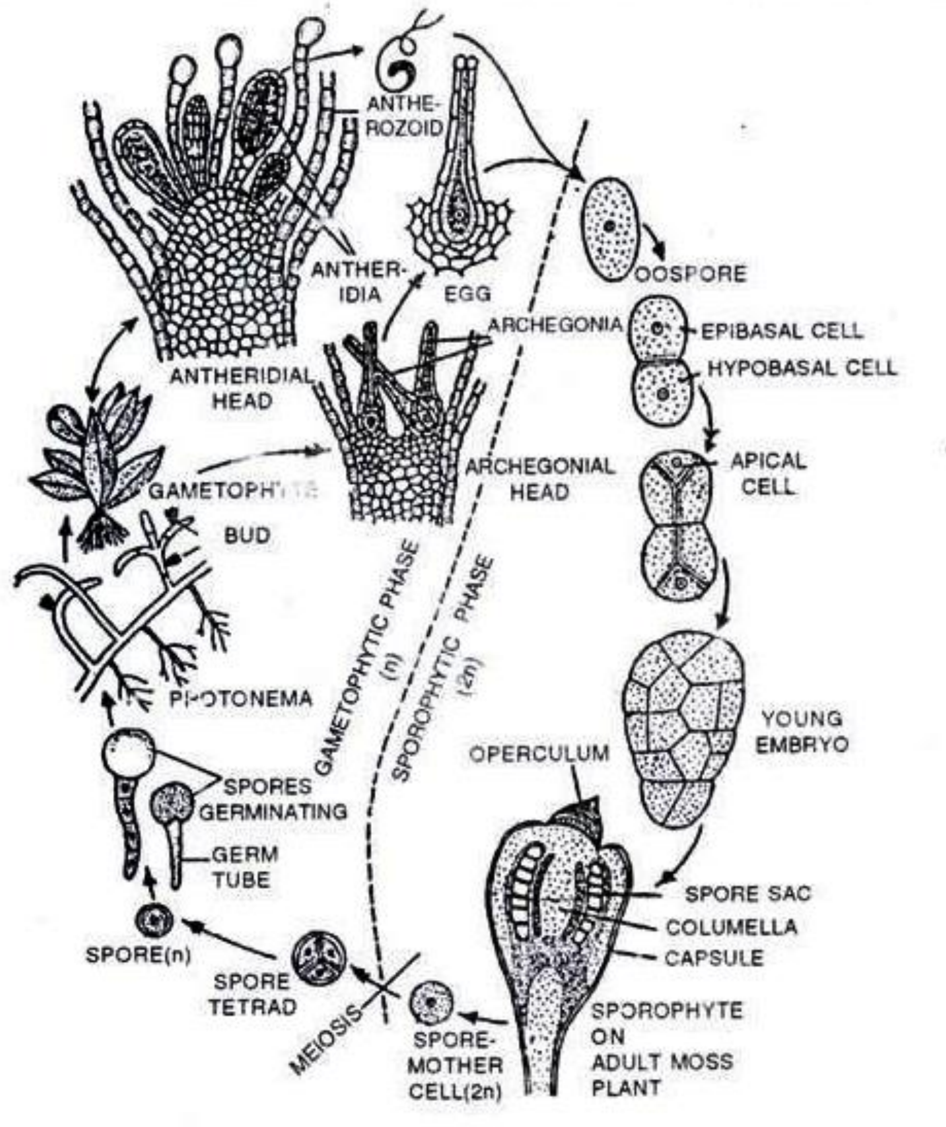
Bryales differ from other Musci in the following respects: Prtonema are almost always filamentous. Gametophytes have leaves with a midrib more than one cell in thickness. Pseudopodium absent. The capsule is usually elevated above the gametophyte by elongation of the seta. Sporogenous tissue is drived from the endothecium and does not overarch the columella. Most genera have the spore cavity covered by a peristome.

Funaria

Funaria grows intensely in humid habitats. The gametophyte consists of a stem almost covered with small spirally arranged leaves. The leaf is one bell in thickness and there is a distinct midrib. Mlticellular rhizoids arise at the base of the stem. The latter is differentiated internally into central conducting tissue small and usually thin-walled cells surrounded by cortex and epidermis. The central cells of the cylinder may be thick walled. The outer portion of the cylinder may be in the form of a pericycly-like sheath of thin walled cells. Some layers of the cortex may become thick. Some species of *Funaria* are monoecious others are dioecious. In dioecious species we have male gametophytes bearing male moss flowers, and female gametophytes bearing female moss flowers. The male plant differs to a certain degree from the female plant. The former is much smaller in size and has a brighter color than the latter. It is also natural that sporophytes terminate only female plants. In monoecious species the gametophyte either has bisexual “flowers" or the end female "flowers" terminate different branched. A male moss flower consists of a number of club-shaped, short-stalked antheridia intermingled with paraphyses, all borne on a receptacle which represents the expanded tip of the stem. The paraphyses are sterile filaments, the cells of which contain chloroplasts. The terminal cell of each filament is round in shape. The antheridia and the paraphyses are surrounded by the terminal leaves of the gametophyte (or the involuore) may differ in shape from other leaves lower on the stem. In the female "flower" as well the archegonia are mixed with paraphyses, but these have pointed terminal cells.

Fertilization is achieved in the presence of water. The resulting zygote divides to give the sporophyte. The archegonial wall remains enveloping the newly formed sporophyte. The archegonial wall elongates to face the increase in the size of the growing sporophyte However, after a while, the growth of the sporophyte causes the rupture of the archegonial wall at its base. The seta then elongates rapidly bringing the capsule to a comparatively great height above the gametophyte. The calyptre still covering the tip of the capsule turns brown in color and falls off after a while. The sporophyte consists of a foot, seta, and capsule. The foot fixes the sporophyte to the gametophyte; it also absorbs water & food materials to the gametophyte. The seta transfers the absorbed materials from the capsule. The sporophyte however, does not depend entirely on this gametophytic food supply since there is a green photosynthetic tissue (the spophysis) supplied with stomata and situated at the base of the capsule. There is a central columella and the sporogenous tissue is in the form of a cylinder which is open at both its upper and lower ends. The wall of capsule is several layers in thickness.

At maturity the thin walled cells of the annulas disorganize and the lid separates. The peristome teeth (16) become exposed to the lid separates. They are hygroscopic, they close the capsule in humid weather and leave it open in dry weather. When the wind shakes the open capsule spores are scattered. Spores on germination give filamentous protonema, the cells of which contain chloroplasts and bear rhizoids with oblique transverse walls. The protonema develops buds. Each bud grows to give an erect gametophyte (=gametophore). Every gametophyte develops its own rhizoids and become independent and separated from the protonema. The gametophyte forms male and female gametes within antheridia and archegonia respectively and upon fertilization new sporophytes are formed and so on.



Funaria. Diagrammatic life cycle.

Mnium

Mnium is a shade-loving moss and requires a humid atmosphere. Involucral leaves are larger than other green leaves straight and not oblique as in *Funaria*.

Polytrichum

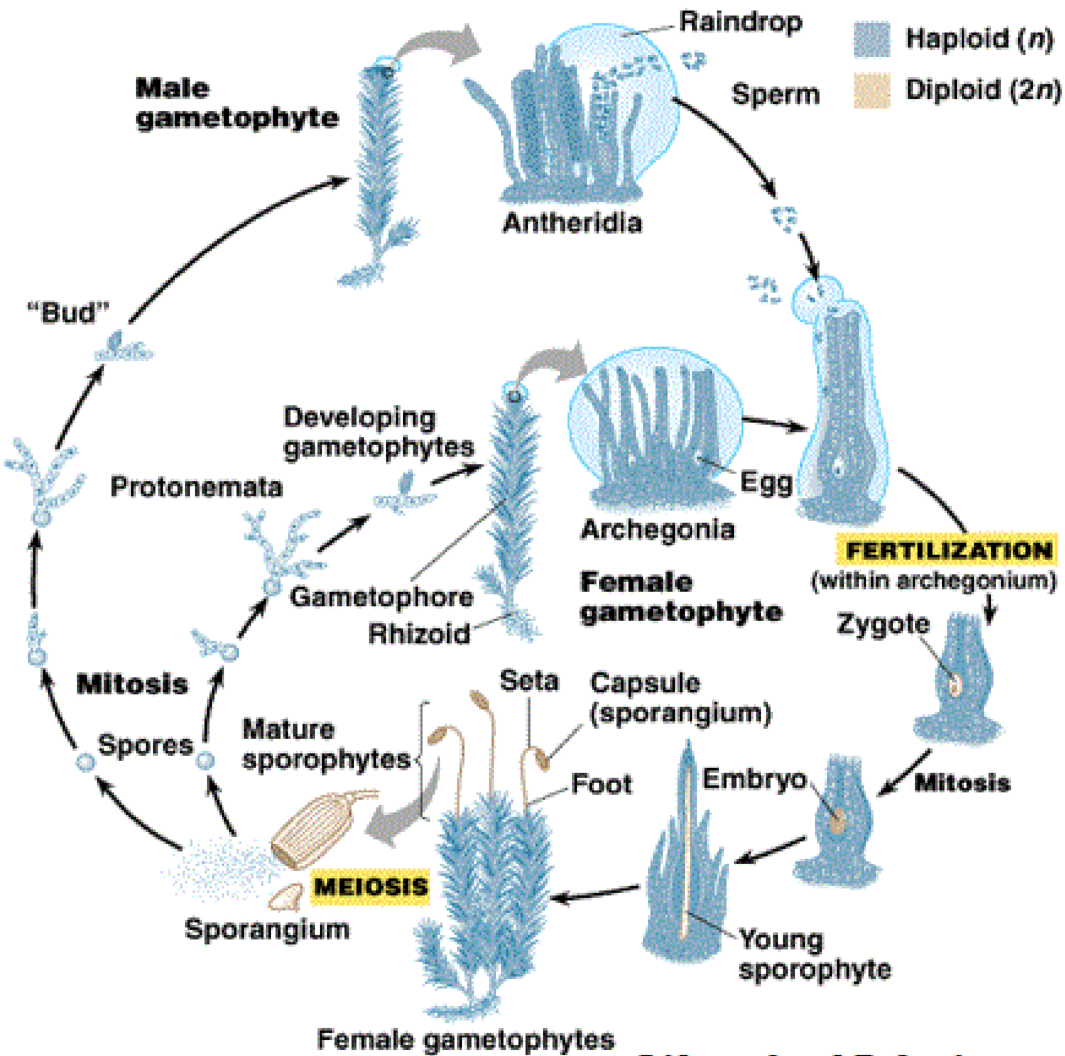
The gametophytes live in humid habitats. The length of the stem of the gametophyte varies according to species; in some it is 3 or 4 cm. long in others it may be 30 cm or more complicated than what we have seen in *Funaria*. The stem consists of an epidermis, a cortex, and a central conducting tissue. This latter tissue consists of large central conducting tissues consist of thick-walled cells (hadrome plays an important role in water conduction and the leptome is supposed to have a food- conducting function. The conducting tissue is surrounded by a zone of thickened cells containing starch grains. There is a wide cortex of thick-walled cells. Strands from the conducting tissue are given off to the leaves, they join the leaves.

Finally there is an external epidermis of highly thickened cells. The leaf is several of large cells thick. The lower epidermis consists of one layer of larger of large cells whose outer walls are much thickened. Inside the lower epidermis there are one or two layers of very small thick walled cells. The central tissue of the leaf (which is continues with the leaf trace) is composed of thin-walled parenchymatous cells, among which are scattered patches of small thick-walled cells. The upper surface is formed of single layer of large cells from which arise numerous long tudinal plates. Each plate is five to eight cells high, one cell in thickness, and the cells contain chloroplasts. The distal cells of each plate are enlarged in such a way that those of neighboring plates almost touch one another.

Sex organs:

The antheridia and archegonia are found at the top of leafy branches and are surrounded by an involucre of leaves which are similar in size to other foliage leaves on the stem. However, the involucral leaves surrounding antheridia are reddish in color. In the male plant, also, the apex of the stem or branch terminates in a vegetative bud in the middle of the anotheridial head. After maturity of the antheridia and liberation of the spermatozoids this bud may grow in the following year to give a fresh shoot, at the apex of which new antheridia may arise. This proliferation through the antheridial head may be repeated several times. The antheridia arises in the axils of the involucre leaves. The sporophyte (= sporogonium).

Fertilization results in a zygote and this develops into a sporonium. The latter consists of a foot, seta, and capsule. The capsule is more highly specialized than that of *Funaria* and *Mnium*. The apophysis is larger in size but the stomata have no pore opening and apper to be functionless. The capsule is square in cross section instead of being round (compare your drawings of *Polytrichum* and *Funaria*). The sporogenous tissue is in the form of a cylinder or a tube which is separated from the columella internally and from the capsule wall externally by air space which are traversed by filaments of assimilatory tissue or aerenchyma and this is a very advantageous position to receive the maximum amount of food materials. The calyptra remains attached to the top of the capsule for a considerable time. It develops a brown color, and grows in size forming a hairy cap which a long beak or rostrum. The annulus is not well-marked but there is the usual thickened rim. There are 32 peristome teeth which are short, of no hygroscopic nature; and are arranged in a ring which does not close the capsule. However, the top of the columella expands into a flat disc, the epiphragm, which fills the space inside the ring of peristome teeth and is attached ot their tips. The openings between the teeth thus form a ring of pores through which spores are dispersed by the force of wind shaking the long stalked capsule. Spores on germination give a protonema and this develops new gametophytes.



Life cycle of *Polytricum*

Morphology and Anatomy

The stem cortex comprises parenchyma-like cells typically become narrow and thicker walled towards the outside of the stem, but other patterns occur. A central strand of narrow cells is commonly present. It is only a few cells wide in some species, but occupies a substantial proportion of the stem in others. Where well – developed, the central strand consists rarely of water – conducting hydroids, while specialized parenchyma cells in the surrounding layers of the inner cortex functioning the conduction of organic nutrients. Leaves in the Bryales are typically sessile but very in shape from linear and linear-lanceolate to ovate or almost circular. The margins may be toothed or entire, but the leaves are never lobed as in many hepatics. The lamina comprises a unistratose plat of photosynthetic cells. A strong, unbranched midrib is present in many species running form the base of the leaf and ceasing below the apex or excurrent at a hair point. The midrib commonly contains hydroids, thick- walled supporting cells termed stereids, and specialized parenchyma cells involved in the translocation of assimilate. Leaves of other species have a short midrib that divides into two near the leaf base, while those of still others are unistratose throughout. Leaf cells show major variation in shape, size, and wall thickness between species and between different parts of an individual leaf. There is not functional cuticle in many species, whose leaves in consequence have little resistance to the entry or loss of water, but a cuticle, is commonly present in spaces in species with strong midribs and central strands. It is of interest to go though the gametophytic and sporophytic structures in Bryophytes to show how the morphological and anatomical differentiations can serve in classification of this group.

Gamtophyte structure

Gametophyte or gametophytic generation is the dominant and the green plants. It may be thalloid (in Hepaticae only) or leafy form (in all Musci and Jungermanniales that known as leafy liverworts). It carries the sporophyte at the apex of the stem or inside the thallus.

I. Thallose Forms

In these forms the thallus varies the sporophyte at the apex of the stem or inside the thallus.

A. The simplest thalli: The thallus is composed of one to several layers of nearly uniform cells without any internal differentiation of tissues such as in ***Anthoceros*, *Plellia* and *Blasia*.**

B. Thalli with high degree of internal differentiation: This type is represented in most members of Marchantiales. Thallus is differentiated into ventral and dorsal regions:

1- The ventral region of the thallus is composed of large colorless compact parenchymatous cells containing starch and serve mainly for the storage of food reserve.

2- The dorsal region of the thallus is mainly photosynthetic portion. In ***Marchantia***, there is a single horizontal layer of air chambers, below the upper epidermis, which are separated from one another laterally by vertical partitions. While in ***Riccia*,** the horizontal layer is usually vertical rows of chlorophyll containing cells separated by narrow vertical air canals which open on the dorsal surface by simple pores.

II. Leafy Forms

It was found that leafy forms are represented in all Mosses and in Jungermanniales only from Liverworts. The structure of both stem and leaf will be discussed in the two groups as follows:

A. Liverworts (Hepaticae)

Stem: The stem of the leaf liverworts is composed of uniform cells without any differentiation of tissues, just only conical cells and medullary cells. There is no well-developed conducting strand in the stem and they are capable of absorbing water through any part of the external surface of the shoot. They are, therefore, termed **ectohydric**.

Leaf: The leaf is usually one layer of cells in thickness. It composed of uniform parenchmatous cells, and usually, lacks a midrib. The cells of the leaf contain numerous chloroplasts and glistening oil bodies of various shapes and size.

B. Musci (Mosses)

Stem: the stem in Musci may be contains efficient of insufficient central cylinder (strand). In some mosses central cylinder is absent. So, mosses can be differentiated into three patterns: **endohydric** (with efficient central cylinder), **ectohyric** (without central cylinder) or **mixohydric** (inefficient central cylinder, depend mainly upon the water ascending between leaves and stem).

In ***Sphagnum***, the stem is usually differentiated into a central cylinder and an encheathing cortical layer.

In ***Andrea,*** the stem is not differentiation into cortex and central conducting strand, but it consists of uniform thick walled cells.

In most Bridae (e.g. ***Funaria***), the stem in internally differentiated into an epidermis, cortex and central conducting strand. The epidermis may be one or more thick layers, but lacks stomata. The stem has a well- conducting strand in ***Polytrichum, Bryum , Mnium*** and ***Dawsonia*****.** Such mosses have been called **endohydric**. On the other side, some mosses are without well differentiated conducting strand such as those of ***Tortella*** and ***Hedwigia***. Such mosses have been called **ectohydric.**

In mosses whose leaves possess midribs, the cortex of the stem usually contain leaf traces.

Leaf: leaves of most mosses usually possess a midrib except a few genera (*Andreaea*, *Hedwigia* and *Ephemerum*). The midrib when present is composed of narrow elongated cells whose walls are usually thickened and show some differentiation of tissue.

In ***Sphagnum***, the leaf is one cell thick and lacks a midrib. It consists of two types of cells, a) large hyaline dead porous cells with thickening, b) narrow elongated chlorophyll- containing living cells.

In ***Bridae***, the leaf consists of one cell thick layer (the two ends known as wings) except in the middle part where the midrib found (e.g. ***Funaria &Mnium*****).** While in ***Polytichum*****,** the dorsal part is represented by vertical filaments.

Sporophyte structure

I- Hepaticae

1- In *Riccia*:

Sporogohium is simple, with non-differentiation into foot, seta and capsule. It consists only of a single layered jacket enclosing a mass of sporogenous cells, some of the potential spore mother cells fail to produce spores but, form abortive nutritive cells which considered as forerunners of true elaters

2- In *Corsinia* sp:

Sporogonium differentiate into smrid capsule. The capsule consists of single layered sterile some of the sporogenous cells form sterile cell initials which mature into sterile nurse cells. The nurse cells are homologous with elaters but lacking the thickenings, characteristic of the elaters.

3- In *Spherocarpos*:

Sporogonium is composed of a small bulbous foot, a narrow seta two cells broad and a capsule with single –layered sterile jacket containing sterile cells like those of *Corsinia*.

4- In *Targionia*:

Sporogeninum consists of a broad foot a narrow seta and a capsule with a single- layered jacket which contain large numbers of elaters with 2 or 3 spiral thickenings.

5- **In *Marchantia*:**

Sporophyte consists of broad foot, well developed seta and capsule with a single layered sterile jacket contains long elaters with spiral thickenings.

6- In *Pellia*:

The sporophyte consists of a foot, seta, and a capsule with two to many layered jacket with diffuse elaters and mass of sterile cells (elateriphore) attached to the basal end.

7- In *Anthoceros*:

Sporophyte consists of a foot, meristematic zone and a capsule with 4 to 6 – layered wall, the capsule wall is differentiated into epidermis with stomata and chlorophyllose tissue. The capsule consists a central columella of elongated cells and pseudoelaters.

II- Musci:

8- In *Sphagnum*:

Sporogonium consists of a nearly spherical capsule and a large bulbous foot, the two being connected by a short, narrow, neck-like suppressed seta. The capsule has a central columella which overarched by a dome-shaped sporogenous tissue. The wall of the epidermis showed non-functional stomata. The cells of the contain chloroplasts- at the top of the capsule there is an operculum separated from the rest of the capsule by the annulus.

9- In *Funaria* & *Polytrichum*:

Sporophyte is composed of a foot, a long seta and capsule. The capsule may be pyriforme (pear- like shape) as in ***Funaria*** or cylinder as in both ***Mnium*** and ***Polytrichum***. The capsule in the three mosses is with many layered wall, contains two parallel spore sac sandwiches the columella. The base of capsule is known as **apophysis** while the apex of each capsule is equipped by peristome teeth and the operculum or the lid is attached with annulus. A sterile structure known as **epiphragm** and hood- like operculum found only in ***Polytrichum.***

Reproduction in Bryophytes

The reproduction bryophytes can be summarized as follows:

A. Vegetative Reproduction:

One of the characteristic features of bryophytes is their tendency towards vegetative reproduction by a large variety of means as follows:

1- Separation of younger branches of a dichotomy due to the death of older parts of gametophyte.

2. Gemmae on rhizoids, on leaf margin, on leaf tips, on leaf vein and stem apex.

3. The development of protonema originated from rhizoids (in this case they termed secondary protonema) into gametophyte.

4. The development of protonema on stems.

5. Abogamy which means that gametophyte gives a haploid sporophyte directly without forming sexual gametes. Abospory that means that the sporophyte gives a gametophyte (2n) directly without forming spores.

B. Asexual reproduction:

Spores from the spore mother cells.

C. Sexual reproduction: it is carried out by the fusion of male (spermatozoid) and female (ovum) games inside the archegonium.

Origin of the Byophyta

Bryophytes are generally small and delicate plants. They usually perish and wither before they become fossilized. Those which become fossilized are usually ill-preserved. The oldest known fossil bryophyte is of an upper Devonian age. On the contrary, pteridophytes (which are more complex plants) date back to upper Silurian age. This simply means that pteridophytes appeared on the surface of the earth a long time before bryophytes. This is unless the absence of fossil bryophytes in Silurian age is only due to the misfortune or bad luck of workers. The structure of the discovered fossil bryophytes is very similar to that of those living today. This, most probably, means that this group of plants remained without any pronounced change or evaluation since these ages (about 300 million years). Hence it is probable that bryophytes present the final product of one of the lines of evolution in the plant kingdom. (Again this means that the origin of bryophytes cannot be seeked in its fossil forms, because they have similar structure to living forms. In a recent publication, however, the following opposing opinion has been stated:

1- The fossil bryophytes indeed imply that the principal groups of both hepatics and mosses must have been differentiated by the end of the palaeozoic.

2- There did exist in palaeozoic and Mosozoic times bryophytes unlike those we know today; so that on the evidence available, they are difficult to place in any known major group. However, there are different opinions concerning the origin of the bryophytes.

Some botanists think that the bryophytes evolved from the algae, especially from the chlorophyceae because the structure of the chlorophyll and xanthophyll of green algae is exactly the same as that of bryophytes. They also think that bryophytes of more or less the same structure as *Anthoceros* evolved long ago to give Psilophytes appeared on earth before pteridophytes but there is no fossil proof for that.

A second opposing opinion is that; bryophytes were derived from pteridophytes by reduction / this means that pteridophytes appeared on earth first them some of them (psilophytales) become reduced forming the bryophytes. The fossil record is in favor of this opinion because fossil pteridophytes are known in older strata than fossil bryophytes.

A third and quite different view is that; no direct relationship exists between bryophytes, psilophytes and pteridophytes, and that these three groups represent three independent lines of evolution within the plant kingdom. Similar features that may be exhibited by plants belonging to these different plants. This shows that the origin of bryophytes is not exactly known till now, there are different opinions. This will remain sc until new fossils solve the problem otherwise it will remain so for ever.

Bryophytes Recorded In Egypt

Class I: Hepaticae (Liverworts):

Includes 6 genera fall into 15 species.

Order: Marchantiales (3 genera, full into species).

1- *Riccia:* Nine species were recorded in Egypt

2- *Marchantia* two species only. *M. placea & M. polymorpha*

3- *Plagiochasma upestre*

4- *Mannia androgyna***:**

Order: Sphaeroearpales (one species only).

5- Riella helicopmanniales: (one species only).

6- *Fossomberonia* sp.

Class 2: Musci (Mosses):

Mosses are drought – tolerant more than hepaties therefore the number of mosses recorded in Egypt is much higher than of hepatics. As concluding remarks it may be said that the moss flora of Egypt is now known to include approximately 400 taxa. Those taxa, have been recorded in different parts of Egypt and all these mosses belong to the class Mniopsida (true mosses) and that they represent 7 orders & distributed in 14 families. These orders are fissidentales (5 % of the moss flora of Egypt), Dicranales (12%), Eubryales (30%), and Hypnobryales (44%).

Ecological distribution of Egyptian moss species:

Ecological distribution of mosses in the world indicated the presence of some strategies for surviving bryophytes in arid environments, their roles in biodiversity and range land condition i.e. some mosses are indicators of soil pH. Previous Egyptian workers revealed that only 275 entities or moss taxa had been recorded-up till now-in Egypt (shabbara, 1990 &1991). These 275 entities were found growing in either one or more of 12 different microhabitats. These microhabitats were as follows:

1) On and between moist red-bricks of walls and bridges.
2) On moist shaded fine granite soil.
3) On and between lime stone.
4) On muddy banks of the Nile and irrigation canals.
5) On mud in green houses or "Mashtals"
6) Inside wet rock crevices and between rocks.
7) On moist shaded ground.
8) On moist semi-shaded fine granite soil.
9) On moist shaded sandy soil.
10) On wall of porous porcelain water pots.
11) In water (Submerged) in shaded places.
12) In Caves and moist semi-protected places.

In the following, the characteristic differences between the taxonomic ranks of the bryophytes are listed in the following tables. These plants are grouped into two classes.

Structures	Liverworts	Mosses
Protonema	- Much reduced, often form only one plant.	- Usually strongly developed filamentous or plate- like, generally forming many plants.
Apical cell	- 2 or 3 or 4 sided	- 2 or 3 sided
Vegetative body	- Generally dorsiventral and bilateral either with two lateral rows of leaves and a ventral row of under leaves or the vegetative body is more developed and thalloid often with ventral scales.	-Gametophyte generally radially symmetrical, with simple conducting strand, histologically differentiated.
Archegonia	- borne apically or laterally on the stem.	- Always borne apically, generally in special buds.
Seta	Soft, not developing more quickly than the capsule.	-firm and wiry completing its development before the capsule.
Calyptra	- Persistant or evanescent, not forming a cap carried up with the young capsule.	- Archegoium wall forming vaginula and calyptra.
Sterile tissues	- Generally no columella, Elater found.	Columella, apophysis, annulus, peristome are present-no elaters.

Class: Musci (Mosses)

	Sphagnales	Andreaeales	Bryales
Gametophyte	-Mature plants are without rhizoids. -Phyllids one cell thick, and without midrib.	-Rhizoids present -Costa usually present.	Rhizoids, present -Costa usually present and phyllids are thicker.
Sporophyte	-It is elevated by means of a pseudopodium. -Seta short. -Sporogenous tissue originates from amphithecium (such as *Anthoceros* sp.) -Sporogenous tissue overarches columella. -Annulus & lid are present but peristome absent.	-Also by pseudopodium -Seta short -Sporogenous tissue from Endothecuim -Sp. Tissue overarches columella Dehiscence by 4 clefts.	-No pseudopodium but an elongated seta. -Seta long. -Sporogenous tissue from Endothecuim. -Sporog. Tissue not overarche columella. -Dehiscence by siding of annulus, lid & peristome.
Protonema	Thalloid, plate-like.	Plate-like	Filamentous

Pteridophyta

Ferns are quite successful plants. They grow as perennial herbs, trees, epiphytes, and floating plants. They have exploited almost all terrestrial and freshwater environments, and dominate in some of them. Similarly, ferns have dominated terrestrial plant communities to varying degrees since their appearance in the Devonian. The ferns are megaphyllous plants whose leaves (fronds) usually emerge by circinate vernation. The leaves also usually are compound and are among the most complex leaves of any in the kingdom of green plants. Their axes vary in complexity with steles of almost all types possible: protosteles, actinosteles, plectosteles, ectophloic siphonosteles , amphiphloic siphonosteles (solenosteles), dictyosteles, and eusteles.

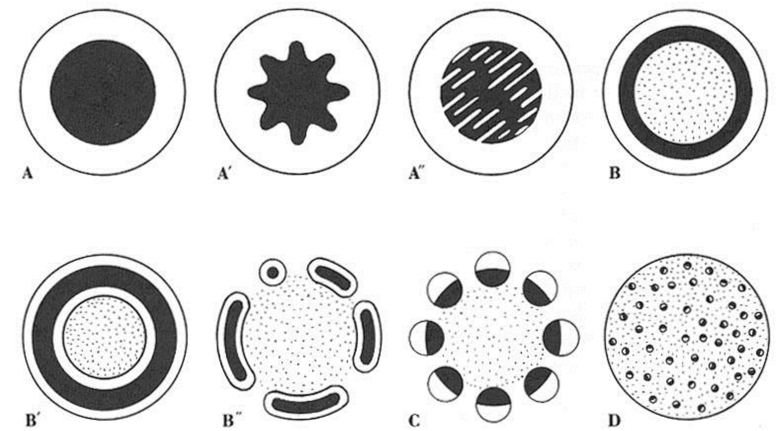
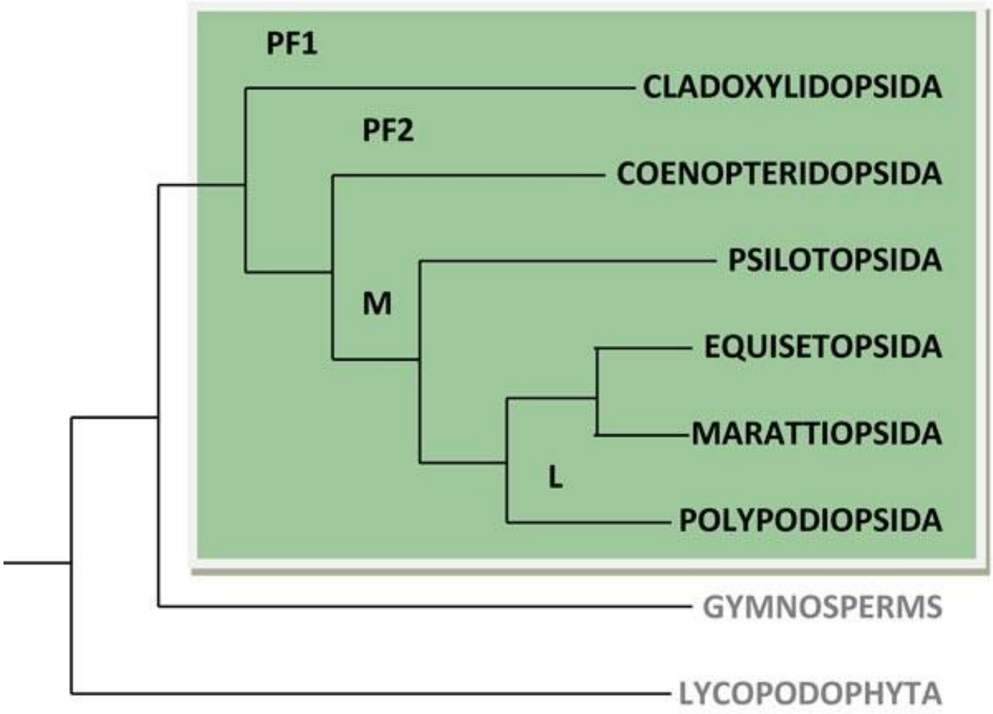


FIGURE 13-6
Types of stele, diagrammatic transections. A–A″. Protosteles. A. Haplostele. A′. Actinostele. A″. Plectostele. B. Ectophloic siphonostele. B′. Amphiphloic siphonostele or solenostele. B″. Dictyostele. C. Eustele. D. Atactostele. Xylem, black; phloem, white; pith, stippled.

Types of Steles in Vascular Plants



PF1 & 2 = Preferns. M = megaphyllous ferns. L = leptosporangiate ferns

The Preferns

The cladoxylids and coenopterids were the groups of plants, which together are called the preferns. They showed the spectrum of steps required to form a webbed branch system that we recognize as a megaphyll. Indeed, the terminal fertile appendage of *Cladoxylon* looked very much like a spore-bearing megaphyll. The cladoxylids were monopodial with small microphylls and spore-bearing frond-like branching systems. Thus, they resembled the Trimerophytophyta from which they likely emerged. All extinct, these organisms flourished during the Devonian but died out by its end. Pearson (1995) believed that the cladoxylids gave rise to the Progymnospermophyta and, thus, to the seed plants. Stewart and Rothwell (1993) demonstrate potential affinities between the cladoxylids and all major groups now considered to be within the Pteridophyta as well as the seed ferns. However, they end their discussion by saying, "...the Cladoxylids...can be added to our list of plant groups that represent unsuccessful evolutionary 'experiments' that ended in extinction".

The Euphyllophytes, the Megaphyllous Ferns

These are the plants that have megaphyllous leaves. That is, the megaphyll is a branch system that has become planar and webbed. Despite the name, size is not an adequate diagnostic character to use in distinguishing megaphylls from microphylls. Some taxa like *Lepididodendron*, a microphyllous plant, have very large leaves. On the other hand, the scale-like megaphylls of cedars are quite small. The principle character that distinguishes a megaphyll is a leaf-gap in the stele. This is an opening or gap made by the stele of a branch (called a leaf trace) as it emerges from the stele of main stem.

The steps leading to the formation of a megaphyll are given in Figure. It was proposed that all of the main plant organs can be derived from simple *Rhynia*-like axes called mesomes (sterile axes) and telomes (fertile axes). The derivation of megaphylls in this scenario is that the dichotomously-branching axis develops an unequal branching form (Figure A) called overtopping. The lateral branch system then becomes planar (Figure B) and webbing elaborates between the axes. Thus, a megaphyll is not a structure that evolved *de novo* but was assembled from existing structures. Tomescu (2008) argures that such a sequence for megaphyll evolution must have occurred multiple times thus calling into question the homology of early megaphyllous appendages.

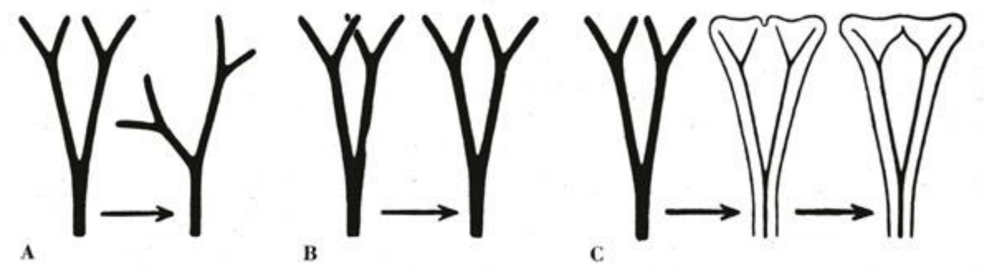


Figure: Evolution of a Megaphyll.

A. Overtopping B. Planation C. Webbing

Psilotopsida

<u>Psilotales</u>

Structurally, the psilophytes would seem to be out of place. They grow as dichotomizing branching systems that do not have leaves or roots. Instead, they have a prostrate rhizomatous branching system with rhizoids. The upright stems are photosynthetic and are covered by enations or microphylls. The sporangia occur as eusporangiate synangia at the terminus of short lateral stems (Figure). The gametophyte is small, inconspicuous, and saprobic. Also, it is monoecious, producing both antheridia and archaegonia on the same thallus.

The overall structure of the sporophyte would seem to make them remnants of the earliest radiation of vascular plants. Such is the classical view that associates the psilophytes with the Rhyniophyta. However, molecular evidence suggests that the psilophytes are reduced ferns. Modern molecular cladistic analyses show that they are sisters to *Botrychium Ophioglossum.* However, morphology-based analyses suggest that they should be sisters to Equisetopsida.

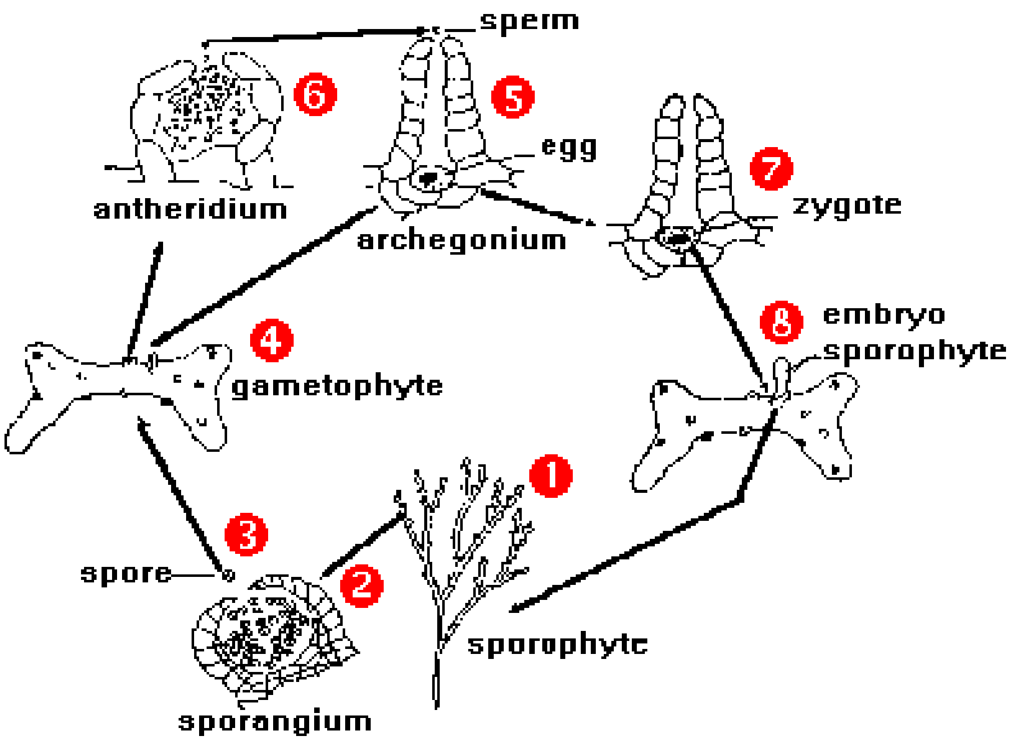
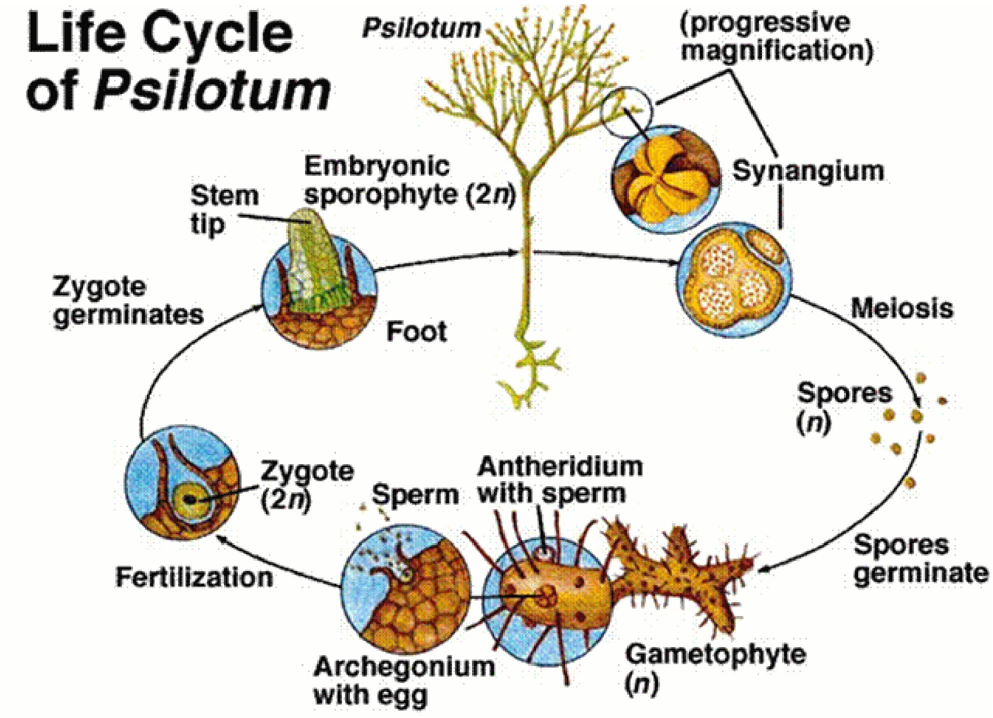


Figure. Life History of *Psilotum*.
The sporangium (1-2, a eusporangiate synangium) produces spores. They germinate to produce inconspicuous thalloid gametophytes (4), which produce both archaegonia (5) and antheridia (6). Antheridia release flagellated sperm which fuses with the egg to form a zygote (7). The embryonic sporophyte (8) emerges from the archaegonium.



Equisetopsida

The horsetails or scouring rushes are distinctive in two ways: they have a stem that is jointed and ribbed and a strobilus of sporangiophores. Although represented today by a single genus, *Equisetum*, the horsetails have a very long history and diverse representation in the fossil record. They were especially abundant from the Devonian to the end of the Paleozoic. A common feature of the class is the production of jointed stems (thus it refer to this group as the Arthrophyta). Also, branches arise from beneath the leaves rather than the more typical adaxial emergence. The stele is difficult to interpret, but stems appear to grade from siphonostelic to eustelic. A very distinctive feature of the equisetophytes is the type of complex strobili. Cones like those of *Equisetum* are made of sporangiophores (modified leaves), each with multiple homosporous sporangia.

Equisetum is homosporous and its gametophytes are saprophytic, monoecious, and cryptic.

Hyenia, a Devonian age equisetophyte, grew as a creeping rhizome from which upright photosynthetic stems emerged. Some of the terminal branches of *Hyenia* are loosely-clustered sporophylls whose structures suggest the evolution of the *Equisetum*-like cone by reduction of internodes and reduction of the sporophylls.

Calamites grew as trees with strong monopodial growth and whorled leaves (megaphylls) at the jointed nodes. Indeed, *Calamites* showed strong secondary growth. They had compound strobili with heterosporous sporangia. Gametophytes have not been found in the large extinct forms. These plants appeared in the upper Devonian and persisted to the Permian. *Calamites* was one of the dominant plants in the great Coal Age forests during the Carboniferous period.

Pseudobornia were large trees (up to 20m tall) with articulating stems. The dichotomizing branches grew up to 3m long. These plants appeared appeared to be simpler that Calamites. They did not show evidence of secondary growth (or, if so, it was limited), and their sporangia were homosporous. They were restricted to the Upper Devonian and may have given rise to the Calamites line.

Sphenophyllum were creeping plants with prostrate stems that had solid cores and were triangular in cross-section. Like *Calamites*, though, *Sphenophyllum* had whorls of wedge-shaped leaves. These plants appeared in the lower Devonian and persisted through the Permian, and may have survived into the early Triassic.

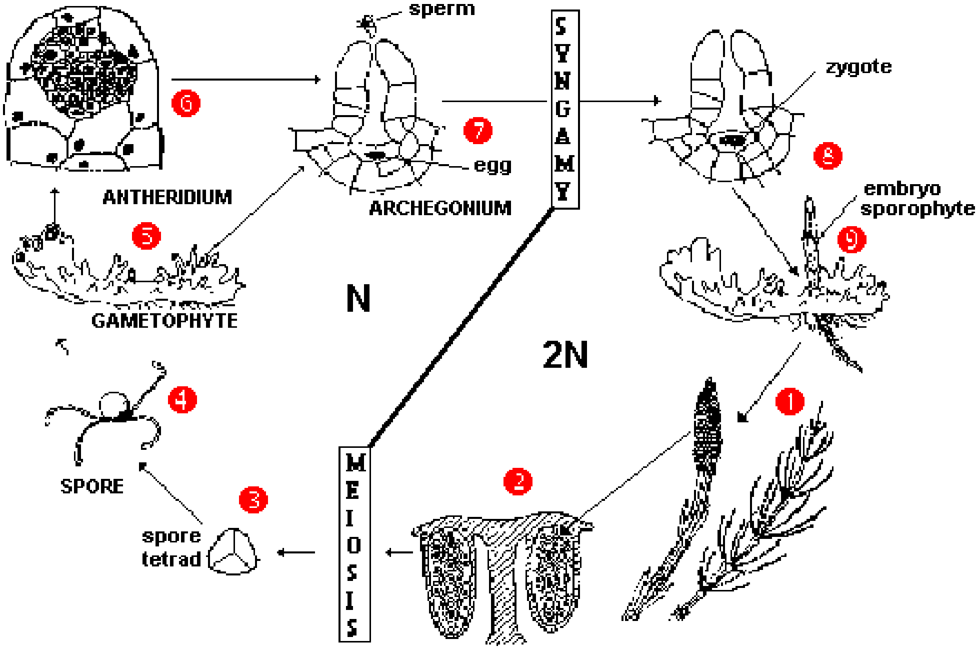


Figure. Life History of *Equisetum*.

The sporophyte (1) produces a terminal strobilus of sporangiophores (2). Spore tetrads mature with attached elater tissue (3-4). The gametophyte (5) is inconspicuous and monoecious. It produces small antheridia (6), and archaegonia (7). Following syngamy (8), the embryonic sporophyte (9) emerges from the archaegonium.

Marattiopsida

The marattiopsids are massive ferns that seem to be sisters to the equisetopsids, and have a fossil history which goes back to the Carboniferous. Everything about them is large. Their leaves can be up to 7.5 meters long, and their sporangia likewise are large, eusporangiate, and usually fused into large synangia. The gametophytes are large, thallose and often perennial causing them to resemble *Marchantia*. The stems are supported as a palm-like tree by persistent leaf bases and exhibit secondary growth by a polycyclic dictyostele. The fleshy stems and roots often have mucilage chambers in a thick cortex.

A common genus is *Angiopteris*, a name that means "angel wings". The rhizomes are very large and fleshy, some are edible. One species of *Angiopteris* has become an invasive plant on the island of Jamaica.

Polypodiopsida, the Leptosporangiate Ferns

Most of the living Ferns are assigned to the class, Polypodiopsida. This class is, by far, the most speciose and most diverse in form of all the living fern groups. The most fundamental synapomorphic character is the leptosporangium. This is a particular type of fern sporangium that develops from one or two superficial cells and can have as few as 16 to 32 spores per sporangium. They have characteristic springy, gracile stalks with a sporangium on the top. Typically, the sporangium has cells of different thicknesses such that the sporangium dehisces suddenly via a horizontal slit and flings the spores by the combined actions of the sudden opening and the recoil of the springy stalk. In most taxa the leptosporangia are clustered in sori and usually associated with indusia, extensions of leaf tissue that may cover or surround sori.

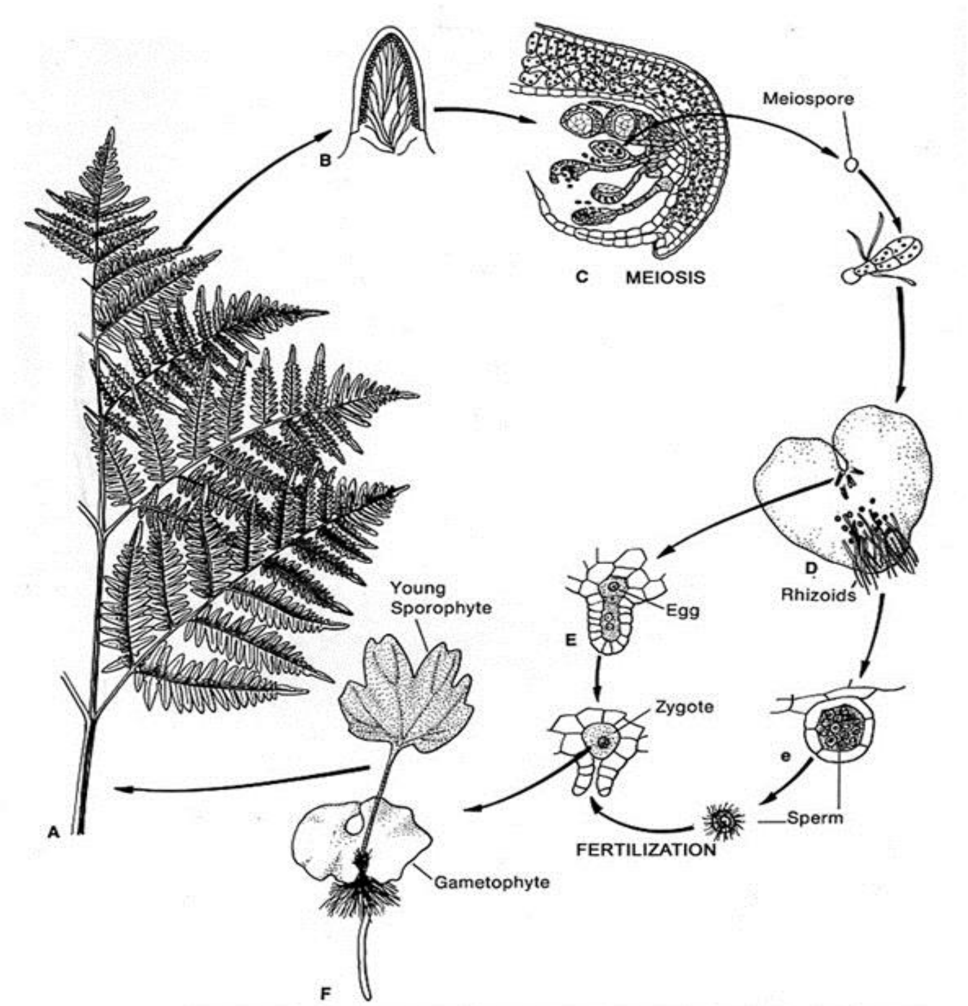


Figure: Life Cycle of *Pteridium*

A. Fertile megaphyll of the sporophyte B. Fertile pinna with sorus along the margin of the leaf C. Leptosporangia emerging from the sorus and covered by a false indusium D. Cordate gametophyte E. Archaegonium, antheridium, syngamy to produce a zygote F. Emergence of an embryonic.

Osmunda and their relatives have a very complete fossil history which goes back to the Permian. The plants have a short erect stem with persistent leaf bases. The leaves are large with dichotomous venation in the pinnae. Sporangia are more massive than the typical leptosporangiate condition. Indeed, they appear to be intermediate between aleptosporangiate condition and a eusporangiate condition. Still, the sporangium has a unistratose wall, but it opens by a longitudinal slit (most leptosporangia open by a horizontal slit). The sporangia never occur in a sorus. The gametophyte is large (up to 5 cm long) and photosynthetic.

The filmy ferns, like *Trichomanes*, occur mainly in the southern hemisphere and in the tropics. Most are small, with very thin leaves, usually unistratose. Furthermore, the stems are equally delicate and usually protostelic. Sori are marginal and are surrounded by a cup-shaped indusium. The *Trichomanes* species that occurs in Pennsylvania lives entirely as a gametophyte on seeps and protected areas. They are small branched filaments that reproduce only asexually as gemmae.

Lygodium is a member of the Schizaeales, an order that has a fossil history which dates from the Jurassic. Mainly, members of this order are tropical, but *Lygodium* occurs as far north as Pennsylvania. The sporangium has a thick stalk and an annulus which forms an apical cap (a longitudinal slit in *Lygodium*). Sporangia may be covered by an indusium-like flap, but the sporangia do not occur in sori. The leaves are quite variable, but usually small. However, the leaves of *Lygodium* remain meristematic at the tip and continue to grow as vines, more than 30 meters long for each leaf. Stems are less significant and range from protostelic to dictyostelic. The gametophytes vary from filamentous to carrot-like.

The water ferns are all heterosporous with their gametophytes rarely exceeding the bounds of the spore wall. This is true both of the megaspore and the microspore. The plants differ vegetatively though they are all aquatic or semi-aquatic.

Marsilea is rhizomatous with leaves which resemble four-leaf clovers. Their rhizomes have a solenostele. At the nodes, leaves and adventitious roots emerge. At some of the nodes, fertile leaves called sporocarps emerge. They resemble seeds and remain closed until scarified (either through physical abrasion or through chemical degradation) at which point the gelatinous leaf emerges with its sori filled with sporangia.

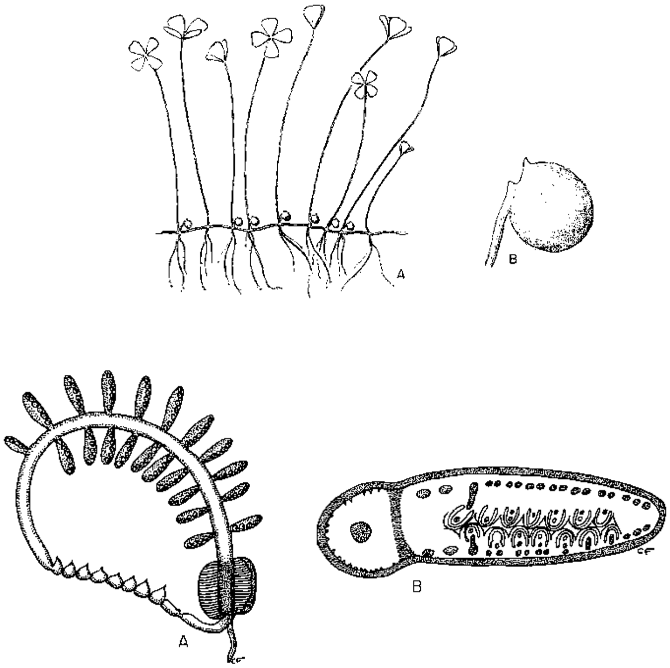
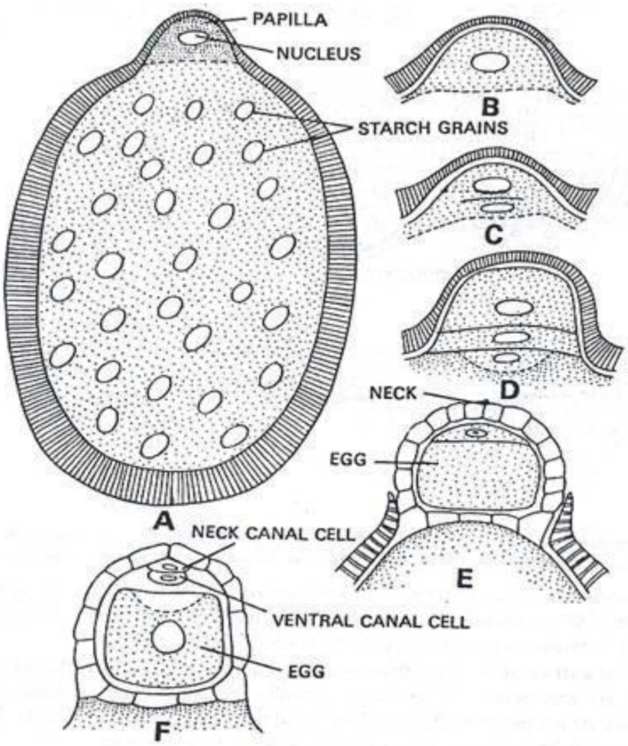


Figure: Life History of *Marsilea*

The water fern, *Marsilea*, looks like a four-leaf clover, but circinate vernation gives it away as a fern. It is rhizomatous from which leaves emerge at the nodes. The base of some of the leaves, a sporocarp (a hardened folded leaf with sporangia inside) develops (Top a&b in figure). The sporocarp develops as a gelatinous ring which allows the sori to emerge into the water (Bottom a&b in figure), these are heterosporous. Microspores develop into multiflagellate sperm and the megaspores develop into a megagametophyte which does not exceed the bounds of the spore wall.

The daughter sporophyte grows from the zygote in the archegonium in the megaspore and appears almost like a germinating seed.



Marsilea sp. A, L.S. of mature megaspore; B-F, successive stages in the development of megagametophyte (female gametophyte) and archegonium; F, mature archegonium.

Gymnosperms

The characteristic that sets gymnosperms apart from angiosperms is the production of „naked" seeds, seeds that are not enclosed in fruit. In fact, the word gymnosperms means "naked seed". Ancient seedy ferns appearing in the Permian (end of the Paleozoic Era) are considered to be the earliest gymnosperms. During the Mesozoic Era, the ability produce seeds enabled gymnosperms to become the dominant plant life. After the evolution of angiosperms in the Cretaceous period, gymnosperms lost their world dominance.

Classification

Gymnosperms today are represented by about 800 species only, of which classification into classes in a subject to disagreement.

1.) CYCADS found exclusively in the tropics and subtropics are ancient gymnosperms, which shared Earth's forest with the dinosaurs during the Mesozoic. Many of them resemble palm trees in appearance, but they bear seeds in cones and have separate male and female plants.

2.) GINKGOS are also a very ancient group with a single living species (in Asia), the Ginkgo biloba. Its relatives died out about 65 million years ago, so this species is a „living fossil". It has fansabed leaves and it is deciduous as it is an attractive tree and resistant to air pollution, ginko is often planted in urban parks and gardens.

3.) **GNEOPHYTES** are a less know group with some strange species, such as the *Welwitschia* in the Africa desert. It grows closed to the ground and has a large tuberous root. Although it may live 100 years, this plant has only two leaves, which continue to lengthen and become tattered by the desert wind, as the plant grows older. Other species of this group are *climbing vines* found in tropical and subtropical forests. There is a single species living in Hungary, the *ephedra*, which is a very rare, protected shrublike plant. Its drug is a valuable cough-relief.

4.) **CONIFERS** form the larges, the most diverse and best-known group of gymnosperms. It includes the biggest, tallest and oldest trees of the world. Seeds of Gymnosperms are naked or exposed, i.e. they are not enclosed in ovaries as are ovules of Angiosperms. Members of the Cycadopsida have large frond- like leaves and seeds with radial symmetry. Those belonging to the conifersida have needle- shaped or fan- shaped leaves and seeds with bilateral symmetry.

- **Pine Family** (Pinaceae) -- This family includes not only many species of **pines** but also species of **larch, fir, spruce, hemlock, Douglas Fir** and others.
- **Cypress Family** (Cupressaceae) -- **Arbor-vitae** & **Redcedar** possibly occur in our backyards.
- **Mormon Tea Family** (Ephedraceae) -- Shrubs of arid regions in western North America, probably not in your backyard unless you live in the desert.

- **Ginkgo Family** (Ginkgoaceae) -- **Gingko** trees may appear in your neighborhood as street trees.
- **Yew Family** (Taxaceae) -- **Yew** shrubs, often pruned into geometric forms, often are planted next to doors and along sidewalks.
- **Cycas Family** (Zamiaceae) -- palm-like **Sago-Palms** may be found in some tropical and semi-tropical backyards

Order: Pteridospermales

Pteridospermales are also known as Cycadfilicales or seed ferns. Leaves are similar to those of ferns and the seeds are borne on leaves are similar to those of ferns of the order Cycadales. There are no cones. Pteridospermales extended into the Permian.

*Lygiopteris***:**

This stem attained a diameter of about 4 cm and branched frequently. The outer cortex had alternating parenchyma and Scleren chyma. The sclerenchyma cells were in the form of longitudinal plates. There is an inner cortex zone of parenchyma cells followed by periderm. Phloem and cambium are usually ill-preserved, secondary xylem and wide rays. Primary xylem had mesarch protoxylem. The pith consists of parenchyma cells in which were scattered “sclerotic nests”.

Heterangium:

This stem reached 5 cm in dimeter. The outer cortex had characteristic sclerenchyma strands. Secondary xylem is a narrow zone. Primary xylem had mesarch protoxylem and there is not pith.

Lagenostoma:

Lagenostoma lomaxii is the seed of *Lyginopteris Hoeninghausii*. The seed was about 5,5 x 4,25 mm. The structure of the is well shown in the longitudinal section .The megaspore (embryo sac) is surrounded by a nucleus (megasporangial wall). The nucleus is fused with the integument in its lower part but the upper part is free and is extended in the form of bottle- shaped beak or cap surrounded by a pollen chamber. The seed is surrounded by an outer cover known as the cupule, however, most seeds were found without this cupule.

***Sphaerostoma*:**

One of the species of the seed genus S*phaerostoma* is believed to be the seed of one of the species of the stem genus *Heterangium*. *Sphaerostoma* is more or less similar to *Lagenostoma* in its structure but it was smaller only about 3,5 x 2 mm.

***Physostoma*:**

This seed in usually frond without a cupule and it is not known whether it had one or not. It was about 6 x 2,25 mm. There was no nuclear beak, the projection is part of the megaspore and is surrounded by the pollen chamber. The free upper part of the integument is in the form of 10 (9-12) lobes or ten tacles. The outer surface of the integuments is covered by large club- shaped epidermal hairs *Physostoma* (and the two previous seeds) are supplied with several vascular bundles that ran in the integument.

***Medullosa*:**

Stems known as *Medullosa* were found in Upper Cabonifer and in Permian deposits. *Medullosa* was usually polystelic and the species *M. anglica* had three or four steles surrounded by a layer of periderm. Each stele represents that of Heterangium. The outer cortex is, as well, characterized by the vertical selerenchyma bands.

***Myeloxylon* (Wedullosa petiole)**:

The stem *Myeloxylon* was about 8 cm. In diameter and its petioles were about 4 cm in dimeter. The petiole had numerous vascular bundles. These were collateral (i.e. xylem and phloem on one radius) the phloem is towards the outside and the protoxylem is exarch. Vertical sclerenchyma strands existed in the outer cortex as in the stem.

Trigonocarpus **(Medullosa seed):**

The stem of *Medullosa* is known as *Trigonocarpus* when preserved in the form of comperssion and as *Pachytesta* when petrified. It was a much larger seed; the length was between 3 and 11 cm. And the width between 1,5 and 6 cm. The megaspore is surrounded by the nucleus which is completely fused without inner integument. The outer flashy layer called sarcotes, in the upper part of the seed the sarcotesta extended forming two wings.

Pollen grains (icrospores) must have passed through the microplye to the pollen chamber.

Bennettitales and Cycadales

(Cycadophytes)

Members of the two orders are known together as the Cycadophytes. Most probably they evolved from the previous order Cycadofilicales. Bennettitales includes only fossil plants that were flourishing in the Jurassic age.

Class: Cycadopsida

Order: Pteridospermales (Cycadofilicales or seed forms)

Fam.: Medullosaceae

e.g.: *Medullosa*

C Y C A D A L E S

Cycadaceae

Members of this family were more abundant and more flourishing during the Lower Cretaceous agte than they are today. The family includes a number of genera the most important of which is the sago palm, *Cycas revoluta* which is known as “the living fossil” for its primitive characters.

Cycas revoluta

Cycas plants live several hundred years and may reach 3 or 4 meters in height. *Cycas* looks like a palm plant. The trunk is normally unbranched, however, certain cultivates varieties produce lateral adventitious branches and this gives the trunk the appearance of being dichotomously branched. The surface of the old stem is completely covered with hard woody leaf bases. Leaves are formed in a close spiral succession. Young leaves are circinately coiled like fern frons. Leaves are pinnate; each pinna has a single unbranched midrib. *Cycas* is dioecious; there is a male and a female plant. The cones of *Cycas* are terminal on the main stem. In the female strobilus the vegetative apex is not affected and continues its growth directly through the strobilus but in the male an axillary bud is formed at the base of the strobilus which displaces it laterally and becomes the new stem apex and this gives the male cone the appearance of being lateral and not terminal.

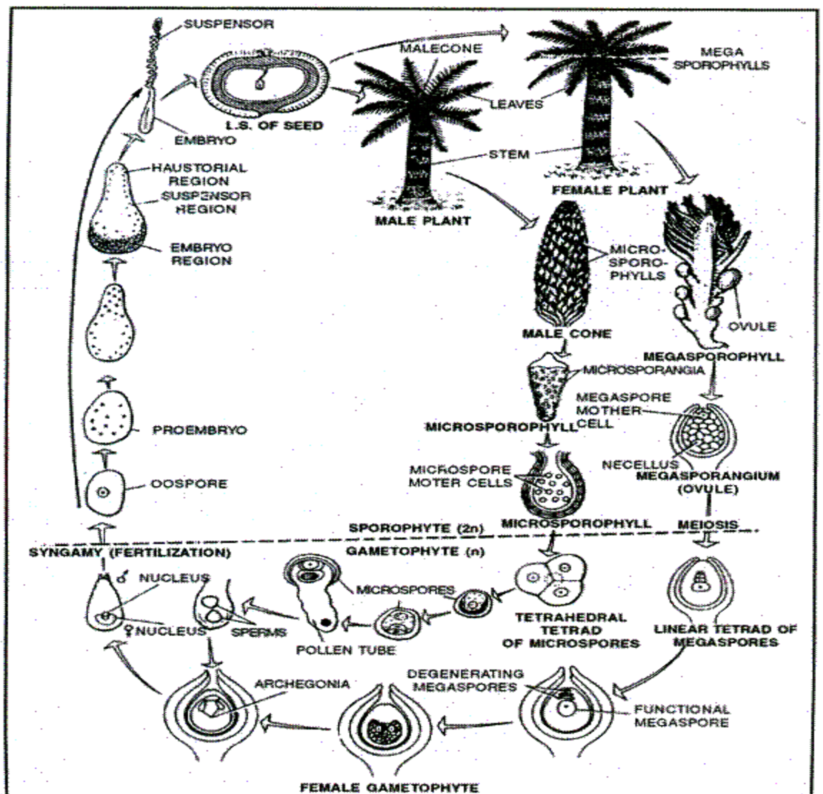
The male cone

The male cone may be 50 cm. Long. Its axis bears spirally arranged microsporophylls. These are woody and hard, each bearing several hundred sporangia on its lower surface. The sporangia are very crowded, so, they appear continuous, but, they are grouped into sori. Each sorus consists of 3 to 6 sporangia arising from a central papilla. Each sporangium consists several thousand spores (pollen grains). The pollen grain germinates before its liberation from the sporangium; it cuts off a single prothallial cell (representing a male gametophyte), an antheridial cell and a tube cell. Pollen grains are then shed at this stage of development.

The female cone, Pollination and fertilization:

There is no properly organized cone: only a crown of megasporopylls formed in acropetal succession, Leaving the apical meristem unaffected, to grow on and form future leaves and sporophylls. The megasporophyll is about 15 to 20 cm. Long. The upper part of a megasporophyll is pinnate like a sterile leaf and tapers to a sharp point. On the lower half there are two lateral rows of ovules, apparently replacing the pinnae on this part the rachis. The whole sporophyll is coverd densely with hairs. *Cycas* ovules are the largest in the plant world; they may be as large as a hen's egg. The structure of the ovule is best seen in a longitudinal section. There is an embryo sac (= megaspore) with prothallus, archegonial chamber at its top. The embryo sac is surrounded by a nucleus (= indehiscent sporangium) which is fused to the integument except at its upper part which forms a beak with a pollen chamber. The integument consists of a stony layer (sclerotest) with flashy layers (sarcotesta) both outside and inside it. There is a narrow micropyle.

A drop of a mucilaginous fluid fills the micropylle and exudes as a pollination drop outside the ovule. In this drop pollen grains are caught and as the drop dries up, pollen grains are down into the pollen chamber. Pollen grains germinate; the antheridial cell divides into a stalk cell and a body cell which together represent an antheridium. The tube cell grows into a pollen tube, but this is not an agent of fertilization as it is in angiosperms. The pollen tube of *Cycas* is a simple untrition haustorium, it penetrares the nucellus and gradully digests and breaks down the nuclear tissues above the archegonial chamber. The body cell then enlarges enormously and finally divides producing two antherozoids. *Cycas* antherizoids are multiciate and are the largest male cells in the plant kingdom. The osmotic pressure causes the pollen tube to burst and discharge its fluid content including the two antherozoids into the archegonial chamber. When the antherozoid touches a neck cell it is sucked violently into the inside of the archegoium and fertilizes the ovum. The zygote develops into an embryo. Seeds of *Cycas* have no resting period; they germinate directly giving new sporophytes.



Diplontic life cycle of *Cycas*.

Order: Ginkgoales

The order Ginkgoales comprises many fossil species, but, it is represented by a single living genus. This genus is monotypic, i.e., it has only one species; namely Ginkgo biloba, Ginkgo resembles *Cycas* in the formation of multiciliated antherozoids which is considered to be a primitive character.

Order: CONIFERALES

The largest of them are the *giant sequoia* and *redwoods,* which can grow as tall as a 30-story skyscraper. A 4,800-year-old pine from California is the oldest living tree known. Other conifers are *pines, firs, spruces, larches, cedars, junipers, cypresses* and *yews.* Some taxonomists classify yews into a separate class, because it has more developed features than the other conifers.

One megaspore develops into the female gametophyte which contains thousands of cells and is considerably larger than the male gametophyte. Conifers produce “exposed” seeds in **woody cones**. The naked seeds have many cotyledons. Conifers are trees or shrubs with needle- or scale like leaves. The vascular tissue that makes up much of the trunk of a conifer- The tissue we refer to as wood- is composed of dead, lignified *tracheids* and alive *xylem parenchyma.* They don’t contain xylem vessels. Most conifers are **evergreen**; only a few, including larches, are deciduous. Conifers form large forests in many regions of the world and have many adaptations to cold or dry habitats. The needle-like leaves provide a reduced surface for transpiration. They are covered with a thick waxy cuticle and have their stomata sunken in the epidermis, which helps retain water. The bark of trees also helps reduce water loss by forming a protective covering over the stem. Being evergreen means that these trees can being photosynthesis in the early spring as soon as the temperature warms. The branches and needles of conifers are extremely flexible. They allow snow and ice to slide off the tree, rather than build up and break the branches, especially if the tree is cone- shaped.

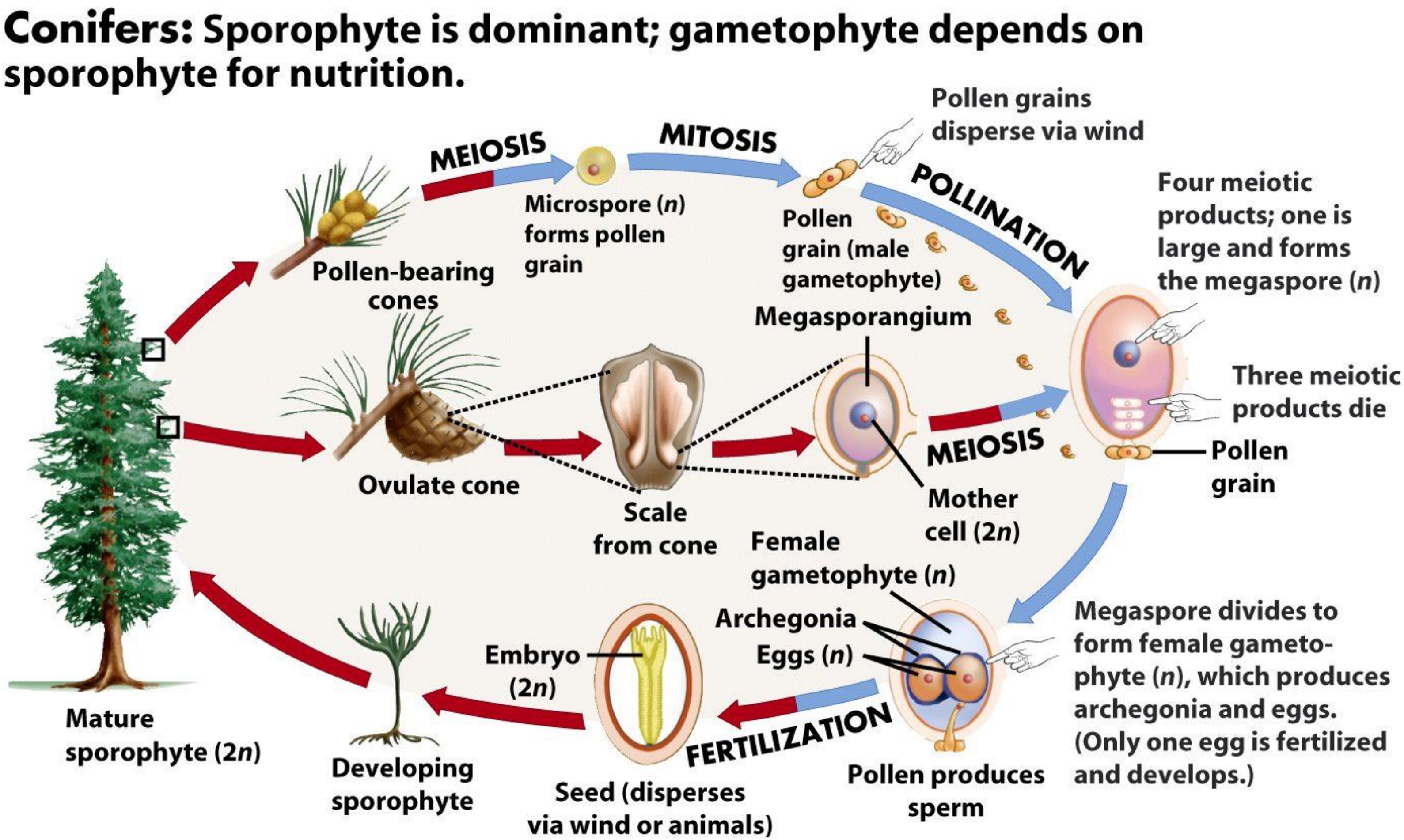
Conifer leaves are needle or scale-like. They result from the downsizing of true megaphylls and unlike the microphylls of lower plants they are connected to the vascular system of the stem. Conifers are often large and can dominate the plant life in some ecosystems because their stems continue to expand in width as well as length throughout the life of the plant. The older parts of the stem become woody, which provides a further distinction from the seedless vascular plants of which there are no surviving woody representatives. The wood of conifers is more primitive than that in angiosperm trees. It contains tracheids but no vessel elements, and there is generally less ray parenchyma in conifer wood than in dicot wood.

Conifer life cycle

Microspores and megaspores are formed on sporophylls in male and female cones respectively. Each scale in the male cone has two sporangia in which meiosis occurs to produce tetrads of spores, just as in a fern sporangium. Male gametophyte development starts in the microspore (or pollen grain) before it is shed. Mitotic divisions result in two prothallial cells, a tube cell and a generative cell. The sporangium breaks open to shed the immature gametophytes which are carried on the wind and may chance to arrive at a sporophyll on a female cone.

The ***life cycle of a conifer*** with the asexual and sexual generations. The tree, the diploid ***sporophyte*** bears both male and female cones with the reproductive structures, usually on separate branches. The small **male cones** made up of papery scales appear in clusters at the tips of the branches. By meiosis microspores are produced, which develop into small, light **pollen grains** with sperm representing the ***male gametophytes***. The open cones shed clouds of yellow, dust like pollen grains into the wind. **Female cones** are much larger with woody scales, on which macro/megaspores appear by meiosis. The growth into few-cell large **ovules** with the egg representing the **female gametophytes.** On each cone scale, two ovules develop into two seeds, which stay on the tree until they have matured. This is a period that may take from several months up to two years. For the development of seeds, **pollination**, the transferring of pollen grains from the male cones to the ovules must first occur. Gymnosperms are wind pollinated as the wind-blown pollen grains fall on the open scales of the female cone. After pollination, the female cones close up tightly.

Fertilization takes place when the sperm of the pollen fuses with the egg of the ovule and a diploid zygote is produced. The zygote grows into an *embryo* with many cotyledons, which together with storage food and a **seed** coat make up a seed. There are two "naked" seeds produced on the upper surface of each female cone scale and when they are mature the female cone opens, releasing the seeds. When the conditions are favorable, the seed germinates into a *seedling*, a **young sporophyte**. Observer that during the alternation of the two generations, the sporophyte is dominant while the pollen (the male gametophyte) and the ovule (the female gametophyte), both nourished by the sporophyte, are small structures.


Conifers: Sporophyte is dominant; gametophyte depends on sporophyte for nutrition.
MEIOSIS
MITOSIS
Pollen grains disperse via wind
POLLINATION
Microspore (n) forms pollen grain
Pollen grain (male gametophyte)
Four meiotic products; one is large and forms the megaspore (n)
Pollen-bearing cones
Megasporangium
Three meiotic products die
Ovulate cone
MEIOSIS
Pollen grain
Scale from cone
Mother cell (2n)
Female gametophyte (n)
Archegonia
Eggs (n)
Megaspore divides to form female gameto-phyte (n), which produces archegonia and eggs. (Only one egg is fertilized and develops.)
Embryo (2n)
FERTILIZATION
Mature sporophyte (2n)
Developing sporophyte
Seed (disperses via wind or animals)
Pollen produces sperm

Fam. Pinaceae

There are about 75 sp. of this genus. It grows a on the slopes where rain water is easily drained off. It is an over green tree. The tree is the “sporophyte”. It is differentiated into leaves, stem, and root. The *Pinus* tree carries lateral branches arranged in whorls in acropetal succession and this gives the whole tree its familiar cone shape. The stem is covered with scale leaves in the axils of which are buds. These buds give rise either to long shoots, similar to the main stem, or to dwarf shoots. These dwarf shoots carry the green needle- shaped leaves. The number of these green needles varies according to species. *Pinus* is monoecious; the carries both male and female cones. The female cones are usually borne on the upper branches of the tree whereas the male cones are borne on the lower branches.

The male cone:

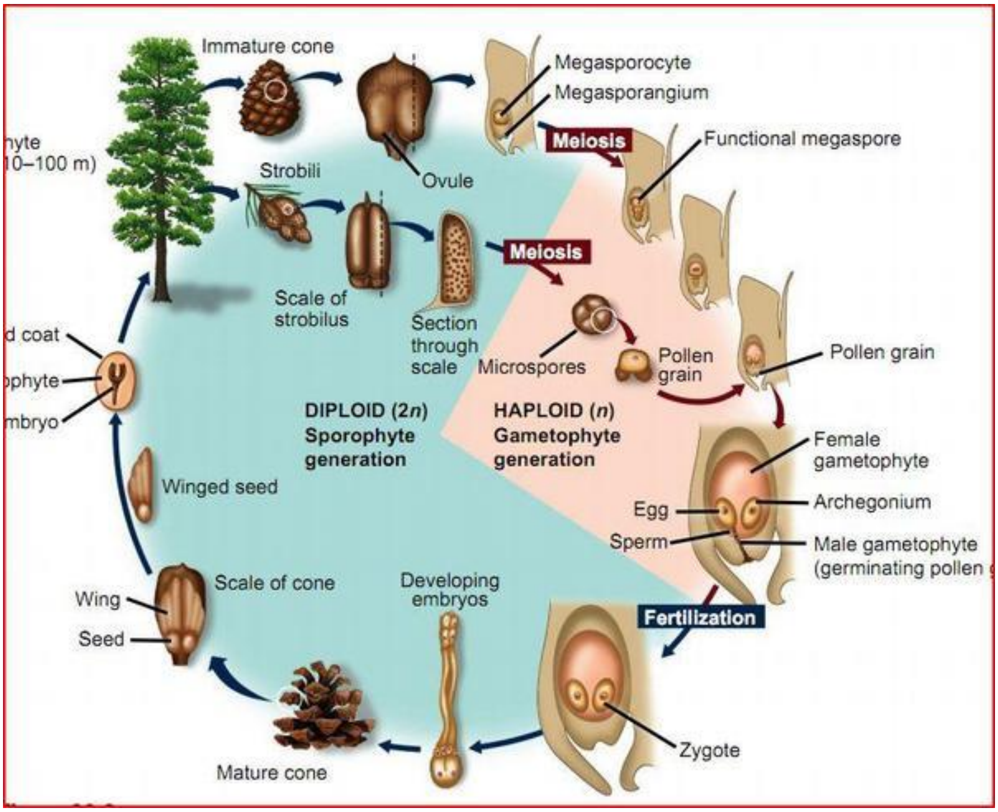
Male cones are found in clusters just behind the growing point of new young lateral branches. Each male cone arises in the axil of a scales (=microsprophylls). Each staminate scale consists of a stalk which is perpendicular to the cone axis. This stalk terminates in a flattened head, part of which projects upwards and overlaps the sporophyll above, the other part turns down and covers the two pollen sacs (= microspores) which are attached along the underside of the staminate scale. The pollen sacs contain pollen grains (= microspores); these start germination before they are liberated from the saes through the dehiscence.

Summary of the life cycle of pinus:

Pinus tree is the sporophyte. It carries male and female cones. The male cones are in clusters and replacing “dwarf shoots”. The female cones are generally singly borne and replacing along branch. Microsporophylls in the cones are spirally arranged on the main axis of the cone. The overlap with each other on the lower surface filled with winged microspores (pollen grains). The pollen grain divides to give the gametophyte as follows:

Division of the nucleus of the pollen grain results in the formation of two nuclei, one of them is the first vegetative cell “, the second divides to a “second” vegetative cell and an “antheridial nucleus” which gives a “generative cell” and a tube cell”, the “generative cell” divides to give “two male nuclei of unequal size. All these are found in a pollen tube ready to reach a female gametophyte to fertilize the egg of the archegonium. Megasporophylls in the o cones are of “ovulifernes scales” and “bract scales” Each “ovuliferous scale” beass two inverted ovules. The ovule is composed of an integument (“3 layers, the middle stony), micropyle (limited by the part of the integument free grom the nucleus, nucleus, and megaspore. The megaspore develops the female gametophyte generally with two archegoia” at its top.

The large o nucleus fertilize (fuses with) the egg nucleus. The diploid zygote is formed. It divides to give four tiers of cells, the lowest gives the “suspensor” the next is the rosette tier, and the upper most is of four free nuclei. The “suspensor” elongates, the embryo is differentiated into a radicle, a hypocotyl, and epicotyl and cotyledons. As a result a tather bard seed is formed. The seed is “naked” and composed of a testa (the hard integument layer), a tegmen (the inner integument fleshy layer), the “endosperm” (the nused portion of the o gametophyte), the remnants of the “nucleus” at the top, and the embryo (enclosed within endosperm). The seed is winged to help in dispersal by winds. Its germination is epigeal. It develops into the mature sporophyte (*Pinus* tree). Each grain becomes differentiated into the prothallial cells (representing a male gametophyte) and large antheridial cell. Each pollen grain is supplied with two large air sacs (which help in its dispersal by the wind).



The Female Cone:

The female cone arises in the axil bears spirally arranged carpals (=megasporophylls). Each carpel consists of a large ovuliferous scale and a small bract scale. Each ovuliferous scale bears two ovules on its upper surface. Ovules are inverted; this means that the micropylle is directed towards the cone axis. The ovule, as shown in L.S., consists of an embryo sac, containing archegonia, surrounded by a nucleus to which is fused an in tegument, The latter consists of three layers; a middle stony layer, inner and outer fleshy layers. There is a micropyle, a nuclear beak but no pollen or archegonial chambers.

Pollination and Fertilization:

Pollination is the transference of the pollen grains to the ovule and this is affected by the wind. A drop of a mucilaginous fluid exudes from the micropylle. In this drop pollen grains are caught. Before pollination the ovuliferous scales of the female cone are tightly closed, then they open for pollination in spring by the action of the bract scales and, after pollination they become closed again and remain so until the seeds are ripe when they open again for seed dispersal. The pollination drop dries up with drawing the pollen grains through the micropyle to the apex of the nucleus. The antheridial cell if the pollen grain divides giving a generative cell and a tube cell. The latter forms a pollen tube which penetrates through the nucleus and stopes before reaching the archegonium until next spring when it starts its activity and elongates again meanwhile the generative cell divides into a stalk cell and a body cell. The body cell forms two male cells. The nucleus of the pollen tube, the stalk cell and the two male cells, all pass down to the apex of the pollen tube. The tip of the pollen tube penetrates the neck of an archegonium releasing the four nuclei inside the archegonium. Three nuclei disintegrate and only one male nucleus remains to unite with the nucleus of the egg and a diploid zygote is formed.

Embryo and seed:

The zygote develops into an embryo, which is a young sporophyte. The embryo consists of a radicle (towards the micropyle), a plumule (directed downwards), and a number of cotyledons (between 3 and 17 according to species). The embryo is surrounded by the remains of the female prothallus which form the endosporm of the seed. The two fleshy layers of the integument dispersal but the stony layer thin wing derived from the upper surface of the ovuliferous scale. This wing helps in seed dispersal by the wind. When the seeds are mature, they dry brown woody ovuliferous scales spring apart explosively with cracking sounds, the separation of the woody scales is due to renewed growth in the cone axis. The seeds are liberated and are borne away by the wind. When they fall in suitable place they start germination almost at once. The radicle is the first organ to appear outside the testa it grows downwards. The hypocotyl elongates carrying means that germination in *Pinus* is epigeal. The seedling continues to grow to give a tree (Sporophyte).

In *Pinus* there is the same alternation of generation as in all previous plants. However, here the gametophytes are very much reduced, they are entirely dependent upon the sporophyte for food and they are kept within the spores. The pollen tube grows slowly through a pore in the integument of the megasporangium and eventually the generative cell divides to produce two sperm cells. One of these fertilizes an egg cell to produce a zygote. Usually only one archegonium will produce a zygote in each megagametophyte so that there is only one embryo per seed.

The mature seed consists of three generations of tissues: maternal sporophyte tissue (seed coat and nucleus), gametophyte and daughter sporophyte (embryo) - After about two years the mature seeds are shed.

Conifer seedlings have several needle-like cotyledons in a whorl and the seedlings produce scattered leaves until adult foliage develops. Unlike the seedless vascular plants, conifers are more prevalent in cooler regions and in xeric habitats. Because of their leaf and stem anatomy they are better adapted to drought than most broadleaved trees. In addition many conifers have evolved cold hardiness so that above ground structures can persist even in harsh environments. The bristlecone pines that grow on mountain ridges in California are an extreme example.Conifer leaves are needle or scale-like. They result from the downsizing of true megaphylls and unlike the microphylls of lower plants they are connected to the vascular system of the stem.

Conifers are often large and can dominate the plant life in some ecosystems because their stems continue to expand in width as well as length throughout the life of the plant. The older parts of the stem become woody, which provides a further distinction from the seedless vascular plants of which there are no surviving woody representatives. Of course conifers are also important economically as a tree crop for pulp and timber. Their ability to grow in areas that are unsuitable for other crop production is an asset for this purpose. Similarly, since most (though not all) conifers are evergreen they are valued as landscape plants, particularly in areas like Ohio where few broadleaved evergreens can withstand the winter. The evergreen habit does have its disadvantages since premature leaf death caused by pollution, disease or insect attack can be more damaging than in plants which produce a complete new flush of leaves each spring.

Cycadophyta

Cycads or similar plants were the food of herbivorous dinosaurs and the fate of both of these groups of organisms was probably closely linked. They survive as a few species of tropical palm-like trees, including one which is native to the USA, *Zamia pumila* the cardboard palm. This is found on sandy soils in Florida and is sometimes grown as a foliage plant. *Cycas* species are larger and are often used as ornamentals in tropical areas. The cycads can be viewed as beneficial as they form symbiotic associations with nitrogen fixing bacteria, but they have also been the subject of extermination programs since they are highly toxic to livestock. Their life cycle is rather similar to the conifers' but they have free-swimming sperm (a primitive feature) and sometimes they are pollinated by insects (an advanced feature

Seed Evolution

Bryophytes are homosporons plants, the sporophyte produces spores which are all alike and of one size. These spores, on germination, give rise to gametophytes which bear both antheridia and archegonia. In the first class of Pteridophytes; Psilopside, all plants, whether fossil or living, are homosporous. Some members of the lycopsida are homosporous (e.g. *Lycopodium*) while others are heterosporous (e.g. *Selaginella*). Most members Sphenopside are homosporous, however, certain *Calamites* species are heterosporous. Most members of the Pteropsida are homosporous, but, the water ferns are heterosporous. In heterosporous plants there are microsporangia containing large numbers of microspores which on germination give rise to male gametophytes, and megasporangia which contain female gametophytes. Heterospory is usually regarded as the first importantstep towards seed evolution.

The steps that may have lead to the evolution of the seed may be summarzed as follows;

1- Heterospory (e.g. *Lepidodendron* and *Selaginella*).

2-Reduction of the number of megaspores within a megasporangium to one as in *Selaginella* sulcata and *Selaginella rupestris*.

3-Retention of the megaspore within the dehisced megasporangium, as what happens in *Selaginella rupestris*, where fertilization takes place while it is still inside the dehisced megasporangium and later young sporophyte.

4-Retentionof the megaspore within the indehiscent megasporangium. The megaspore here is referred to as the "embryo sac" inside which the female prothallus and a certain number of archegonia develop. The megasporangium is indehiscent, i.e., it does cot open and surrounds the embryo sac completely and is referred to as the "nucellus". An additional cover the "integument" surrounds the nucellus. It is believed that the integument represents some modified pinules. The embryo sac, the nucellus, and the integument are all known together as the "ovule, and after fertilization and maturity it is called the "seed" Examples of this type of ovale may be seen in Pteridospermales e.g. *Lagenostoma*, *Physostoma* …ect. In these ovules, also, the upper free part of the nucellus forms a chamber for the reception of the microspores. The latter, in seed plants, are referred to as "Pollengrains". The seed of *Cycas*, also, represents this same level of evolution where we have a "pollen chamber" at the apex of the nucellus.

In the following step of evolution the pollen grain develops a pollen tube which penetrates through the nucellus and elongates until it reaches the archegonium, hence, there is no need for pollen chamber. This level of evolution is represented in *Pinus*, its ovule has no pollen chamber but there is a pollination drop which is responsible for the capture of the pollen grains. The embryo of

Pinus which is in fact a new young sporophyte is on the parent sporophyte. In Pteridophytes and Gymnosperms, the sporophyte is the dominant generation, whereas, the gametophyte is usually thalloid and simple (e.g. *Lycopodium* and *Adiantum)*. However, one may notice that seed evolution is accompanied by more reduction in the structure of the gametophyte; meanwhile, the process of pollination is in advancement. (Thus in *Selaginella* (as shown in the figures) we see, for the first time, a male gametophyte developed within the microspore and represented by a single prothallial cell and an antheridium which produces a number of flagellated spermatozoids within the megaspore wall, it bears archegonia towards which the antherozoids swim for fertilization. In *Cycas* the male gametophyte is also represented by one cell, but, the antheridium of *Cycas* produces only two antherozoids which are multiciated, however, they do not have to swim since they are liberated from the pollen tube in the archegonial chamber and then by osmotic pressure differences they are sucked violently inside the archegonia. In *Pinus*, no spermatozoids are formed, but, there are 2 male cells and the pollen tube is well developed and is responsible for the transference of the male nucleus from the pollen grain to the inside of the archegonium.

The highest level of evolution concerning pollination, fertilization, and seed structure is to be found in the flowering plants “the Angiosperms”. These plants are also characterized by

1) the possession of xylem vessels and phloem companion cell. **2)** The seed of angiosperms is completely surrounded by the carpel (= megasporophyll). This means that (the ovule is not exposed directly to the atmosphere) but, it is surrounded and protected by the carpel. Hence, the 3) pollen grains do not fall directly upon the ovule (as in Gymnosperms) but they are caught by a special receptive part of the carpel known as the "Stigma". The pollen tube, therefore, has to travel a long distance, in case of angiosperms, from the ovule inside the ovary. The carpels, in the majority of angiosperms, are surrounded by the male organs, which are called stamens. Each stamen consists of a filament terminating in another. The latter contains 4 pollen sacs (=4 microsporangia) carpels and stamens are usually surrounded by petals and sepals or by a perianth and all are borne on a receptacle. This structure is the flower. It is found only in angiosperms, hence, they are also called the "flowering plants".

Pollination in angiosperms, i.e., the transference of the pollen grains from the pollen sacs to the stigmas is usually achieved by wind or insects and rarely by water. When a pollen grain rests on a stigma it starts germination by the production of a pollen tube. This penetrates through the style until it reaches the ovule then it passes through the micropylle and penetrates the nucleus until it reaches the embryo sac. Meanwhile the nuclei one of which unites with the egg is found inside the embryo sac and there are archegonia. This means that, in Angiosperms, also there are two generations; a sporophyte and a gametophyte. In this respect the life- cycle of angiosperms is similar to that of Bryophytes, Pteridophytes, and Gymnosperms, but, in angiosperms the gametophyte almost disappears; it is represented only by the two male nuclei and the egg, whereas the sporophyte is highly organized and complicated in structure

Ginkgophyta

This is a monotypic division, a single species of a single genus, *Ginkgo biloba* the maidenhair tree. Several relatives are known as fossils dating back to Pennsylvanian times. *Ginkgo biloba* was preserved in the gardens of Buddhist monasteries in China and Japan where it was encountered by Westerners in the eighteenth century. It has turned out to be a valuable street tree because of its unusual foliage and tolerance of pollution.

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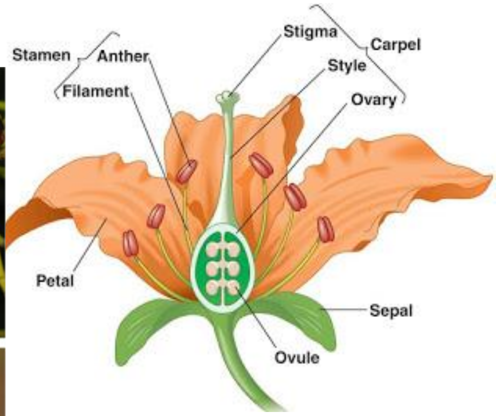
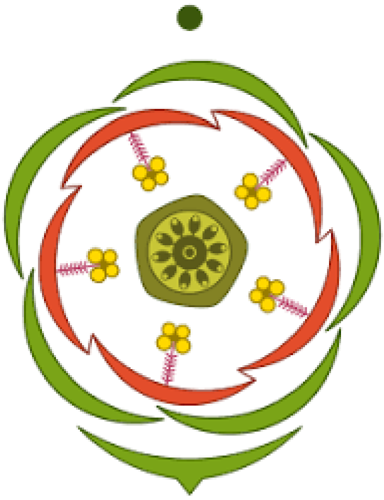
Taxonomy of Flowering Plants (I)





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PART (1) Flower morphology

Flower

sometimes known as a bloom or blossom, is the reproductive structure found in flowering plants (plants of the division Magnoliophyta, also called angiosperms). The biological function of a flower is to effect reproduction, usually by providing a mechanism for the union of sperm with eggs. Flowers may facilitate outcrossing (fusion of sperm and eggs from different individuals in a population) or allow selfing (fusion of sperm and egg from the same flower). Some flowers produce diaspores without fertilization (parthenocarpy). Flowers contain sporangia and are the site where gametophytes develop. Flowers give rise to fruit and seeds. Many flowers have evolved to be attractive to animals, so as to cause them to be vectors for the transfer of pollen.

Morphology

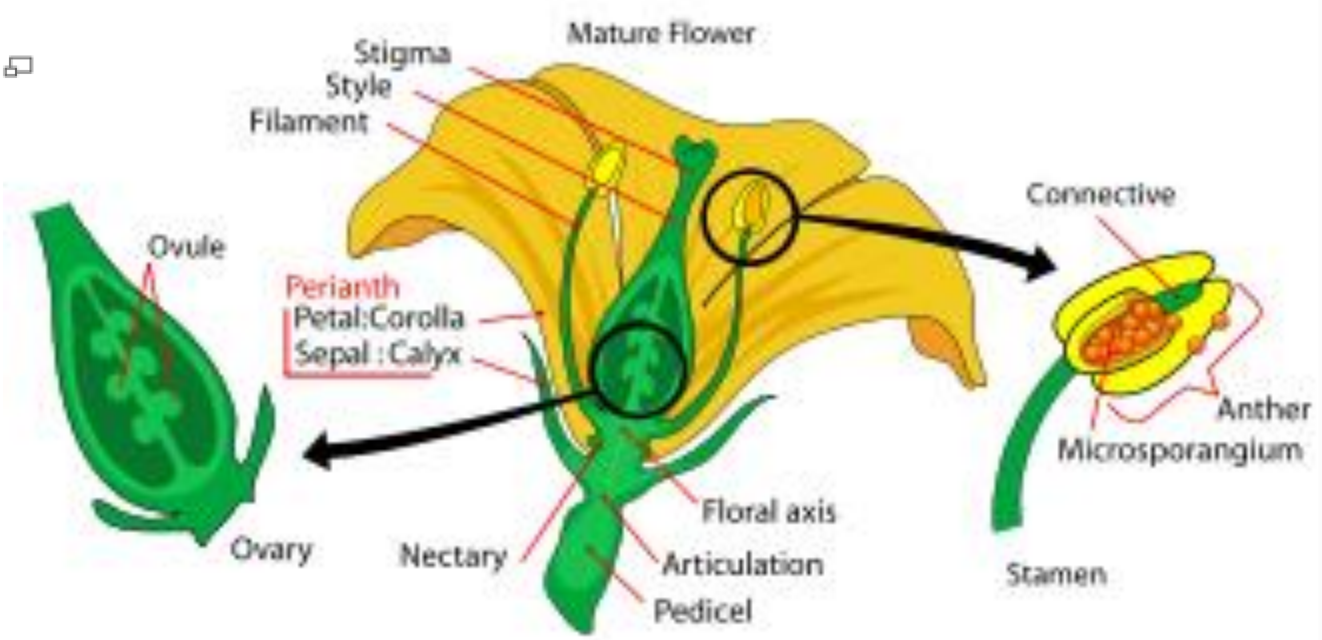


Diagram showing the main parts of a mature flower

A stereotypical flower consists of four kinds of structures attached to the tip of a short stalk. Each of these kinds of parts is arranged in a whorl on the receptacle. The four main whorls (starting from the base of the flower or lowest node and working upwards) are as follows:

- ***Calyx***: the outermost whorl consisting of units called *sepals*; these are typically green and enclose the rest of the flower in the bud stage, however, they can be absent or prominent and petal-like in some species.
- ***Corolla*****:** the next whorl toward the apex, composed of units called *petals*, which are typically thin, soft and colored to attract animals that help the process of pollination.

Collectively the Calyx and Corolla form the Perianth (see diagram).

- ***Androecium*** (from Greek *andros oikia*: man's house): the next whorl (sometimes multiplied into several whorls), consisting of units called stamens. Stamens consist of two parts: a stalk called a filament, topped by an anther where pollen is produced by meiosis and eventually dispersed.

- ***Gynoecium*** (from Greek *gynaikos oikia*: woman's house): the innermost whorl of a flower, consisting of one or more units called carpels. The carpel or multiple fused carpels form a hollow structure called an ovary, which produces ovules internally. Ovules are megasporangia and they in turn produce megaspores by meiosis which develop into female gametophytes. These give rise to egg cells. The gynoecium of a flower is also described using an alternative terminology wherein the structure one sees in the innermost whorl (consisting of an ovary, style and stigma) is called a pistil. A pistil may consist of a single carpel or a number of carpels fused together. The sticky tip of the pistil, the stigma, is the receptor of pollen. The supportive stalk, the style, becomes the pathway for pollen tubes to grow from pollen grains adhering to the stigma. The relationship to the gynoecium on the receptacle is described as **hypogynous** (beneath a superior ovary), **perigynous** (surrounding a superior ovary), or **epigynous** (above inferior ovary).

Although the arrangement described above is considered "typical", plant species show a wide variation in floral structure. These modifications have significance in the evolution of flowering plants and are used extensively by botanists to establish relationships among plant species.

The four main parts of a flower are generally defined by their positions on the receptacle and not by their function. Many flowers lack some parts or parts may be modified into other functions and/or look like what is typically another part. In some families, like Ranunculaceae, the petals are greatly reduced and in many species the sepals are colorful and petal-like. Other flowers have modified stamens that are petal-like, the double flowers of Peonies and Roses are mostly petaloid stamens. Flowers show great variation and plant scientists describe this variation in a systematic way to identify and distinguish species.

Specific terminology is used to describe flowers and their parts. **Many flower parts are fused together;**

Fused parts originating from the same whorl are **connate**, while fused parts originating from different whorls are **adnate**, parts that are not fused are **free**. When petals are fused into a tube or ring that falls away as a single unit, they are sympetalous (also called **gamopetalous.**) Connate petals may have distinctive regions: the cylindrical base is the tube, the expanding region is the throat and the flaring outer region is the limb. A sympetalous flower, with bilateral symmetry with an upper and lower lip, is **bilabiate**. Flowers with connate petals or sepals may have various shaped corolla or calyx including: campanulate, funnelform, tubular, urceolate, salverform or rotate.

Many flowers have a symmetry. When the perianth is bisected through the central axis from any point, symmetrical halves are produced, forming a radial symmetry. These flowers are also known to be actinomorphic or regular, e.g. rose or trillium. When flowers are bisected and produce only one line that produces symmetrical halves the flower is said to be irregular or zygomorphic, e.g. snapdragon or most orchids.

Flowers may be directly attached to the plant at their base (sessile—the supporting stalk or stem is highly reduced or absent). The stem or stalk subtending a flower is called a peduncle. If a peduncle supports more than one flower, the stems connecting each flower to the main axis are called pedicels. The apex of a flowering stem forms a terminal swelling which is called the *torus* or receptacle.

Gynoecium

Gynoecium (from Ancient Greek γυνή, *gyne*, meaning *woman*, and οἶκος, *oikos*, meaning *house*) is most commonly used as a collective term for the macrosporophylls (megasporophylls). In the seed plants, these are the **carpels**. The gynoecium occupies the apex of the flower, and in many cases it may also include other parts of the flower. While the angiosperms enclose their ovules in carpels, the gymnosperms have ovules exposed to the air on the sporophyll margin.

1- Carpels

Traditionally a carpel is defined as an appendage that bears and encloses ovules. Carpels are thought to be phylogenetically derived from ovule-bearing leaves or leaf homologues (megasporophylls), which evolved to form a closed structure containing the ovules. They do this by folding and fusing at their edges to form a chamber in which the ovules develop.
The term gynoecium is useful because it refers to the ovule-producing structure in a flower, whether it is a single carpel, multiple unfused carpels or multiple "fused" carpels. In many flowers, the gynoecium is the innermost whorl of structures and is surrounded by the androecium (stamens) and then by the perianth (all the petals and sepals).
Flowers that bear a gynoecium but no androecium are called **carpellate**.
Flowers lacking a gynoecium are called **staminate**.
A gynoecium may consist of a single carpel, multiple distinct (unfused) carpels or multiple connate ("fused") carpels. Each carpel typically contains one or more **ovules**. During pollination, pollen is deposited on the gynoecium (typically on a **stigma**). Successful germination of pollen and growth of pollen tubes results in fertilization of ova. There is typically one ovum in each ovule. After fertilization, ovules develop into seeds, and the gynoecium forms the pericarp of the associated fruit. Gynoecium development and arrangement is important in systematic research and identification of angiosperms, but can be the most challenging of the floral parts to interpret.

Centre of a *Tulipa aucheriana* (Tulip) showing multiple carpels (a compound pistil) surrounded by stamens.

2- Gynoecium

A monocarpous (single carpel) gynoecium in context. The gynoecium (whether composed of a single carpel or multiple "fused" carpels) is typically made up of an ovary, style, and stigma in the center of the depicted flower.

Carpels are the building blocks of the gynoecium. Gynoecia (whether composed of a single carpel or multiple fused carpels) typically consist of:

- The ***ovary*** (from Latin *ovum* meaning *egg*), is the enlarged basal portion which contains **placentas**, ridges of tissue bearing one or more **ovules** (integumented **megasporangia**). The placentas and/or ovule(s) may be born on the gynoecial appendages or less frequently on the floral apex, the axis of the flower.[9][10][11] To accommodate the latter case, a carpel is more appropriately defined as an appendage that encloses ovule(s) and may or may not bear them.[12][13] The chamber in which the ovules develop is called a **locule** (or sometimes cell).
- The ***style*** (from Ancient Greek meaning a *pillar*), is a pillar-like stalk through which pollen tubes grow to reach the ovary.
- The ***stigma*** (from Ancient Greek *stigma* meaning *mark*, or *puncture*), is usually found at the tip of the style, the portion of the carpel(s) that receives pollen (male gametophytes). It is commonly sticky or feathery to capture pollen.

Carpels begin as small primordia on a floral apical meristem, forming later than, and closer to the (floral) apex than sepal, petal and stamen primordia.

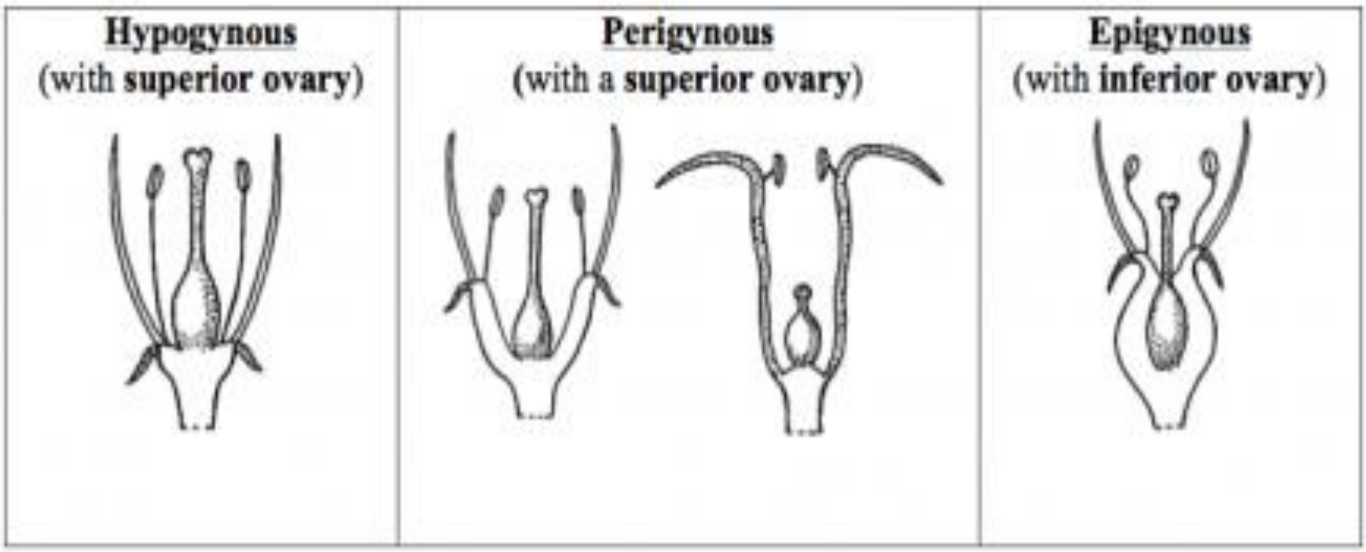
Types of gynoecia

1- If a gynoecium has a single carpel, it is called **monocarpous**.
2- If a gynoecium has multiple, distinct (free, unfused) carpels, it is **apocarpous**.
3- If a gynoecium has multiple carpels "fused" into a single structure, it is **syncarpous**..

The degree of connation ("fusion") in a syncarpous gynoecium can vary:-
1- The carpels may be "fused" only at their bases, but retain separate styles and stigmas.
2- The carpels may be "fused" entirely, except for retaining separate stigmas.
3- Sometimes (e.g., Apocynaceae) carpels are fused by their styles or stigmas but possess distinct ovaries. In a syncarpous gynoecium, the "fused" ovaries of the constituent carpels may be referred to collectively as a single compound ovary. It can be a challenge to determine how many carpels fused to form a syncarpous gynoecium. If the styles and stigmas are distinct, they can usually be counted to determine the number of carpels. Within the compound ovary, the carpels may have distinct **locules** divided by walls called **septa**. If a syncarpous gynoecium has a single style and stigma and a single locule in the ovary, it may be necessary to examine how the ovules are attached. Each carpel will usually have a distinct line of placentation where the ovules are attached.

3- Gynoecium position

Basal angiosperm groups tend to have carpels arranged spirally around a conical or dome-shaped receptacle. In later lineages, carpels tend to be in whorls.



The relationship of the other flower parts to the gynoecium can be an important systematic and taxonomic character. In some flowers, the stamens, petals, and sepals are often said to be "fused" into a "floral tube" or **hypanthium**. If the hypanthium is absent, the flower is *hypogynous*, and the stamens, petals, and sepals are all attached to the receptacle below the gynoecium. Hypogynous flowers are often referred to as having a *superior ovary*. This is the typical arrangement in most flowers.
If the hypanthium is present up to the base of the style(s), the flower is *epigynous*. In an epigynous flower, the stamens, petals, and sepals are attached to the hypanthium at the top of the ovary or, occasionally, the hypanthium may extend beyond the top of the ovary.

Epigynous flowers are often referred to as having an *inferior ovary*. Plant families with epigynous flowers include orchids, asters, and evening primroses.

Between these two extremes are *perigynous* flowers, in which a hypanthium is present, but is either free from the gynoecium (in which case it may appear to be a cup or tube surrounding the gynoecium) or connected partly to the gynoecium (with the stamens, petals, and sepals attached to the hypanthium part of the way up the ovary). Perigynous flowers are often referred to as having a *half-inferior ovary* (or, sometimes, *partially inferior* or *half-superior*). This arrangement is particularly frequent in the rose family and saxifrages.

Occasionally, the gynoecium is born on a stalk, called the gynophore, as in *Isomeris arborea*.

Part (2) Placentation

Within the ovary, each ovule is born by a placenta or arises as a continuation of the floral apex. The placentas often occur in distinct lines called lines of placentation. In monocarpous or apocarpous gynoecia, there is typically a single line of placentation in each ovary. In syncarpous gynoecia, the lines of placentation can be regularly spaced along the wall of the ovary (**parietal placentation**), or near the center of the ovary. In the latter case, separate terms are used depending on whether or not the ovary is divided into separate locules. If the ovary is divided, with the ovules born on a line of placentation at the inner angle of each locule, this is **axile placentation**. An ovary with **free central placentation**, on the other hand, consists of a single compartment without septae and the ovules are attached to a central column that arises directly from the floral apex (axis). In some cases a single ovule is attached to the bottom or top of the locule (**basal** or **apical placentation**, respectively).

The ovule

Longitudinal section of carpellate flower of squash showing ovary, ovules, pistil, and petals

The *ovule* (from Latin *ovulum* meaning *small egg*) is a complex structure, born inside ovaries in angiosperms. The ovule initially consists of a stalked, integumented *megasporangium*. Typically one cell in the megasporangium undergoes meiosis resulting in one to four megaspores. These develop into reduced megagametophytes (often called embryo sacs) within the ovule. Before fertilization, the ovule consists of one or two layers of integuments surrounding the remains of the megasporangium, called the *nucellus* and an embryo sac, with a small number of cells and nuclei, including one egg cell and two polar nuclei (which will form, together with a sperm cell, the primary endosperm nucleus). The gap in the integuments through which the pollen tube enters to deliver sperm to the egg is called the ***micropyle***. The stalk attaching the ovule to the placenta is called the ***funiculus***. Ovules are typically positioned so that the micropyle is facing the point of funiculus attachment, but other positions are found in a variety of plant groups.

The stigma and style

The style and stigma of the flower are involved in most types of self incompatibility reactions. Self-incompatibility, if present, prevents fertilization by pollen from the same plant or from genetically similar plants, and ensures outcrossing.
Stigmas can vary from long and slender to globe-shaped to feathery. The stigma is the receptive tip of the carpel(s), which receives pollen at pollination and on which the pollen grain germinates. The stigma is adapted to catch and trap pollen, either by combining pollen of visiting insects or by various hairs, flaps, or sculpturings.[18] Stigmas must distinguish and reject the pollen of other species, and in some cases are responsible for self-incompatibility.
The style of a pistil is the tube-like portion between the stigma and the ovary. It can be either long or short. In some cases the style is responsible for self-incompatibility, causing pollen tubes to fail.

Pistils

The word ***pistil*** (from Latin *pistillum* meaning *pestle*) is also sometimes used to describe each discrete unit of the gynoecium. A pistil can consist of either a single carpel (in a monocarpous or apocarpous gynoecium), in which case it is called a simple pistil, or of several "fused" carpels (in a syncarpous gynoecium), in which case it is called a compound pistil.

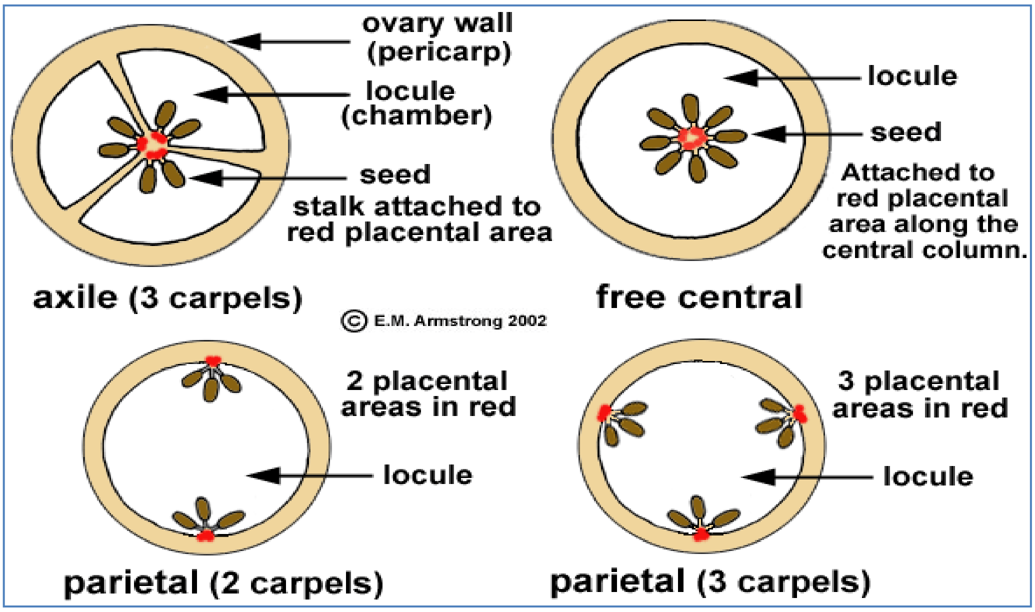
Placentation in plants

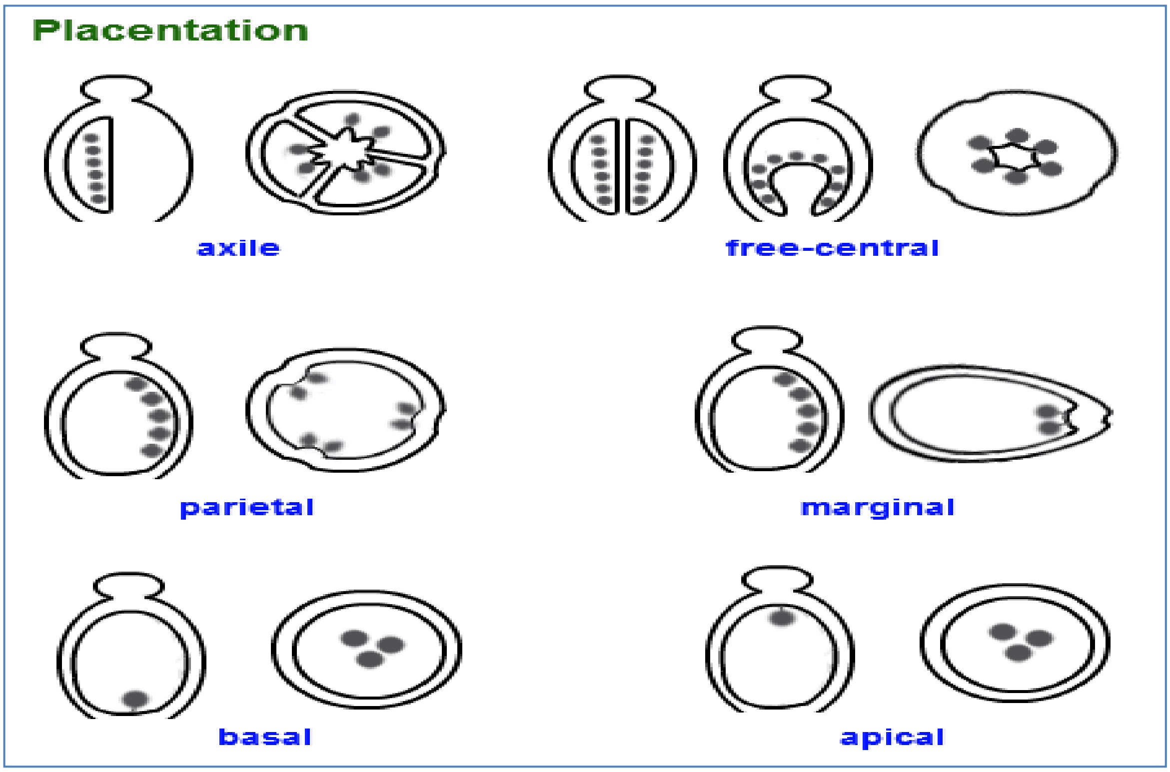
In flowering plants, placentation occurs where the ovules are attached inside the ovary.[11] The ovules inside a flower's ovary (which later become the seeds inside a fruit) are attached via **funiculi**, the plant part equivalent to an umbilical cord. The part of the ovary where the funiculus attaches is referred to as the **placenta**.
In botany, the term placentation most commonly refers to the arrangement of placentas inside a flower or fruit. Plant placentation types include:

- **Basal placentation**: The placenta is at the base (bottom) of the ovary. Simple or compound carpel.
- **Apical placentation**: The placenta is at the apex (top) of the ovary. Simple or compound carpel.

- **Parietal placentation**: The placentas are in the ovary wall within a non-sectioned ovary. Compound carpel.
- **Axile placentation**: The ovary is sectioned by radial spokes with placentas in separate locules. Compound carpel.
- **Free or central placentation**: The placentas are in a central column within a non-sectioned ovary. Compound carpel.

Marginal placentation: There is only one elongated placenta on one side of the ovary, as ovules are attached at the fusion line of the carpel's margins . This is conspicuous in legumes. Simple carpel





Part (3) POLLEN FORMATION

The **stamen** (plural *stamina* or *stamens*, from Latin *stamen* meaning "thread of the warp") is the pollen-producing reproductive organ of a flower. Stamens typically consist of a stalk called the **filament** (from Latin *filum*, meaning "thread"), and an **anther** (from Ancient Greek *anthera*, feminine of *antheros* "flowery," from *anthos* "flower"), which contains *microsporangia*. Anthers are most commonly two-lobed and are attached to the filament either at the base or in the middle portion. The sterile tissue between the lobes is called the **connective**.

The stamens in a flower are collectively called the ***androecium*** (from Greek *andros oikia*: man's house). The androecium forms a great variety of different patterns, some rather complex. It surrounds the gynoecium (carpels) and is inside the ***perianth*** (the *petals* and *sepals* together) if there is one.

1-Variation in morphology

Stamens can be free or fused to one another in many different ways, including fusion of some but not all stamens. The filaments may be fused and the anthers free, or the filaments free and the anthers fused. Rather than including two locules, one of the locules may fail to develop, or alternatively the two locules may merge late in development to give a single locule. Extreme cases of stamen fusion occur in some species of *Cyclanthera* (of family Cucurbitaceae) and in section *Cyclanthera* of genus *Phyllanthus* (family Euphorbiaceae) where the stamens form a ring around the gynoecium, with a single locule.

2- Pollen production

A typical anther contains four microsporangia. The *microsporangia* form sacs or pockets (*locules*) in the anther. The two separate locules on each side of an anther may fuse into a single locule. Each microsporangium is lined with a nutritive tissue layer called the *tapetum* and initially contains diploid pollen mother cells. These undergo meiosis to form haploid spores. The spores may remain attached to each other in a tetrad or separate after meiosis. Each microspore then divides mitotically to form an immature microgametophyte called a pollen grain.

The pollen is eventually released when the anther forms openings (dehisces). These may consist of longitudinal slits, pores, as in the heath family (Ericaceae), or by valves, as in the barberry family (Berberidaceae). In some plants, notably members of Orchidaceae and Asclepiadoideae, the pollen remains in masses called pollinia, which are adapted to attach to particular pollinating agents such as birds or insects. More commonly, mature pollen grains separate and are dispensed by wind or water, pollinating insects, birds or other pollination vectors.

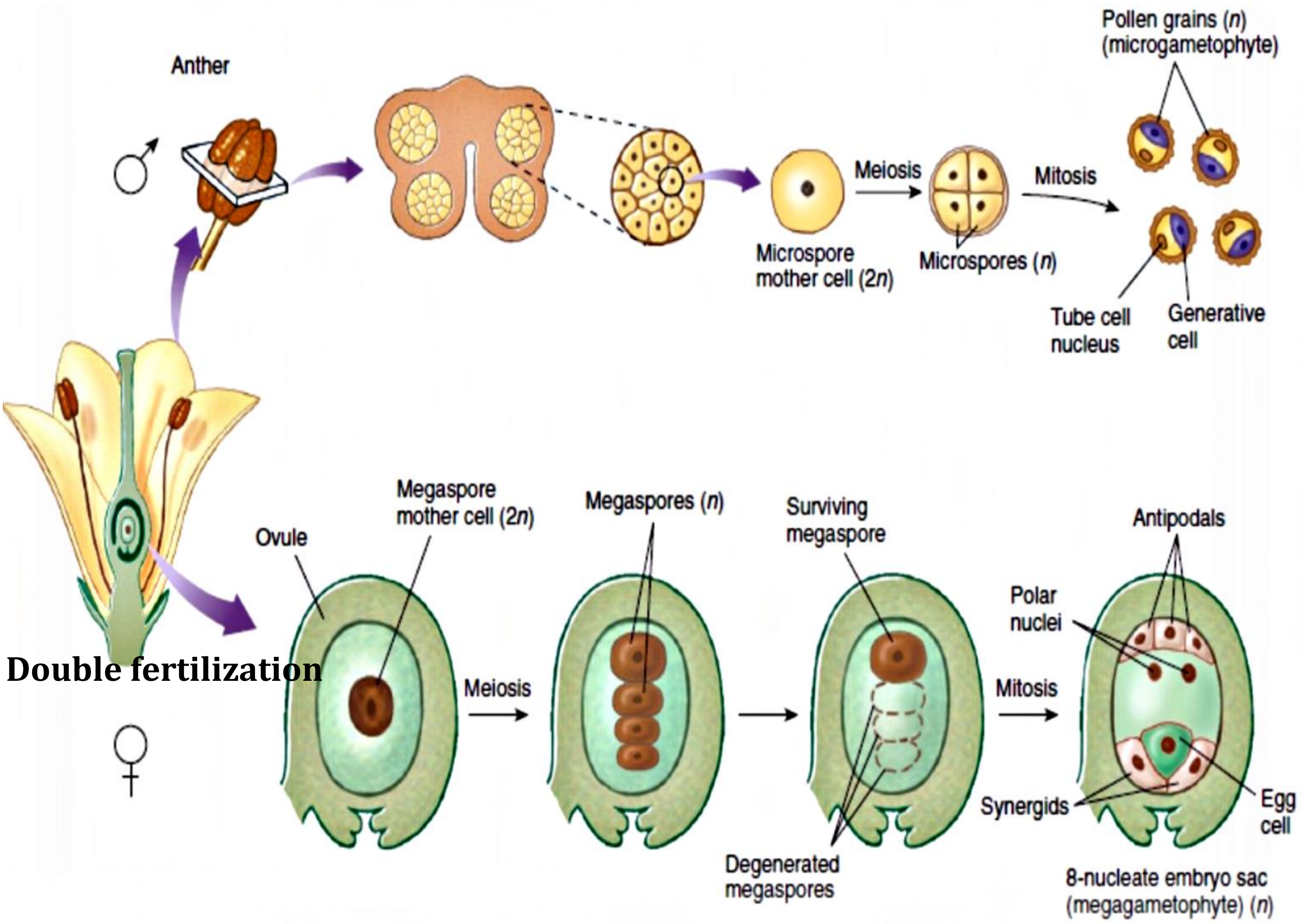
Pollen of angiosperms must be transported to the stigma, the receptive surface of the *carpel*, of a compatible flower, for successful pollination to occur. After arriving, the pollen grain (an immature microgametophyte) typically completes its development. It may grow a pollen tube and undergoing mitosis to produce two sperm nuclei.

Diadelphous
Two groups of stamens fused by the filaments.

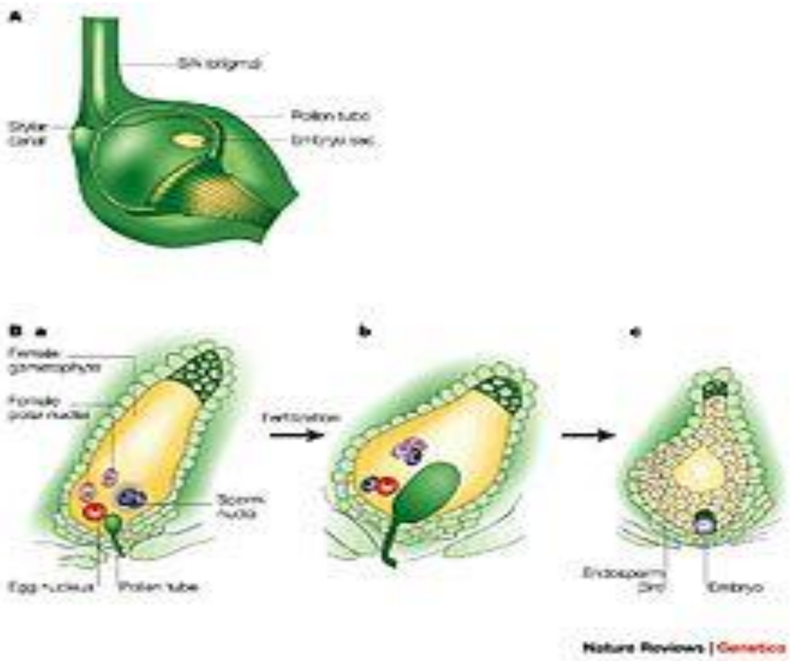
Monadelphous
Stamens fused by filaments into one group.

Syngenesious
Stamens fused by the anthers.

Part (4)Flower fertlization



Double fertilization



Double fertilization is a complex fertilization mechanism of flowering plants (angiosperms). This process involves the joining of a female gametophyte (megagametophyte, also called the embryo sac) with two male gametes (sperm). It begins when a pollen grain adheres to the stigma of the carpel, the female reproductive structure of a flower. The pollen grain then takes in moisture and begins to germinate, forming a pollen tube that extends down toward the ovary through the style. The tip of the pollen tube then enters the ovary and penetrates through the micropyle opening in the ovule. The pollen tube proceeds to release the two sperm in the megagametophyte.

One sperm fertilizes the egg cell and the other sperm combines with the two polar nuclei of the large central cell of the megagametophyte. The haploid sperm and haploid egg combine to form a diploid zygote, while the other sperm and the two haploid polar nuclei of the large central cell of the megagametophyte form a triploid nucleus (some plants may form polyploid nuclei). The large cell of the gametophyte will then develop into the endosperm, a nutrient-rich tissue which provides nourishment to the developing embryo. The ovary, surrounding the ovules, develops into the fruit, which protects the seeds and may function to disperse them.

The two central cell maternal nuclei (polar nuclei) that contribute to the endosperm, arise by mitosis from the same single meiotic product that gave rise to the egg. The maternal contribution to the genetic constitution of the triploid endosperm is double that of the embryo.

In a recent study done of the plant *Arabidopsis thaliana*, the migration of male nuclei inside the female gamete, in fusion with the female nuclei, has been documented for the first time using in vivo imaging. Some of the genes involved in the migration and fusion process have also been determined

Evidence of double fertilization in Gnetales, which are non-flowering seed plants, has been reported.[3]

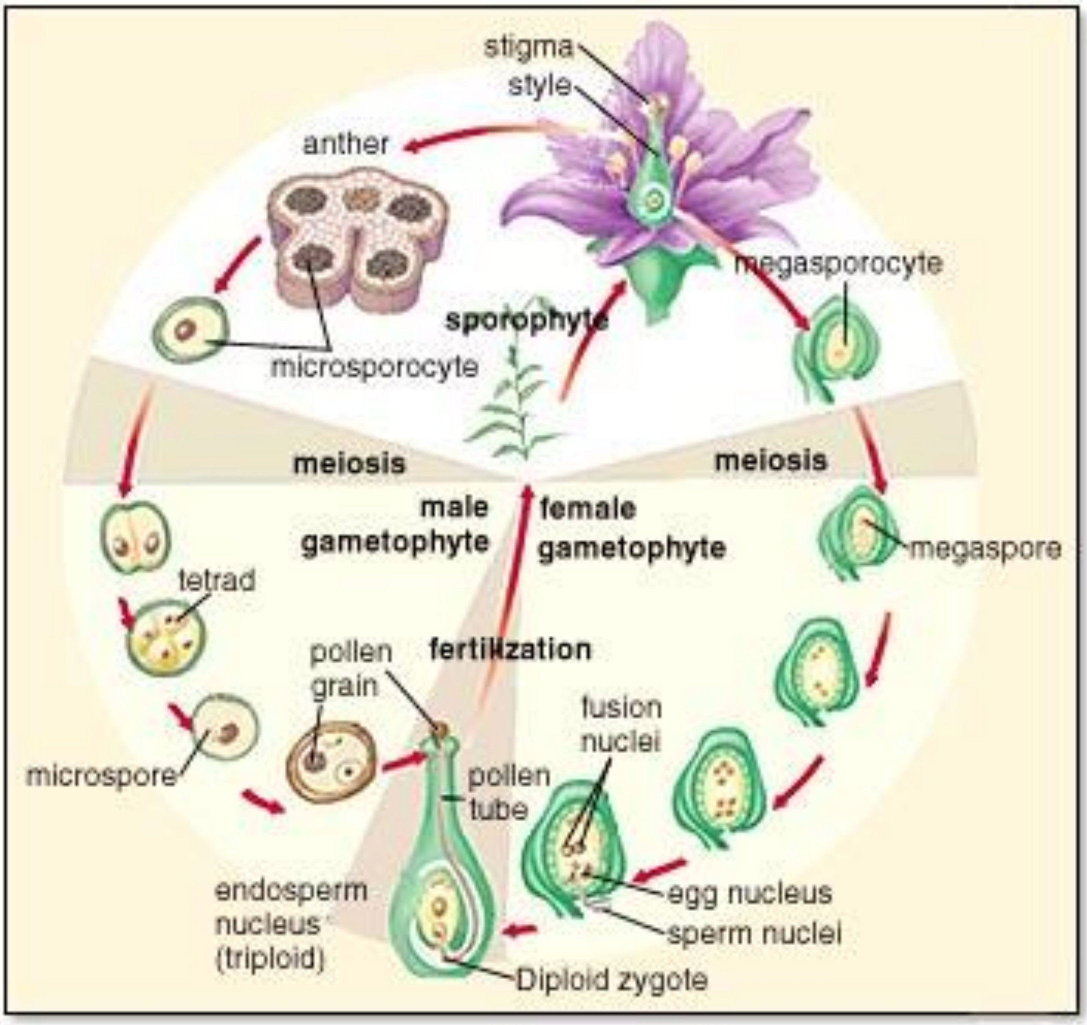
Structures and functions related to double fertilization

Megagametophyte

The female gametophyte, the megagametophyte, that participates in double fertilization in angiosperms is sometimes called the embryo sac. This develops within an ovule, enclosed by the ovary at the base of a carpel. Surrounding the megagametophyte are (one or) two integuments, which form an opening called the micropyle. The megagametophyte, which is usually haploid, originates from the (usually diploid) megaspore mother cell, also called the megasporocyte. The next sequence of events varies, depending on the particular species, but in most species, the following events occur. The megasporocyte undergoes a meiotic cell division, producing four haploid megaspores. Only one of the four resulting megaspores survives. This megaspore undergoes three rounds of mitotic division, resulting in seven cells with eight haploid nuclei (the central cell has two nuclei, called the polar nuclei). The lower end of the embryo sac consists of the haploid egg cell positioned in the middle of two other haploid cells, called synergids. The synergids function in the attraction and guidance of the pollen tube to the megagametophyte through the micropyle. At the upper end of the megagametophyte are three antipodal cells.

Microgametophyte

The male gametophytes, or microgametophytes, that participate in double fertilization are contained within pollen grains. They develop within the microsporangia, or pollen sacs, of the anthers on the stamens. Each microsporangium contains diploid microspore mother cells, or microsporocytes. Each microsporocyte undergoes meiosis, forming four haploid microspores, each of which can eventually develop into a pollen grain. A microspore undergoes mitosis and cytokinesis in order to produce two separate cells, the generative cell and the tube cell. These two cells in addition to the spore wall make up an immature pollen grain. As the male gametophyte matures, the generative cell passes into the tube cell, and the generative cell undergoes mitosis, producing two sperm cells. Once the pollen grain has matured, the anthers break open, releasing the pollen. The pollen is carried to the pistil of another flower, by wind or animal pollinators, and deposited on the stigma. As the pollen grain germinates, the tube cell produces the pollen tube, which elongates and extends down the long style of the carpel and into the ovary, where its sperm cells are released in the megagametophyte. Double fertilization proceeds from here.



Pollination

Since pollen itself is immobile, help is required in order to transport pollen from the loculi of the anthers to the recipient stigma in the pistil so that eventually fertilization can be achieved. This transfer is called pollination. There are in principle three ways to transfer pollen:

Zoophily: by animals

Anemophily: by the wind

Hydrophily: by water

Disperal by animals: Zoophily

In 80%of the plant families pollen is dispersed by animals, mostly by insects (in this case a process called entomophily from the Greek: insects-friendly), who collect pollen and sometimes also consume it, like bumblebees and bees, but also butterflies and hoverflies. In the tropics also birds, in particular colibries, and mammals like bats are involved in the dispersal of pollen. Plant which depend on animals for pollen transport have nearly always large and colorful flowers with a strong smell to attrack the pollinator. These plant species produce much honey and are often adapted to the visit of one particular type of insect. The pollen grains of such plants have often a coarse surface and they are often covered by a sticky oily fluid, the pollenkitt (more hereabout in "Pollen development").

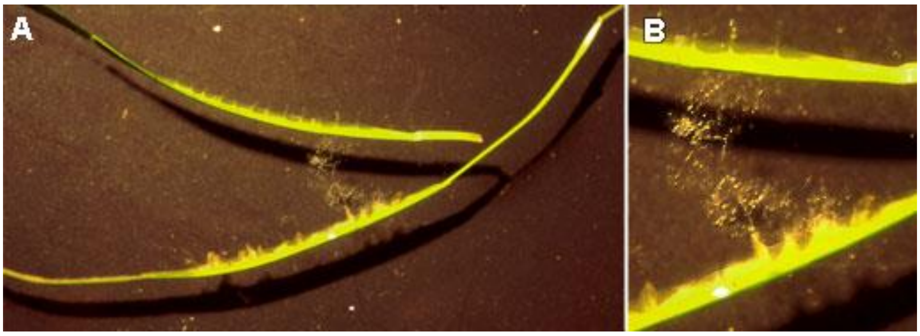
Dispersal by the wind: Anemophily

By dispersal through the air pollen is blown aways from the anthers and reaches the stigma of another plant of the same species by chance. These plants have often small, inconspicious flowers that are clustered in large groups, like in inflorescences of grasses (ears) and in catlins of many trees like Hazel. Characteristic for the anthers of many of those plants is that they stand out. Also the stigmata protrude outside the flowers and they are strongly branched in order to catch as much pollen as possible. Plants employing animophily produce large amounts of pollen grains that are commonly very small, without large extensions or any oily film on their surface. However, some species like Pine (*Pinus sylvestris*) appear to have large pollen grains, but those are relatively light thanks to their air bags, so that the wind can still carry them.

Pollen that is dispersed by the wind can reach the mucosa of nose and eyes. Some species can then cause allergy. However, not all types of airborne pollen are as strongly allergenic. Some species that produce a lot of wind-dispersed pollen grains, like the Ash (Fraxinus excelsior, "pollennieuws" video and illustrated descriptions, both in Dutch), do not cause hay fever.

Pollination by water: Hydrophily

Ephydrophilous (i.e. water surface-pollinated) pollen grains are spherical or reniform and large, while hydrophilous (i.e. subaquatic-pollinated) pollen grains are filiform.



Part (5) Inflorescence

Inflorescence

An **inflorescence** is a group or cluster of flowers arranged on a stem that is composed of a main branch or a complicated arrangement of branches. Morphologically, it is the part of the shoot of seed plants where flowers are formed and which is accordingly modified. The modifications can involve the length and the nature of the internodes and the phyllotaxis, as well as variations in the proportions, compressions, swellings, adnations, connations and reduction of main and secondary axes. Inflorescence can also be defined as the reproductive portion of a plant that bears a cluster of flowers in a specific pattern.
The stem holding the whole inflorescence is called a peduncle and the main stem holding the flowers or more branches within the inflorescence is called the rachis. The stalk of each single flower is called a pedicel.
The fruiting stage of an inflorescence is known as an infructescence.
A flower that is not part of an inflorescence is called a solitary flower and its stalk is also referred to as a peduncle.
Any flower in an inflorescence may be referred to as a **floret**, especially when the individual flowers are particularly small and borne in a tight cluster, such as in a pseudanthium.

General characteristics

Inflorescences are described by many different characteristics including how the flowers are arranged on the peduncle, the blooming order of the flowers and how different clusters of flowers are grouped within it. These terms are general representations as plants in nature can have a combination of types.

Terminal flower

Plant organs can grow according to two different schemes, namely monopodial or **racemose** and sympodial or **cymose**. In inflorescences these two different growth patterns are called indeterminate and determinate respectively, and indicate whether a terminal flower is formed and where flowering starts within the inflorescence.

- **Indeterminate inflorescence**: Monopodial (racemose) growth. The terminal bud keeps growing and forming lateral flowers. A terminal flower is never formed.
- **Determinate inflorescence**: Sympodial (cymose) growth. The terminal bud forms a terminal flower and then dies out. Other flowers then grow from lateral buds.

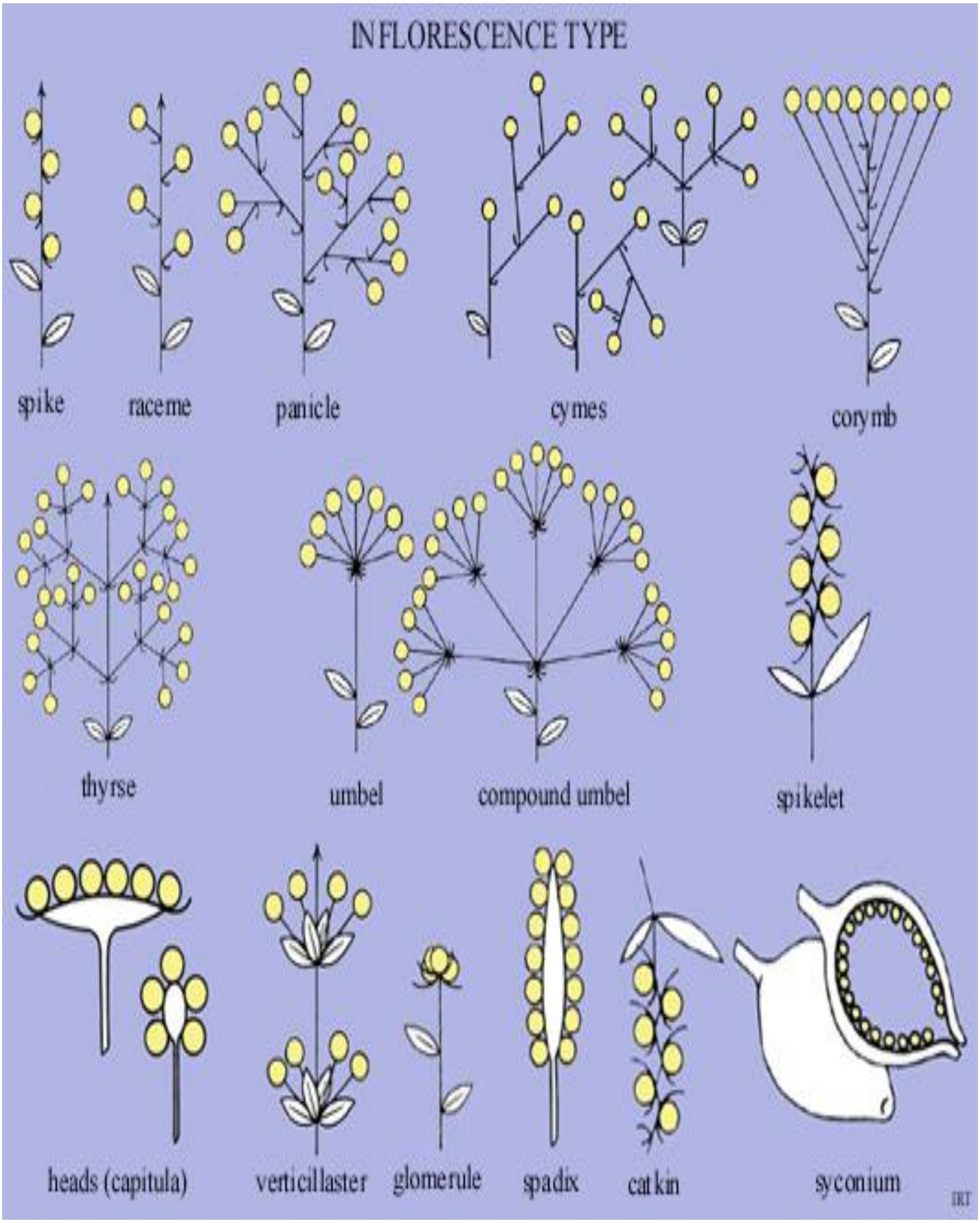
Indeterminate and determinate inflorescences are sometimes referred to as **open** and **closed** inflorescences respectively.
In **indeterminate inflorescence** there is no true terminal flower and the stem usually has a rudimentary end. In many cases the last true flower formed by the terminal bud

(**subterminal** flower) straightens up, appearing to be a terminal flower. Often a vestige of the terminal bud may be noticed higher on the stem.

Indeterminate or Racemose

Indeterminate simple inflorescences are generally called **racemose** /ˈræsɨmoʊs/. The main kind of racemose inflorescence is the **raceme** (/ˈræsiːm/, from classical Latin *racemus*, cluster of grapes).[2] The other kind of racemose inflorescences can all be derived from this one by dilation, compression, swelling or reduction of the different axes. Some passage forms between the obvious ones are commonly admitted.

- A **raceme** is an unbranched, indeterminate inflorescence with pedicellate (having short floral stalks) flowers along the axis.
- A **spike** is a type of raceme with flowers that do not have a pedicel.
- A racemose **corymb** is an unbranched, indeterminate inflorescence that is flat-topped or convex due to their outer pedicels which are progressively longer than inner ones.
- An **umbel** is a type of raceme with a short axis and multiple floral pedicels of equal length that appear to arise from a common point.
- A **spadix** is a spike of flowers densely arranged around it, enclosed or accompanied by a highly specialised bract called a **spathe**. It is characteristic of the Araceae family.
- A **flower head** or **capitulum** is a very contracted raceme in which the single sessile flowers share are borne on an enlarged stem. It is characteristic of Dipsacaceae.
- A **catkin** or **ament** is a scaly, generally drooping spike or raceme. Cymose or other complex inflorescences that are superficially similar are also generally called thus.


INFLORESCENCE TYPE
spike
raceme
panicle
cymes
corymb
thyrse
umbel
compound umbel
spikelet
heads (capitula)
verticillaster
glomerule
spadix
catkin
syconium
IRT

Determinate or Cymose

In **determinate inflorescences** the terminal flower is usually the first to mature (precursive development), while the others tend to mature starting from the bottom of the stem. This pattern is called **acropetal** maturation. When flowers start to mature from the top of the stem, maturation is **basipetal**, while when the central mature first, **divergent**.
Determinate simple inflorescences are generally called **cymose**. The main kind of cymose inflorescence is the **cyme** (pronounced 'saim', from the French *cime* in the sense 'top, summit').[3] Cymes are further divided according to this scheme:

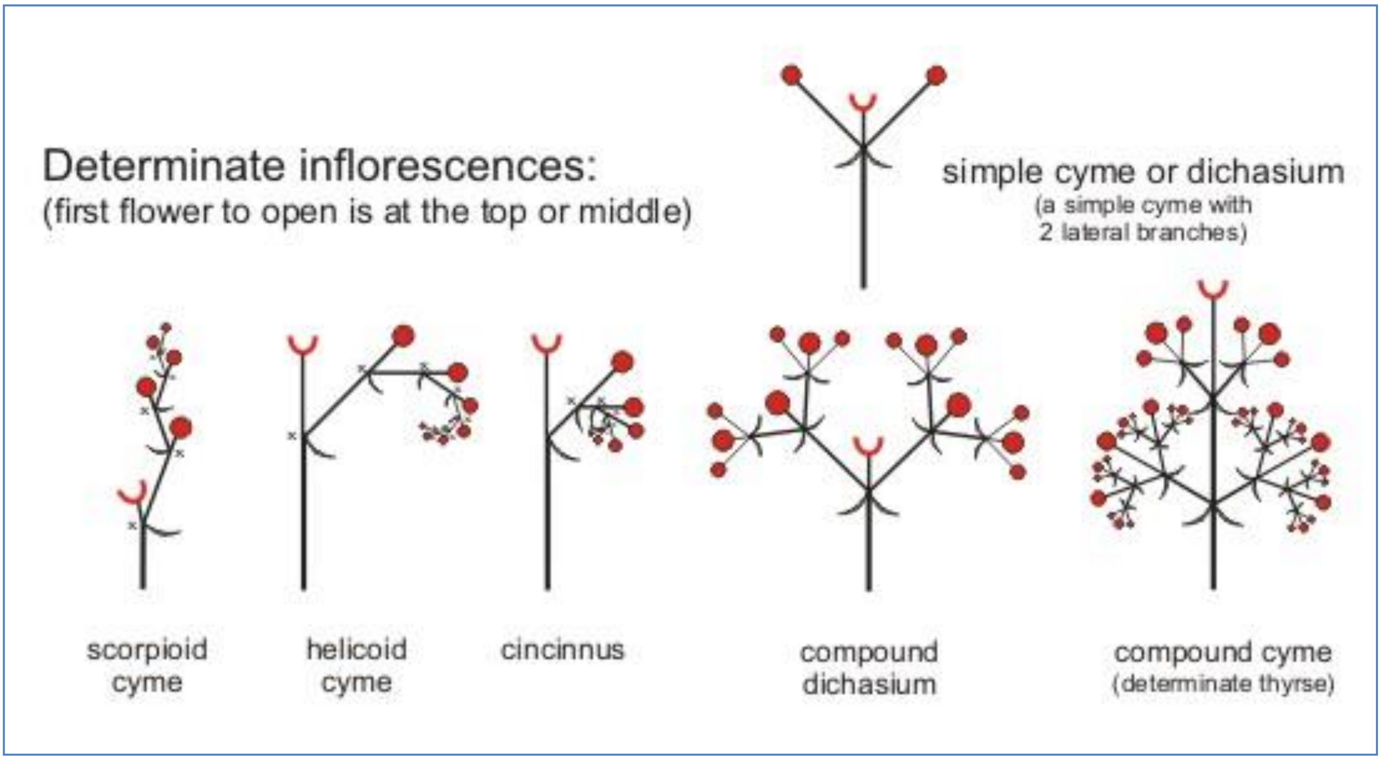
- Only one secondary axis: **monochasium**
  - Secondary buds always develop on the same side of the stem: **helicoid cyme** or **bostryx**
    - The successive pedicels are aligned on the same plane: **drepanium**
  - Secondary buds develop alternately on the stem : **scorpioid cyme**
    - The successive pedicels are arranged in a sort of spiral: **cincinnus** (characteristic of the Boraginaceae and Commelinaceae)
    - The successive pedicels follow a zig-zag path on the same plane: **rhipidium** (many Iridaceae)
- Two secondary axes: **dichasial cyme**
  - Secondary axis still dichasial: **dichasium** (characteristic of Caryophyllaceae)
  - Secondary axis monochasia: **double scorpioid cyme** or **double helicoid cyme**

A cyme can also be so compressed that it looks like an umbel. Strictly speaking this kind of inflorescence could be called **umbelliform cyme**, although it is normally called simply 'umbel'.
Another kind of definite simple inflorescence is the raceme-like cyme or **botryoid**; that is as a raceme with a terminal flower and is usually improperly called 'raceme'.
A reduced raceme or cyme that grows in the axil of a bract is called a **fascicle**. A **verticillaster** is a fascicle with the structure of a dichasium; it is common among the Lamiaceae. Many verticillasters with reduced bracts can form a spicate (spike-like) inflorescence that is commonly called a **spike**.

Compound inflorescences

Simple inflorescences are the basis for compound inflorescences or **synflorescences**. The single flowers are there replaced by a simple inflorescence, which can be both a racemose or a cymose one. Compound inflorescences are composed of branched stems and can involve complicated arrangements that are difficult to trace back to the main branch.
A kind of compound inflorescence is the **double inflorescence**, in which the basic structure is repeated in the place of single florets. For example a double raceme is a raceme in which

the single flowers are replaced by other simple racemes; the same structure can be repeated to form triple or more complex structures.
Compound raceme inflorescences can either end with a final raceme (**homoeothetic**), or not (**heterothetic**). A compound raceme is often called a **panicle**. Compound umbels are umbels in which the single flowers are replaced by many smaller umbels called **umbellets**. The stem attaching the side umbellets to the main stem is called a **ray**.
The most common kind of definite compound inflorescence is the **panicle** (of Webeling, or 'panicle-like cyme'). A panicle is a definite inflorescence that is increasingly more strongly and irregularly branched from the top to the bottom and where each branching has a terminal flower.
The so-called cymose **corymb** is similar to a racemose corymb but has a panicle-like structure. Another type of panicle is the **anthela**. An anthela is a cymose corymb with the lateral flowers higher than the central ones.
A raceme in which the single flowers are replaced by cymes is called a (indefinite) **thyrse**. The secondary cymes can of course be of any of the different types of dichasia and monochasia. A botryoid in which the single flowers are replaced by cymes is a **definite thyrse** or **thyrsoid**. Thyrses are often confusingly called **panicles**.



Simple Cyme or Dichasium	a determinate inflorescence with 2 dichotomous lateral branches and pedicles of equal length.
Compound Dichasium	a branched dichasium
Compound Cyme	a determinate thyrse.
Helicoid Cyme	a determinate cyme in which the branches develop only on 1 side, due

(or bostryx)	to the abortion of opposing paired bud, the inflorescence thus appearing simple.
Cincinnus	a tight, modified helicoid cyme in which the pedicels are very short.
Scorpioid Cyme (or rhipidium)	a zig-zag determinate cyme with branches developing alternately on opposite sides of the rachis, due to abortion of opposing paired bud.

Fruit

fruit is a part of a flowering plant that derives from specific tissues of the flower, one or more ovaries, and in some cases accessory tissues. Fruits are the means by which these plants disseminate seeds. Many of them that bear edible fruits, in particular, have propagated with the movements of humans and animals in a symbiotic relationship as a means for seed dispersal and nutrition, respectively; in fact, humans and many animals have become dependent on fruits as a source of food.[1] Fruits account for a substantial fraction of the world's agricultural output, and some (such as the apple and the pomegranate) have acquired extensive cultural and symbolic meanings.

In common language usage, "fruit" normally means the fleshy seed-associated structures of a plant that are sweet or sour and edible in the raw state, such as apples, oranges, grapes, strawberries, bananas, and lemons. On the other hand, the botanical sense of "fruit" includes many structures that are not commonly called "fruits", such as bean pods, corn kernels, wheat grains, and tomatoes[1]

Fruit structure

The outer, often edible layer, is the **pericarp**, formed from the ovary and surrounding the seeds, although in some species other tissues contribute to or form the edible portion. The pericarp may be described in three layers from outer to inner, the **epicarp**, **mesocarp** and **endocarp**.

Fruit development

A fruit results from maturation of one or more flowers, and the gynoecium of the flower(s) forms all or part of the fruit.

Inside the ovary/ovaries are one or more ovules where the megagametophyte contains the egg cell. After double fertilization, these ovules will become seeds. The ovules are fertilized in a process that starts with pollination, which involves the movement of pollen from the stamens to the stigma of flowers. After pollination, a tube grows from the pollen through the stigma into the ovary to the ovule and two sperm are transferred from the pollen to the megagametophyte. Within the megagametophyte one of the two sperm unites with the egg, forming a zygote, and the second sperm enters the central cell forming the endosperm mother cell, which completes the double fertilization process.[11][12] Later the zygote will give rise to the embryo of the seed, and the endosperm mother cell will give rise to endosperm, a nutritive tissue used by the embryo.

As the ovules develop into seeds, the ovary begins to ripen and the ovary wall, the *pericarp*, may become fleshy (as in berries or drupes), or form a hard outer covering (as in nuts). In some multiseeded fruits, the extent to which the flesh develops is proportional to the number of fertilized ovules.[13] The pericarp is often differentiated into two or three distinct layers called the *exocarp* (outer layer, also called epicarp), *mesocarp* (middle layer), and *endocarp* (inner layer). In some fruits, especially simple fruits derived from an inferior ovary, other

parts of the flower (such as the floral tube, including the petals, sepals, and stamens), fuse with the ovary and ripen with it. In other cases, the sepals, petals and/or stamens and style of the flower fall off. When such other floral parts are a significant part of the fruit, it is called an *accessory fruit*. Since other parts of the flower may contribute to the structure of the fruit, it is important to study flower structure to understand how a particular fruit forms.[3]
There are three general modes of fruit development:

- Apocarpous fruits develop from a single flower having one or more separate carpels, and they are the simplest fruits.
- Syncarpous fruits develop from a single gynoecium having two or more carpels fused together.
- Multiple fruits form from many different flowers.

Plant scientists have grouped fruits into three main groups, simple fruits, aggregate fruits, and composite or multiple fruits.[14] The groupings are not evolutionarily relevant, since many diverse plant taxa may be in the same group, but reflect how the flower organs are arranged and how the fruits develop.

Simple fruit

Epigynous berries are simple fleshy fruit. Clockwise from top right: cranberries, lingonberries, blueberries red huckleberries

Simple fruits can be either dry or fleshy, and result from the ripening of a simple or compound ovary in a flower with only one pistil. Dry fruits may be either dehiscent (opening to discharge seeds), or indehiscent (not opening to discharge seeds). Types of dry, simple fruits, with examples of each, are:

- achene - Most commonly seen in aggregate fruits (e.g. strawberry)
- capsule – (Brazil nut)
- caryopsis – (wheat)

- Cypsela - An achene-like fruit derived from the individual florets in a capitulum (e.g. dandelion).
- fibrous drupe – (coconut, walnut)
- follicle – is formed from a single carpel, and opens by one suture (e.g. milkweed). More commonly seen in aggregate fruits (e.g. magnolia)
- legume – (pea, bean, peanut)
- loment - a type of indehiscent legume
- nut – (hazelnut, beech, oak acorn)
- samara – (elm, ash, maple key)
- schizocarp – (carrot seed)
- silique – (radish seed)
- silicle – (shepherd's purse)
- utricle – (beet)

Lilium unripe capsule fruit

Fruits in which part or all of the *pericarp* (fruit wall) is fleshy at maturity are *simple fleshy fruits*. Types of fleshy, simple fruits (with examples) are:

- berry – (redcurrant, gooseberry, tomato, cranberry)
- stone fruit or drupe (plum, cherry, peach, apricot, olive)

Dewberry flowers. Note the multiple pistils, each of which will produce a drupelet. Each flower will become a blackberry-like aggregate fruit.

An aggregate fruit, or *etaerio*, develops from a single flower with numerous simple pistils. [Magnolia and Peony, collection of follicles developing from one flower.

- Sweet gum, collection of capsules.
- Sycamore, collection of achenes.
- Teasel, collection of cypsellas
- Tuliptree, collection of samaras.

The pome fruits of the family Rosaceae, (including apples, pears, rosehips, and saskatoon berry) are a syncarpous fleshy fruit, a simple fruit, developing from a half-inferior ovary.[17] Schizocarp fruits form from a syncarpous ovary and do not really dehisce, but split into segments with one or more seeds; they include a number of different forms from a wide range of families.[14] Carrot seed is an example.

Aggregate fruit

Aggregate fruits form from single flowers that have multiple carpels which are not joined together, i.e. each pistil contains one carpel. Each pistil forms a fruitlet, and collectively the fruitlets are called an etaerio. Four types of aggregate fruits include etaerios of achenes, follicles, drupelets, and berries. Ranunculaceae species, including *Clematis* and *Ranunculus* have an etaerio of achenes, *Calotropis* has an etaerio of follicles, and *Rubus* species like raspberry, have an etaerio of drupelets. *Annona* have Etaerio of berries.
The raspberry, whose pistils are termed *drupelets* because each is like a small drupe attached to the receptacle. In some bramble fruits (such as blackberry) the receptacle is elongated and part of the ripe fruit, making the blackberry an *aggregate-accessory* fruit.[20] The strawberry is also an aggregate-accessory fruit, only one in which the seeds are contained in achenes. In all these examples, the fruit develops from a single flower with numerous pistils.

Multiple fruits

A multiple fruit is one formed from a cluster of flowers (called an *inflorescence*). Each flower produces a fruit, but these mature into a single mass.[22] Examples are the pineapple, fig, mulberry, osage-orange, and breadfruit.

In some plants, such as this noni, flowers are produced regularly along the stem and it is possible to see together examples of flowering, fruit development, and fruit ripening.

In the photograph on the right, stages of flowering and fruit development in the noni or Indian mulberry (*Morinda citrifolia*) can be observed on a single branch. First an inflorescence of white flowers called a head is produced. After fertilization, each flower develops into a drupe, and as the drupes expand, they become *connate* (merge) into a *multiple fleshy fruit* called a *syncarpet*.

Berries

Berries are another type of fleshy fruit; they are simple fruit created from a single ovary. The ovary may be compound, with several carpels. Type include (examples follow in the table below):

- Pepo – Berries where the skin is hardened, cucurbits
- Hesperidium – Berries with a rind and a juicy interior, like most citrus fruit

KEY to FRUIT TYPES

1a. Fruit derived from several ovaries of one or more flowers

2a. Fruit arising from the several ovaries of as many flowers (examples: pineapple, mulberry)

MULTIPLE FRUIT

2b. Fruit arising from the coalescence of several ripened ovaries of one flower (example: raspberry, blackberry)

AGGREGATE FRUIT

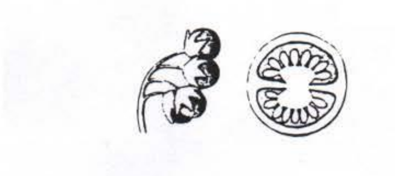
1b. Fruit derived from a single ovary (simple or compound)

3a. Fruit fleshy or juicy when ripe

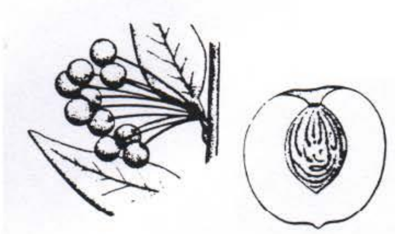
4a. Ovary wall of fruit (or pericarp) entirely or in part fleshy

5a. Fruit indehiscent

6a. Ovary wall entirely fleshy (examples: tomato, cranberry, grape, currant, banana, melon [pepo], and citrus fruit [hesperidium])



BERRY



6b. Ovary wall of three distinct layers, the inner one bony (endocarp), the middle fleshy (mesocarp), and the outer "skin- like" (exocarp) (examples: peach, plum, cherry)

DRUPE

5b. Fruit dehiscent

7a. Fruit derived from one carpel FOLLICLE

7b. Fruit derived from a compound gynoecium CAPSULE

4b. Ovary wall (e.g., the outer layer of an apple 'core') of fruit papery, surrounded by a fleshy material that represents the coalescent parts of the stamens, petals, sepals, and (some believe) receptacle (examples: apple, pear, quince)

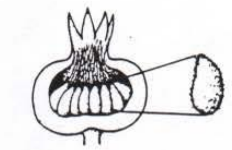
POME

3b. Fruit typically dry and usually hardened when ripe

8a. Fruit indehiscent (does not open or dehisce when mature), generally with one seed

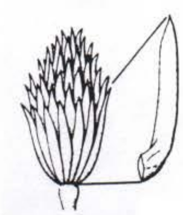
9a. Ovary wall of varying thickness, usually not bony

10a. Fruit not winged (examples: buttercup, 'seeds' of strawberry, sunflower family, sedges, grasses [ovary wall adherent to and surrounding seed, may be called caryopsis or grain])



ACHENE

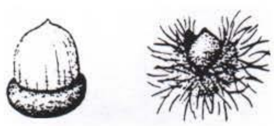
10b. Fruit winged (examples: elm, tulip tree)



SAMARA

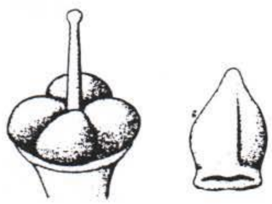
9b. Ovary wall hardened and bony

11a. Fruit usually > 5mm long (examples: oak, chestnut, hazelnut)



NUT

11b. Fruit small, usually < 5mm long (examples: borage and mint families [Boraginaceae and Lamiaceae]



NUTLET

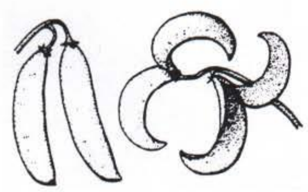
8b. Fruit dehiscent (opens or dehisces when mature, usually along certain definite lines or sutures), with one or more seeds

12a. Fruit derived from a single carpel

13a. Fruit dehiscing along one side (examples: columbine, larkspur, magnolia, milkweed)

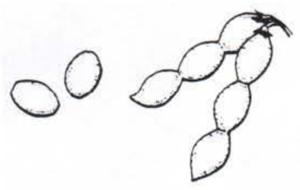
FOLLICLE

13b. Fruit dehiscing along two sides or breaking crosswise into one-seeded segments



14a. Fruit dehiscing along two sides (example: only the legume family [Fabaceae or Leguminosae])

LEGUME



14b. Fruit breaking into one-seeded segments (example: only the legume family [Fabaceae or Leguminosae])

LOMENT

12b. Fruit derived from a compound gynoecium of two or more carpels (types of capsules)

15a. Fruit always 2-carpellate, two-celled, and with parietal placentation

16a. Fruit > 2-3 times longer than wide (example: only the mustard family [Brassicaceae or Cruciferae])

SILIQUE

16b. Fruit <2-3 times longer than wide (example: only the mustard family [Brassicaceae or Cruciferae])

SILICLE

15b. Fruit 2 or more carpellate, one or more celled, and with various types of placentation.

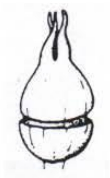
CAPSULE

17a. Fruit dehiscing by pores (poricidal dehiscence; example: poppy)

PORICIDAL
CAPSULE

17b. Fruit dehiscing along the septa or into the locules or by a lid.

18a. Fruit dehiscing by a lid (examples: Portulacaceae and some Caryophyllaceae)



CIRCUMSCISSILE
CAPSULE

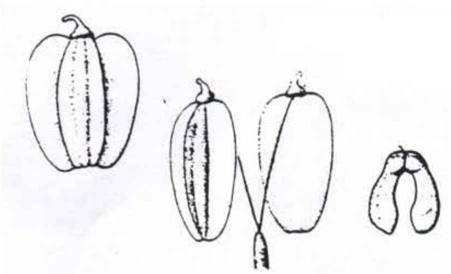
18b. Fruit dehiscing directly into the locules or along the septa.

19a. Fruit dehiscing directly into the locules (examples: iris, phlox, pyrola, violet, waterleaf)

LOCULICIDAL
CAPSULE

19b. Fruit dehiscing along the septa

20a. Fruit dehiscing to form 1-seeded segments called mericarps (examples: carrot, maple, spurge)



SCHIZOCARPOUS
CAPSULE or
SCHIZOCARP

20b. Fruit dehiscing to form several-seeded segments (examples: peppers, figwort, rhododendron))

SEPTICIDAL
CAPSULE

Part (7) Floral diagrams and floral formulae

A floral formula is a way to represent the structure of a flower using specific letters, numbers and symbols, presenting substantial information about the flower in a compact form. It can represent a taxon, usually giving ranges of the numbers of different organs, or particular species.

The structure of a flower can also be expressed by the means of floral diagrams. The use of schematic diagrams can replace long descriptions or complicated drawings as a tool for understanding both floral structure and evolution. Such diagrams may show important features of flowers, including the relative positions of the various organs, including the presence of fusion and symmetry, as well as structural details.

CHARACTERISTICS OF A FLOWER	SYMBOL USED
BRACTS	
Present (bracteate)	Br
Absent (Ebracteate)	Ebr
BRACTEOLES	
Present (Bracteolate)	Bri
Absent (Ebracteolate)	Ebl
SYMMETRY OF THE FLOWER	
Actinomorphic	⊕
Zygomorphic	%
SEXUALITY OF THE FLOWER	
Bisexual	⚥
Unisexual	
Male (staminate) flower	♂
Female (pistillate) flower	♀
NON ESSENTIAL WHORLS	
Perianth	P
Tepals free	P_3
Tepals united	$P_{(3)}$
Calyx	K
Sepsis free	K_5
Sepsis united	K(5)

Corolla	C
Petals free	C5
Petals united	C(5)
ESSENTIAL WHORLS	
Androecium	A
Stamens free	A5
Stamens united monadeiphous	A(10)
diadeiphous	A(9)+1
Stamens numerous	A Infinity
Stamens attached to petals	C5A5
Gynoecium	G
Carpeis free (apocarpous)	G5
Carpels united (syncarpous)	G(5)
Ovary superior	G
Ovary inferior	G

Floral formula is a means to represent the structure of a flower using numbers, letters and various symbols, presenting substantial information about the flower in a compact form. It can represent a taxon, usually giving ranges of the numbers of different organs, or particular species. It is one of the two ways of describing flower structure developed during the 19th century, the other being floral diagrams. The format of floral formulae differs between authors, yet they tend to convey the same information.[2]

Selected families

The Families of Angiosperms according to Melchior system (1964) "modified or updated" Engler system as follows:

Class1: Dicotyledoneae
Embryo with two cotyledons

Subclass I: **Archichlamydeae** Perianth of free parts or absent

A: **Dialypetalae (Choripetalae)** Perianth differentiated into calyx and corolla

- Order: **Rhoedales**
  - Family: **Cruciferae**
- Order: **Malvales (Columniflorae)**
  - Family: **Malvaceae**
- Order: **Rosales**
  - Family: **Leguminosae**
    - Subfamily: **Papilionaceae (Fabaceae)**
    - Subfamily: **Cesalpiniaceae**
    - Subfamily: **Mimosaceae**
- Order: **Umbelliflorae**
  - Family: **Umbelliferae (Apiaceae)**

B: **Monochlamydeae**
Perianth undifferentiated or absent

- Order: **Centrospermae**
  - Family: **Chenopodiaceae**
  - Family: **Nyctaginaceae**

Subclass 2. Sympetalae
Perianth of united parts, at least the corolla

Order: **Tubiflorae**

- Family: **Convolvulaceae**
- Family: **Labiatae (Lamiaceae)**
- Family: **Solanaceae**
- Family: **Bignoniaceae**

Oder: **Gentianales**

- Family: **Apocynaceae**

Order**: Campanulales**

- Family: **Asteraceae (Compositae)**

Order**: Cucurbitales**

- Family: **Cucurbitaceae**

Class2: Monocotyledoneae
Embryo with one cotyledon

Order: **Graminales (Glumiflorae)**

- Family: **Graminae (Poaceae)**

Order: **Cyperales**

- Family: **Cyperaceae**

Order: **Principes**

- Family: **Palmae (Araceae)**

Order: **Liliflorae**

- Family: **Liliaceae**
- Family: **Agavaceae**

Class1: Dicotyledoneae

Embryo with two cotyledons

Subclass1: Dialypetalae

Perianth differentiated into calyx and corolla

1- Order: Rhoedales

1. Family: Brassicaceae (Cruciferae) - The Mustard

Inflorescence and flower

Flowers aggregated in inflorescences, or solitary; in corymbs, or in racemes, or in spikes, or in fascicles. The terminal inflorescence unit racemose. Inflorescences terminal, or axillary.

Perianth

with distinct calyx and corolla, or sepaline; 8 , or 4; characteristically 3whorled (K 2+2 decussate with the outer pair median, C4, the corolla diagonal), or 2 whorled. Calyx 2 whorled. Corolla 4 (diagonal); 1 whorled; polypetalous; imbricate, or contorted; regular ; white, or yellow, or orange, or purple, or blue. Petals clawed , or sessile .

Androecium

6, or 2–4, or 8–16 . free of one another, or coherent (the inner four sometimes basally connate in pairs); 2 whorled (usually, 2+4), or 1 whorled.

Androecium exclusively of fertile stamens. Stamens 6 , or 2–4, or 8–16 ; tetradynamous .

Gynoecium

2 carpelled. Gynoecium syncarpous; eu-syncarpous; superior. Ovary 1–2locular. Stigmas 1–2; commissural,1 lobed, or 2 lobed.

Placentation

parietal.

Fruit

non-fleshy; dehiscent , or indehiscent or a schizocarp or lomentaceous

Mericarps when schizocarpic, 2. Fruit a silicula to a siliqua . Capsules when dehiscent, valvular.

Common Plants

Brassica oleracea var. capitata (cabbage)

Brassica oleracea var. botrytis (cauliflower).

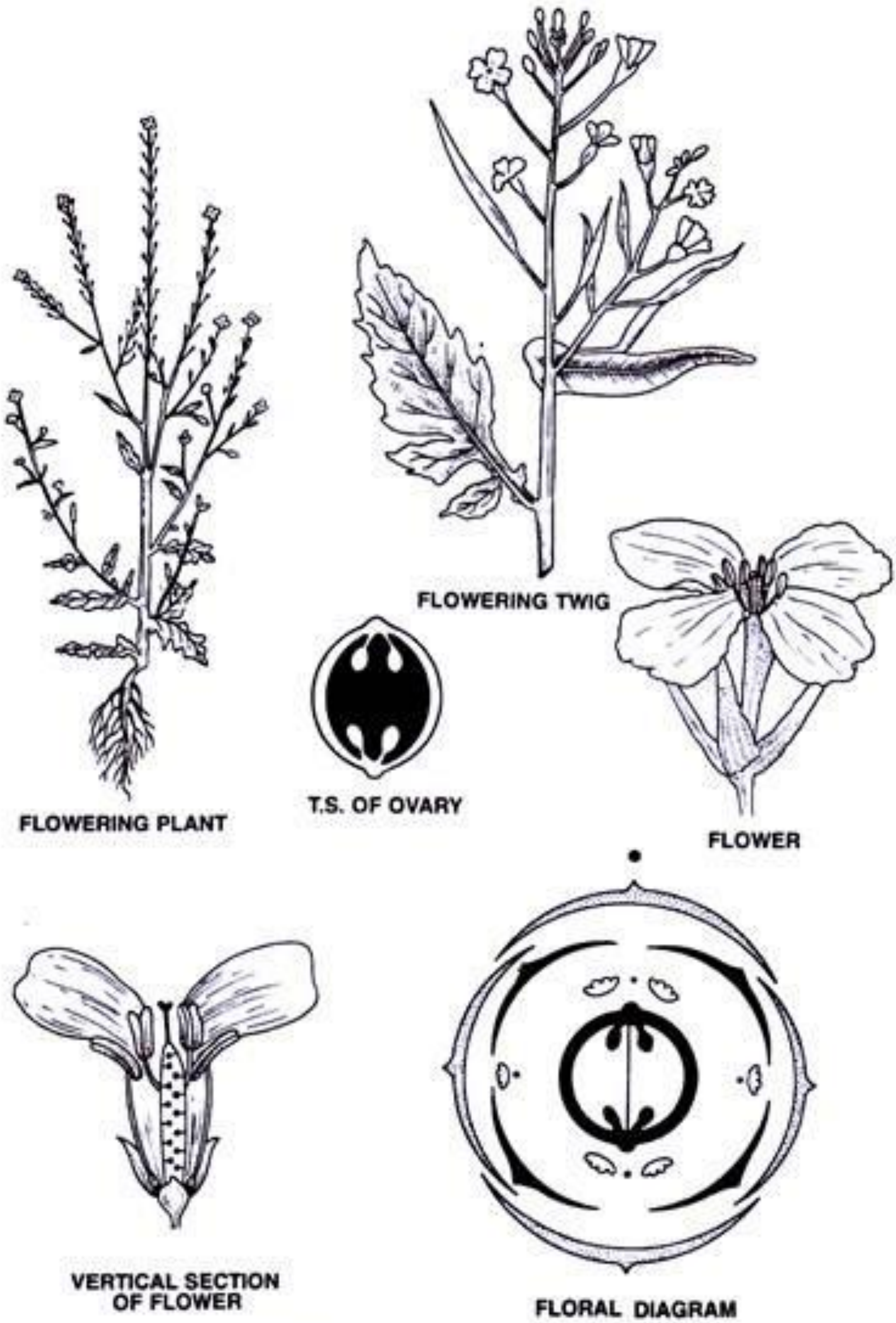


Fig. 31.1. *Brassica campestris.*

Order: Columniferae (Malvales)

1. Family: Malvaceae - The Mallow Family

Inflorescence and flower.

Flowers solitary, or aggregated in 'inflorescences'; in cymes. The terminal inflorescence unit cymose. Inflorescences compound cymose, composed of cincinni. Flowers small to large; regular to somewhat irregular.

Perianth with distinct calyx and corolla; 10; 2 whorled; isomerous. Calyx 5; 1 whorled; polysepalous, or gamosepalous; regular; valvate. Epicalyx present. Corolla 5; 1 whorled; polypetalous.

Androecium

(5–)15–100 . Androecial members branched .

Gynoecium

(1–5(–100) carpelled. Gynoecium syncarpous; synovarious to synstylovarious; superior. Ovary (1–5(–100) locular. Styles (1–)5(–20); free to 48 partially joined; apical. Stigmas dry type; papillate, or non-papillate.

Placentation

axile. Ovules 1–50 per locule.

Fruit

non-fleshy, or fleshy; dehiscent, or indehiscent, or a schizocarp. Mericarps when schizocarpic, (1–)5(–100); comprising follicles, or comprising nutlets. Fruit a capsule , or a berry . Capsules loculicidal.

Common Plants:

Gossypium barbadense (Cotton) important for oil and fibers

Hibiscus cannabinus (Flax) yields fibres of low quality used for rope manufacture

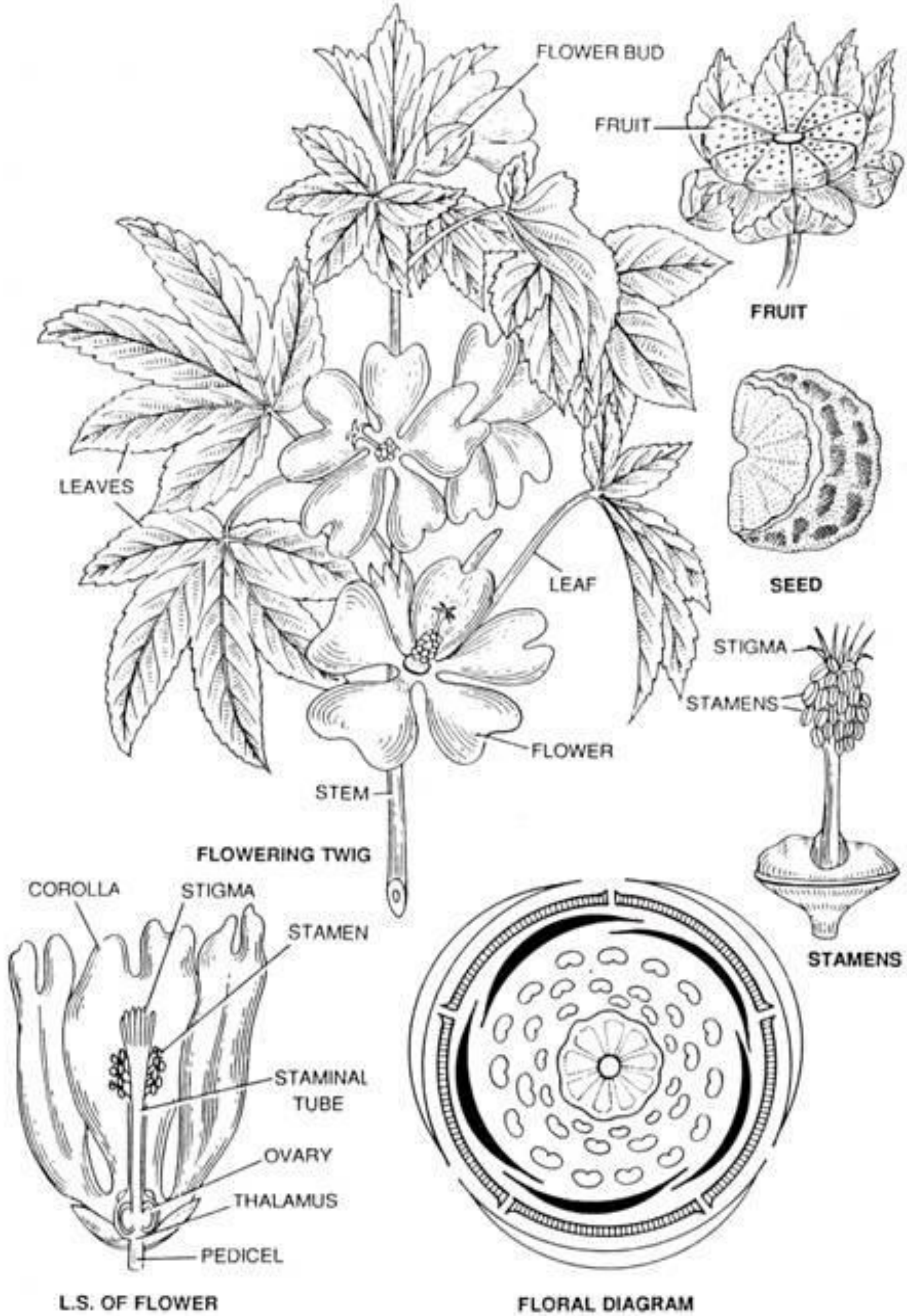


Fig. 16.1. Malvaceae. *Malva sylvestris* Linn., Eng., Common mallow; Verna. **Vilayati Kangi.**

Order: Leguminosae
Key to the families of the Leguminosae:

1. Flowers actinomorphic …………………………………………**Mimosaceae**
1. Flowers zygomorphic ……………………………………………….....2
2. Perianth showing some connation, the uppermost petal (standard) enclosing the lateral petals (wings)………………………………………………..…….**Fabaceae**
2. Perianth with separate parts, the standard enclosed by the wings…………………………………………………..…………………**Caesalpiniaceae**

1. Family: Mimosaceae - the Mimosa Family

Inflorescence and flower.
Flowers aggregated in inflorescences'; in racemes, or in spikes, or in heads. The terminal inflorescence unit racemose. Inflorescences terminal, or axillary. Flowers minute, or small; regular , or somewhat irregular.

Perianth
with distinct calyx and corolla; 6–12; 2 whorled; isomerous. Calyx (3–5(– 6); 1 whorled; gamosepalous, or polysepalous; lobulate, or blunt-lobed, or toothed; regular; valvate, or imbricate.

Androecium
(3–5(–12), or 12–100. Androecial members free of the perianth, oradnate, all equal, or markedly unequal; free of one another, or coherent; often 1 adelphous; 1 whorled, or 2–6 whorled. Anthers separate from one another, or connivent; dehiscing via longitudinal slits; tetrasporangiate.

Gynoecium
1 carpelled , or 2–16 carpelled. Carpel apically stigmatic; 2–100 ovuled.

Placentation
marginal (along the ventral suture).

Fruit
non-fleshy, or fleshy. The fruiting carpel dehiscent, or indehiscent; a legume , or a follicle, or samaroid, or a loment. Fruit elastically dehiscent, or passively dehiscent.

Common Plants
Acacia nilotica, Acacia farensiana
Albizzia lebbek

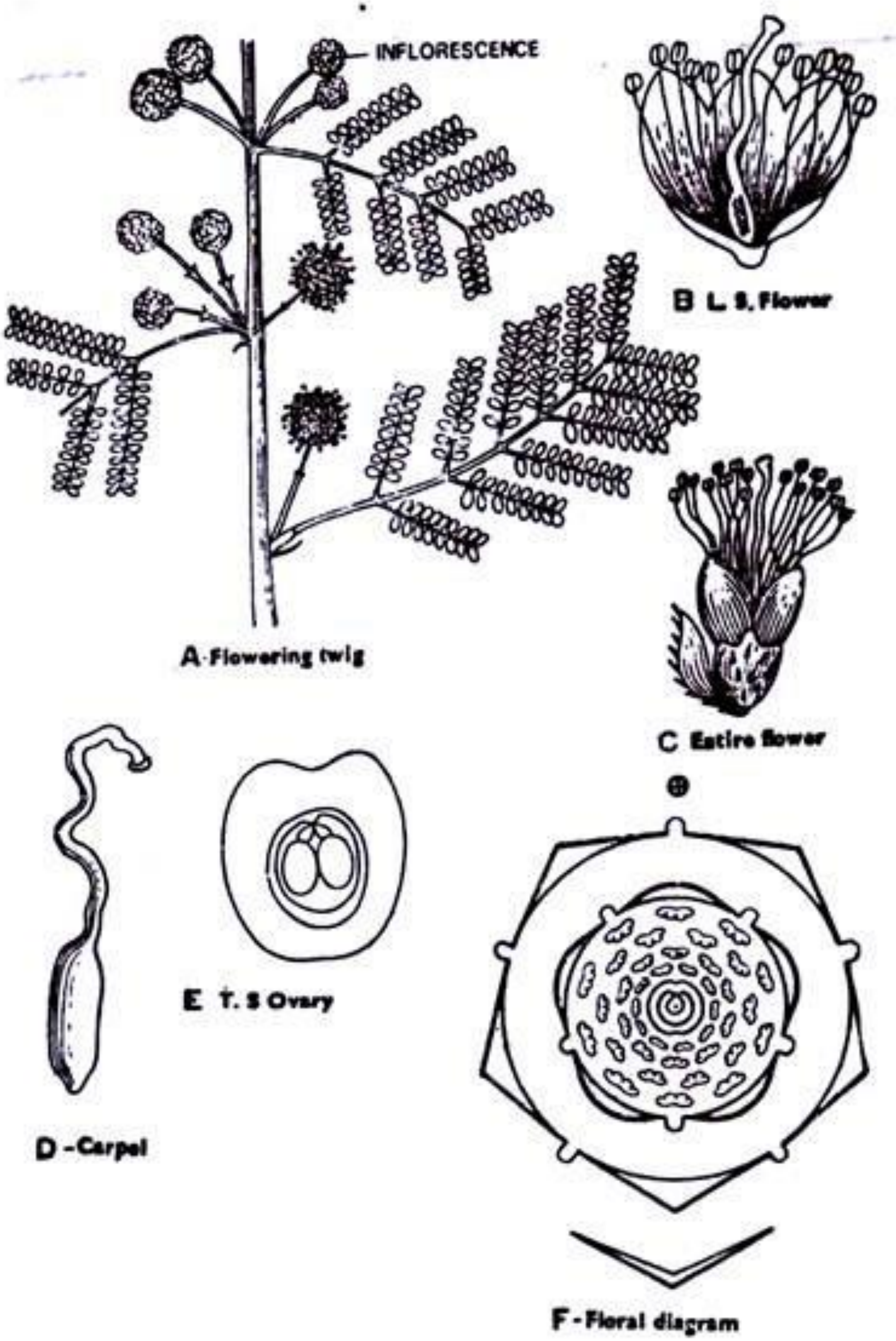


Fig. 54.1. *Acacia nilotica.*

2. Family: Fabaceae (Papilionaceae)- The Bean or Pea Family

Inflorescence and flower.

Flowers aggregated in Inflorescences' , or solitary; in panicles, in fascicles, in racemes, in spikes, and in heads. The terminal inflorescence unit cymose, or racemose. Flowers somewhat irregular to very irregular , or regular; usually zygomorphic.

Perianth

with distinct calyx and, 2 whorled; isomerous, or anisomerous. Calyx 5, or(3-5(–6), 1 whorled; usually gamosepalous; unequal but not bilabiate, or bilabiate, or regular; persistent or not persistent; accrescent, or non-accrescent; ascending imbricate. Corolla when present, 5, or 1–5; 1 whorled.

Androecium

(5–) 9–10(–30), 1 adelphous, or 2 adelphous; even when 10, 1

Stamens

(5–) 9–10(–30); isomerous with the perianth, or diplostemonous (commonly, more or less), or triplostemonous to polystemonous. Anthers separate from one another to connivent.

54

Gynoecium

1 carpelled. Carpels reduced in number relative to the perianth. Gynoecium monomerous; of one carpel; superior. Carpel apically stigmatic; (1–)2–100 ovuled. Placentation marginal (along the ventral suture).

Fruit

non-fleshy, or fleshy. The fruiting carpel dehiscent, or indehiscent; a legume , or a follicle, or an achene, or samaroid, or a loment, or drupaceous. Fruit elasticallydehiscent, or passively dehiscent.

Common Plants

Cicer arietinum Vicia faba

Pisum sativum Phaseolus vulgaris

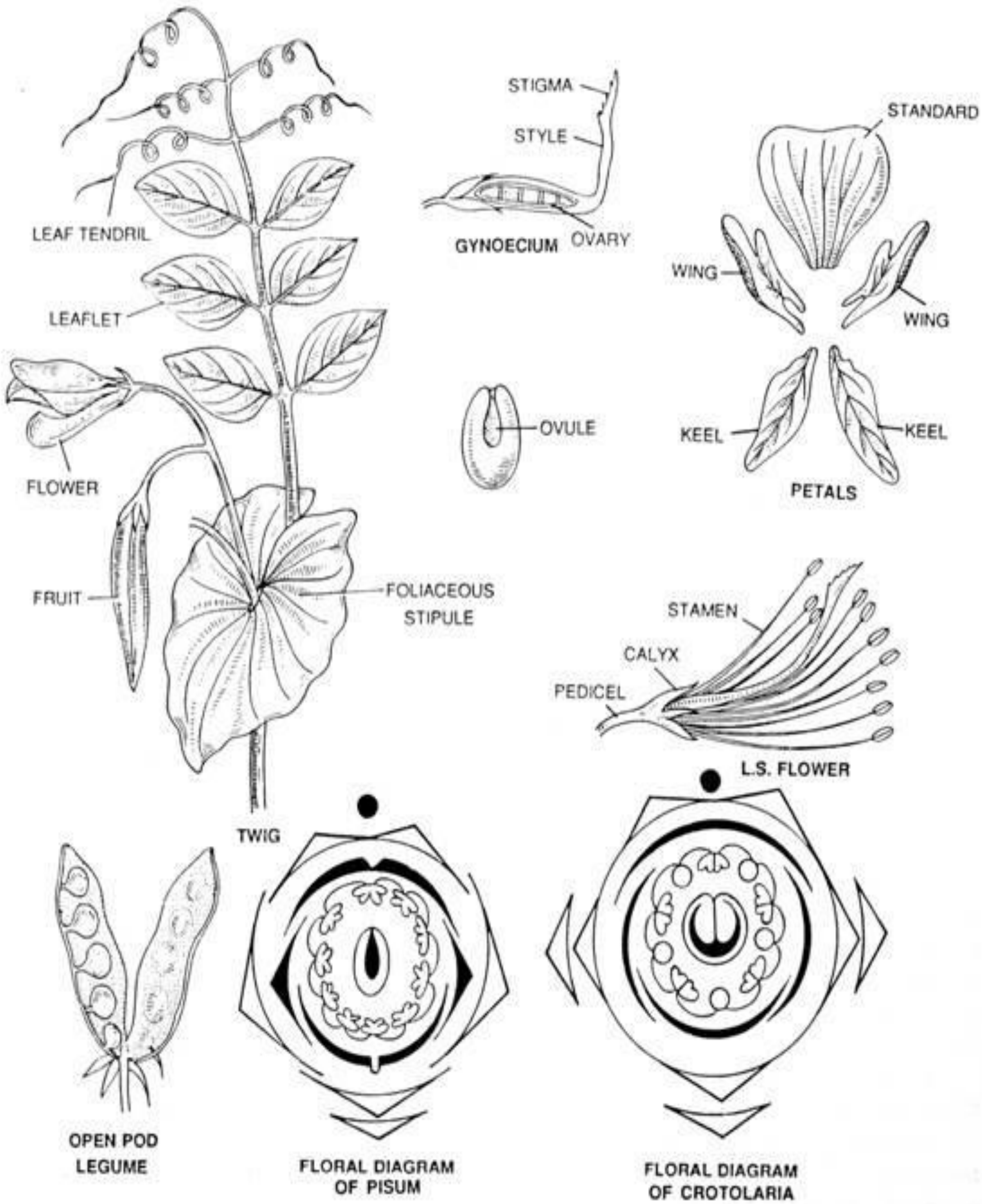


Fig. 15.7. Papilionaceae (Leguminosae)–*Pisum sativum* Linn.

3. Family: Caesalpiniaceae - The Senna Family

Inflorescence and flower.

Flowers solitary, or aggregated in Inflorescences in racemes, or in corymbs. Inflorescences terminal, or axillary. Flowers minute to large; somewhat irregular, or regular; commonly more or less zygomorphic.

Perianth with distinct calyx and corolla, or sepaline; (3–)5, or (6–)10(–11); 2 whorled; isomerous, or anisomerous. Calyx 5, or (3–) 5(–6); 1 whorled; polysepalous, or partially gamosepalous, or gamosepalous; unequal but not bilabiate, or bilabiate, or regular; imbricate, or valvate. Corolla (1–) 5; 1 whorled; polypetalous, imbricate.

Androecium

(1–) 10, or 10–50, free of one another; when cohering 1 adelphous, or 2 adelphous; 1 whorled. Androecium exclusively of fertile stamens, or including staminodes. Stamens (1–)3–10(–50); reduced in number relative to the adjacent perianth, or isomerous with the perianth, or diplostemonous to polystemonous. Anthers separate from one another.

Gynoecium

1 carpelled. Carpels reduced in number relative to the perianth. Gynoecium monomerous; of one carpel; superior. Carpel apically stigmatic; 1–100 ovuled.

Placentation

marginal (along the ventral suture).

Fruit

non-fleshy, or fleshy. The fruiting carpel dehiscent, or indehiscent; a legume or a follicle, or an achene, or samaroid, or a loment, or drupaceous.

Common Plants

Cassia nodosa
Poinciana regia
Cassia obovata
Bauhinia variegata
Tamarindus indicus
Ceratonia siliqua

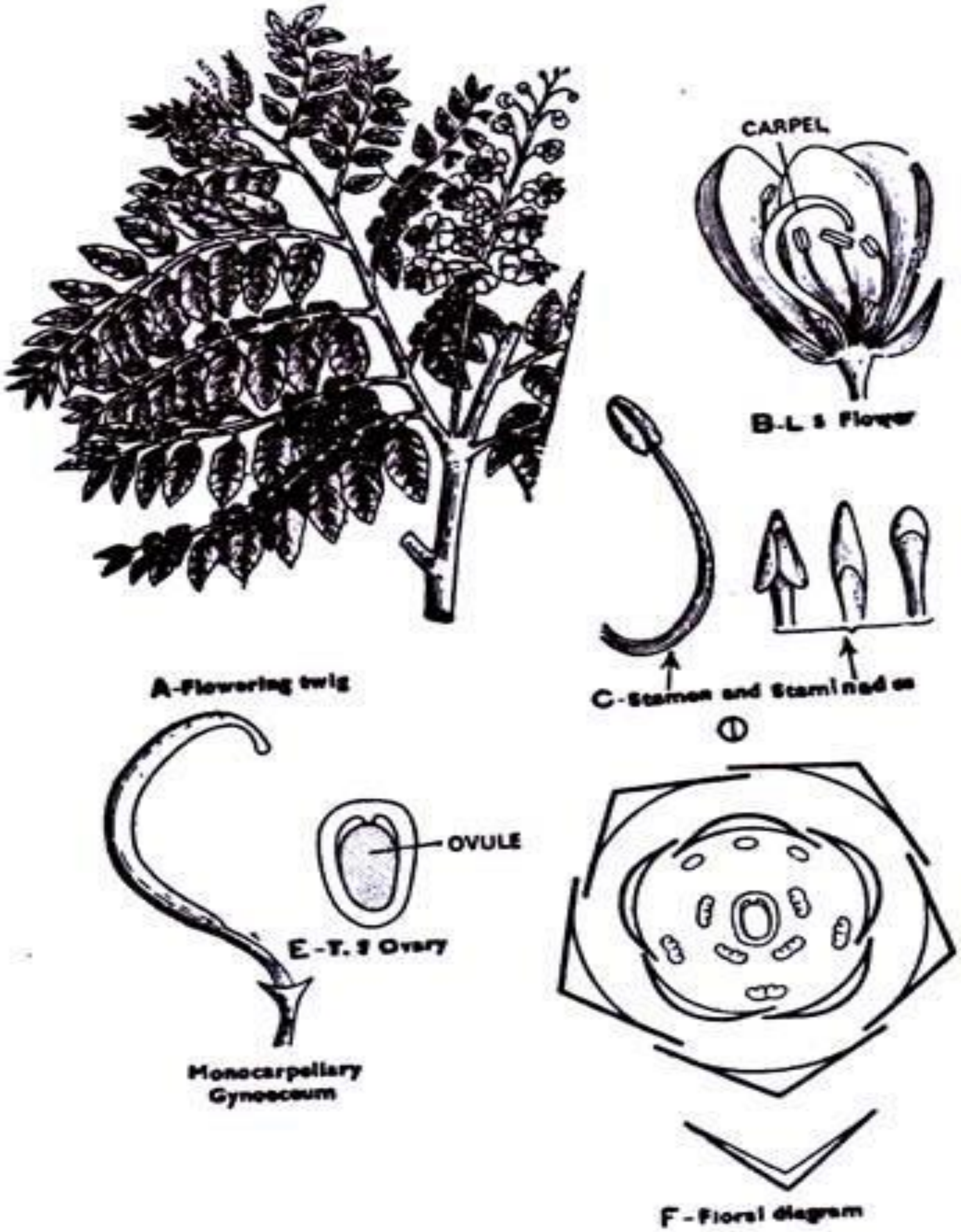


Fig. 53.1. *Cassia fistula.*

Order: Umbelliflorae

1. Family: Apiaceae (Umbelliferae) - The Carrot Family

Inflorescence and flower. Flowers aggregated in 'inflorescences'; in umbels , or in heads. The terminal inflorescence unit cymose, or racemose. Inflorescences terminal; often cymose umbels or heads arranged in cymose inflorescences, sometimes reduced to single flowers.
Perianth with distinct calyx and corolla, 4–10; 2 whorled, or 1 whorled. Calyx when detectable, 5; 1 whorled; polysepalous, or gamosepalous. Corolla 5; 1 whorled; polypetalous; valvate.
Androecium 5. free of one another; 1 whorled. Stamens 5; isomerous with the perianth.
Gynoecium 2 carpelled. Gynoecium syncarpous; inferior. Ovary (1–) 2 locular. Gynoecium median. Styles 2; free to partially joined. Stigmas wet type. Placentation axile, or apical.
Fruit non-fleshy; a schizocarp. Mericarps 2; dry, united facially, 1-seeded, the integument sometimes united with the pericarp.
Common Plants
Daucus carrota Daucus boissieri
Petroselinum sativum Anethum graveolens

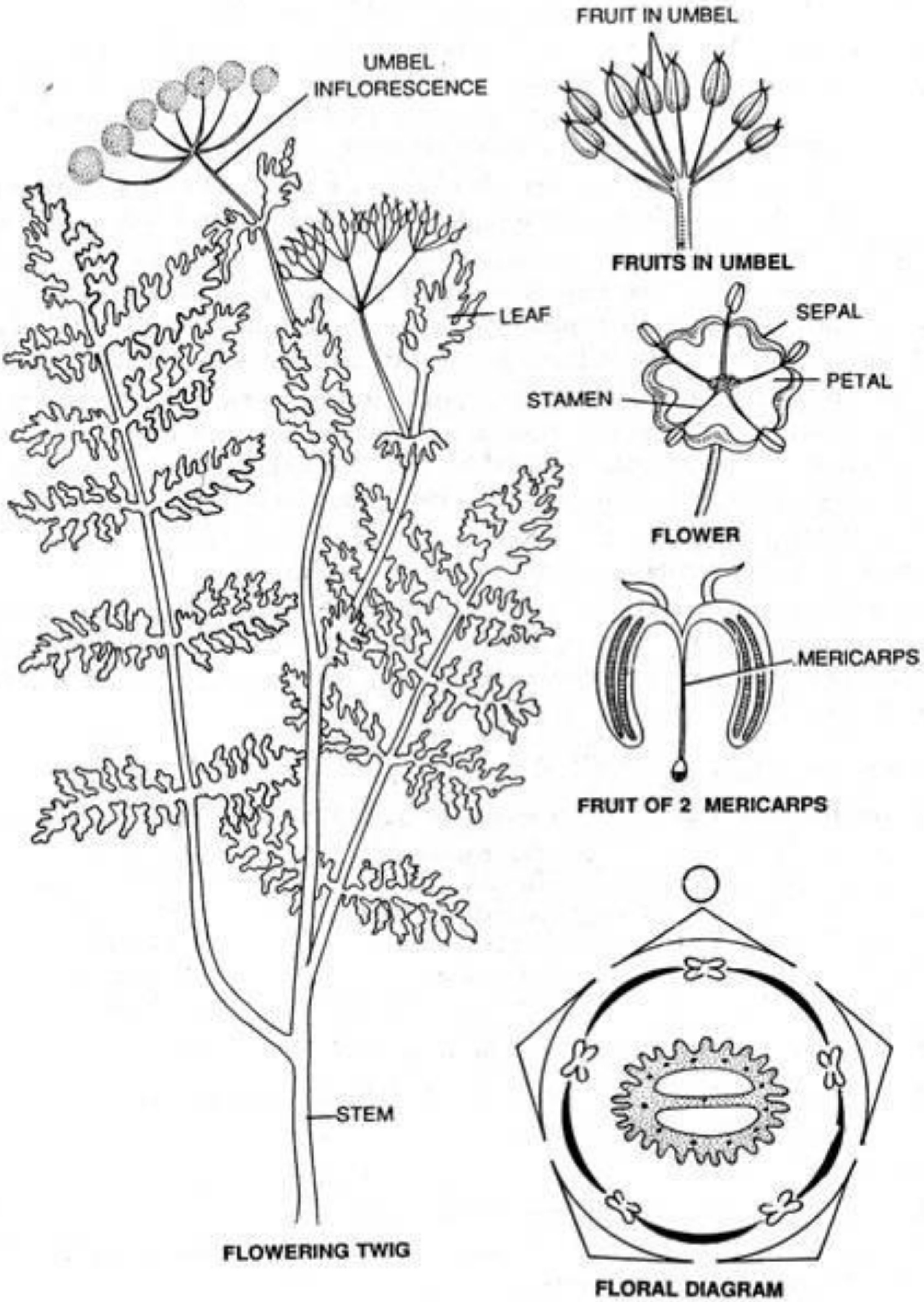


Fig. 25.1. Umbelliferae (Apiaceae). *Trachyspermum ammi* (Linn.) Sprague. (Syn. *Carum copticum*); Eng., lovage ammi, Verna, **Ajwain.**

Subclass 2. Monochlamydeae

Perianth undifferentiated or absent

Order: Centrospermae

1. Family: Chenopodiaceae -The Goosefoot Family

Inflorescence and flower.
Flowers solitary (then axillary), or aggregated in 'inflorescences'. Flowers minute, or small; regular; cyclic; when hermaphrodite, usually tricyclic .
Perianth sepaline,
(1–5(–6); joined (imbricate); 1 whorled; fleshy, or non-fleshy; persistent; accrescent, or non-accrescent. Calyx (1–) 3–5(–6); gamosepalous , or polysepalous, persistent (in the fruit); accrescent or non-accrescent; imbricate.
Androecium
3–5. Androecial members free of the perianth, or adnate . Stamens 3–5; usually isomerous with the perianth;. Anther wall initially with one middle layer, or initially with more than one middle layer; of the.
Gynoecium 2–5 carpelled. Gynoecium syncarpous; superior, or partly inferior. Ovary 1 locular. Styles (1–2–3(–4); usually partially joined. Stigmas dry type; papillate.
Placentation
basal.
Fruit
non-fleshy; indehiscent, or dehiscent; a nut , or capsular-indehiscent, or enclosed in the fleshy perianth , or without fleshy investment.

Common Plants
Beta vulgaris var. rapa
Beta vulgaris var. cicla
Spinacia oleracea
Chenopodium murale
Chenopodium ambrosioides

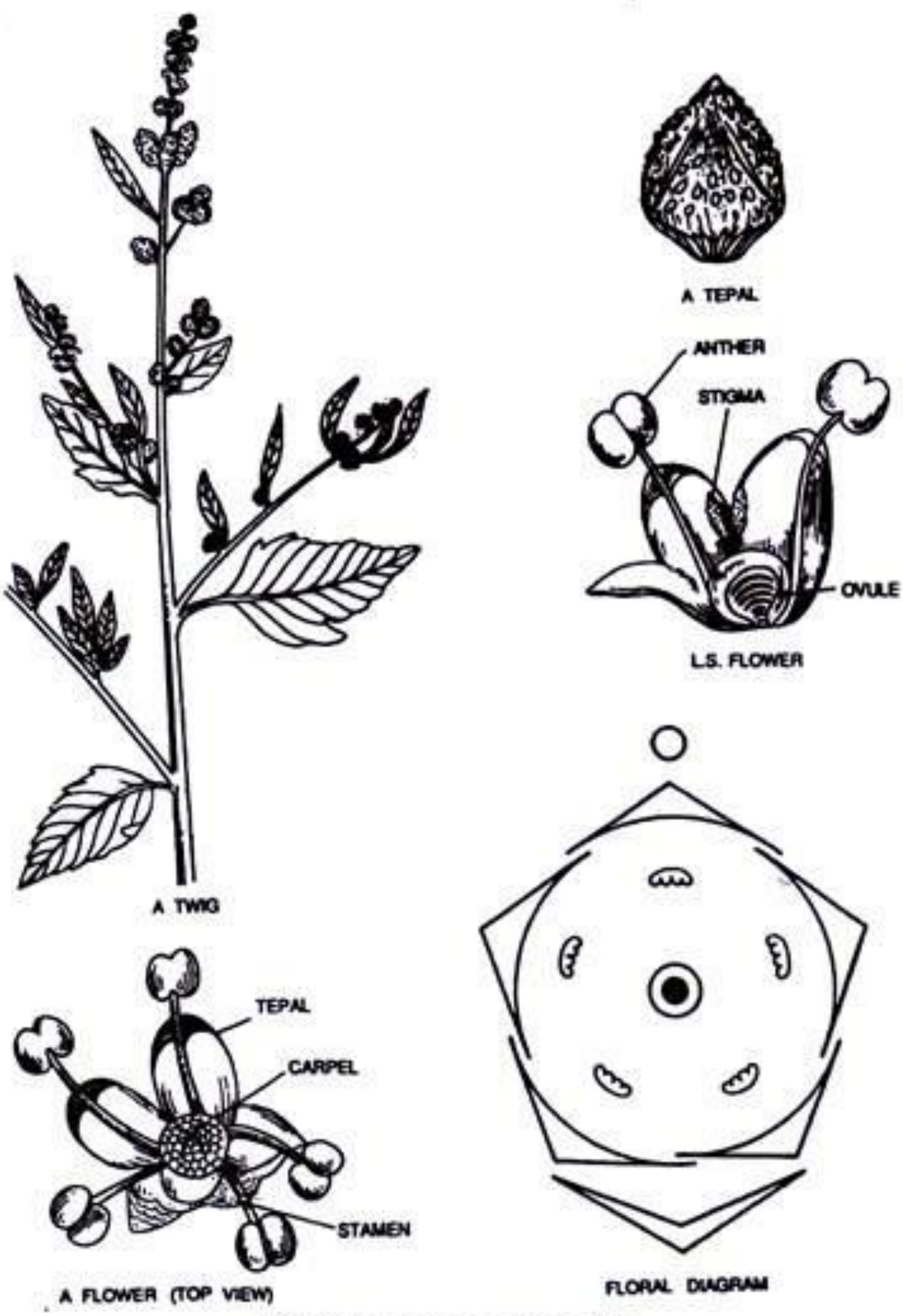


Fig. 87.1. *Chenopodium album*.

2. Famiy: Nyctaginaceae

Inflorescence and flower.
Flowers solitary, or aggregated in 'inflorescences'; in cymes, in panicles, in spikes, and in umbels. Inflorescences terminal, or axillary; with involucral bracts, or without involucral bracts;
Perianth sepaline;
(3–) 5(–10); joined; 1 whorled. Calyx (3–5(–10); 1 whorled; gamosepalous; campanulate, or urceolate, or funnel-shaped, or tubular; regular.
Androecium
(1–)5(–30), 1 whorled.
Gynoecium
1 carpelled. Carpels reduced in number relative to the perianth.
Placentation basal.
Fruit non-fleshy. The fruiting carpel indehiscent; an achene.

Common Plants
Bougainvillea glabra
Mirabilis galaba

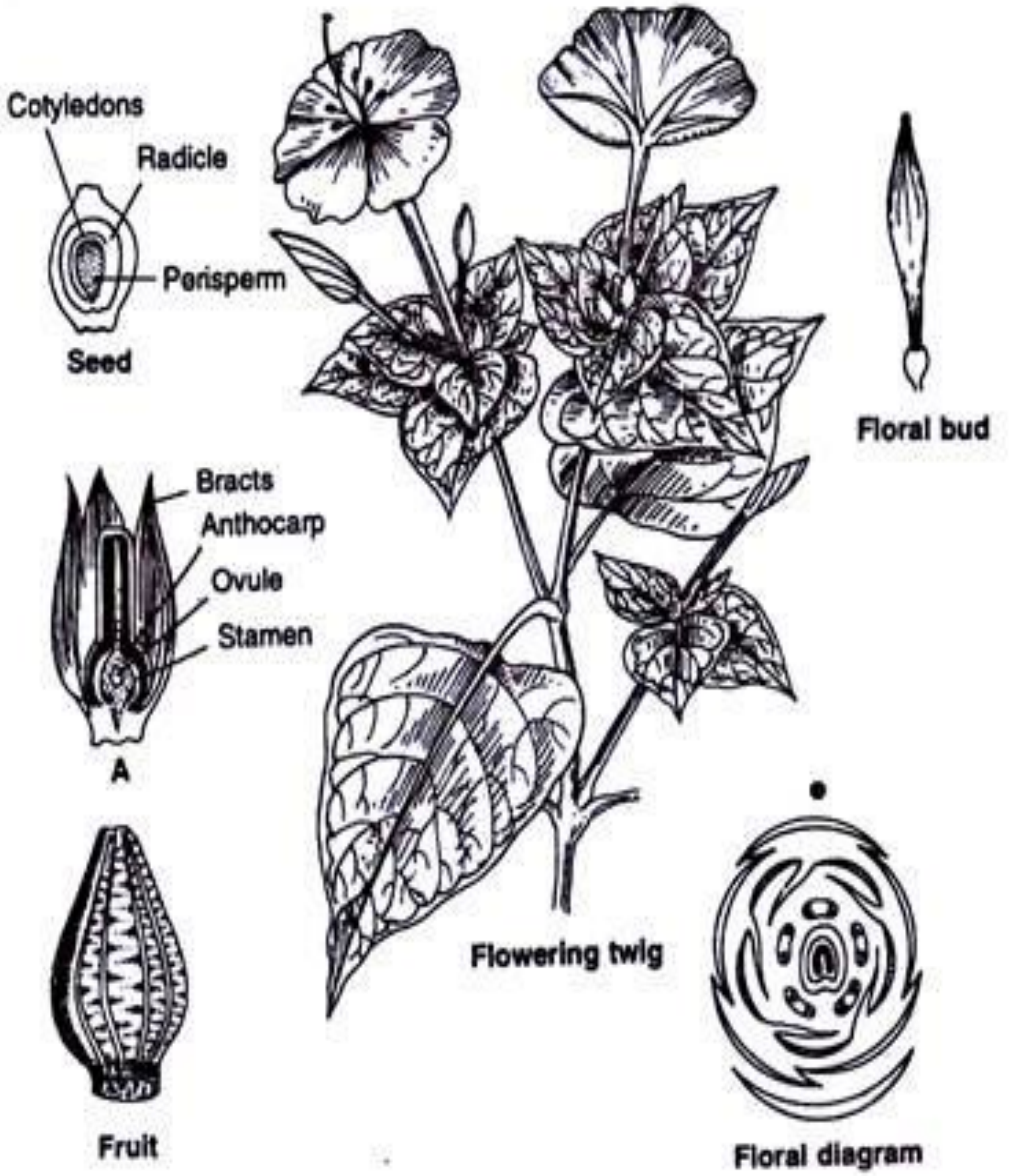


Fig. 89.1. *Mirabilis jalapa* L. A. Lower portion of flower in vertical section showing br, bracts; ant., anthocarp; ov, ovule; st, lower part of filament of stamen.

Subclass 3. Sympetalae
Perianth of united parts, at least the corolla

Order: Contortae

1. Family: Apocynaceae

Inflorescence and flower. Flowers aggregated in 'inflorescences'. The terminal inflorescence unit usually a panicle. Flowers bracteate; bracteolate; regular; usually 4–5 merous; cyclic; tetracyclic.
Perianth with distinct calyx and corolla; 10; 2 whorled; isomerous. Calyx 5; 1 whorled; gamosepalous; regular; imbricate (quincuncial); with the median member posterior. Corolla 5; 1 whorled; appendiculate; gamopetalous
Androecium 5. Androecial members adnate (epipetalous); united with the gynoecium or free of the gynoecium; free of one another. Stamens 5; inserted near the base of the corolla tube, or midway down the corolla tube, or in the throat of the corolla tube; isomerous with the perianth; oppositisepalous; alternating with the corolla members.
Gynoecium 2 carpelled, or 2–5(–8) carpelled. Gynoecium syncarpous; superior, or partly inferior. Carpel when synstylous, 2–50 ovuled. Styles 1.
Placentation when unilocular, with the two placentas parietal; when bilocular, axile, or apical .
Fruit fleshy, or non-fleshy; dehiscent, or indehiscent, or a schizocarp. Mericarps when schizocarpic, 2; comprising follicles, or comprising berrylets, or comprising.

Common Plants
Nerium oleander
Vinca rosea
Plumeria acutifolia

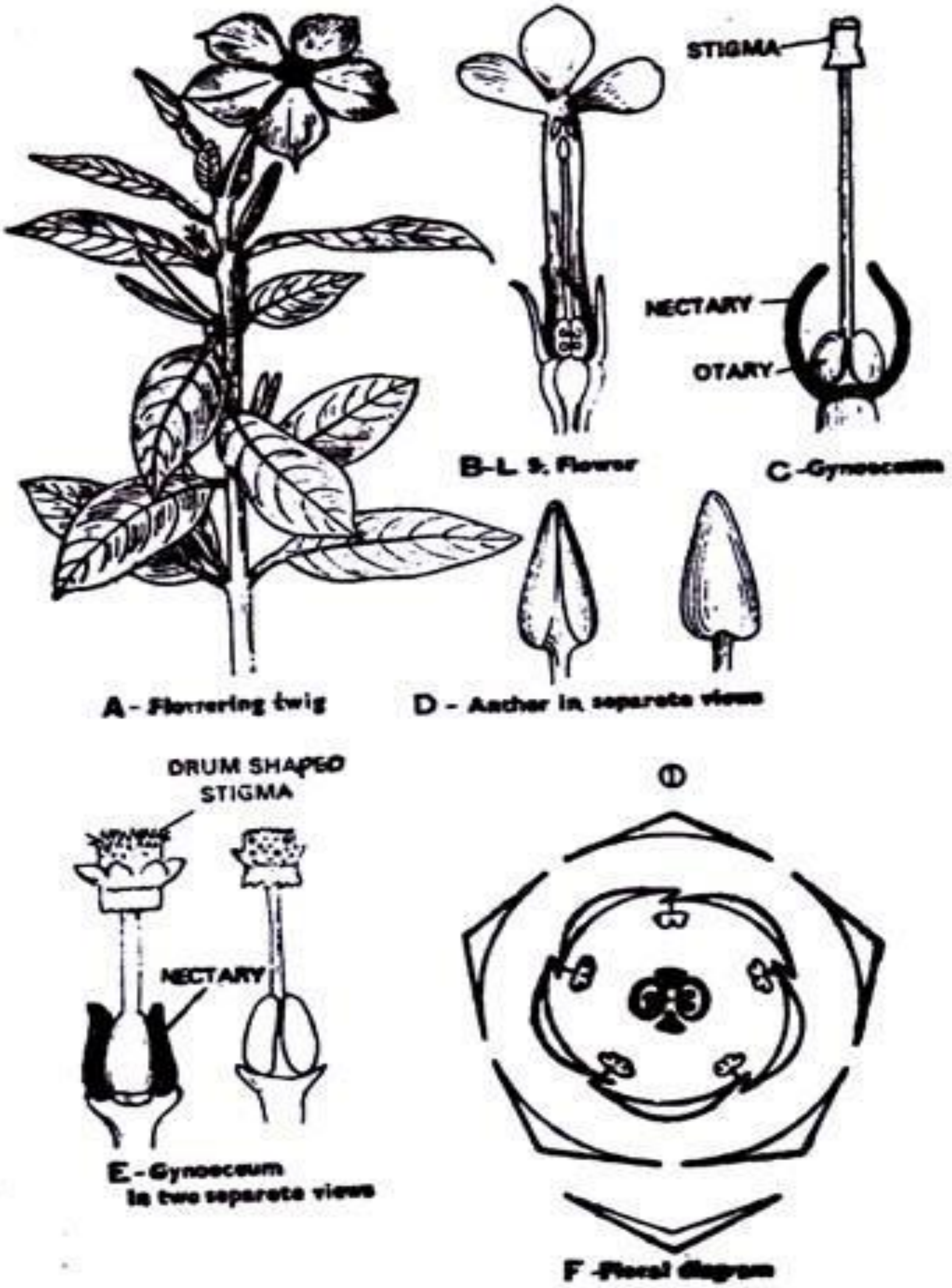


Fig. 74.1. *Catharanathus roseus.*

Order: Tubiflorae

1. Family: Convolvulaceae - The Morning Glory Family

Inflorescence and flower.
Flowers solitary, or aggregated in ‘inflorescences’; in cymes. The terminal inflorescence unit cymose. Inflorescences nearly always simple or compound dichasia. Flowers bracteate; bracteolate, or ebracteolate.
Perianth
with distinct calyx and corolla; 10; 2 whorled; isomerous. Calyx 5; 1 whorled; polysepalous, or gamosepalous ; persistent; imbricate; with the median member posterior. Corolla 5; 1 whorled; gamopetalous; valvate and plicate, or contorted and plicate; tubular.
Androecium
5. Androecial members adnate (to the base of the corolla); free of one another; 1 whorled. Stamens 5; inserted near the base of the corolla tube. Anthers dehiscing via longitudinal slits; introrse; tetrasporangiate.
Gynoecium
2(–5) carpelled. Gynoecium syncarpous; superior. Carpel when the ovaries are free, (1–)2 ovuled. Placentation basal. Ovary (1–2(–5) locular.
Fruit
fleshy, or non-fleshy; when synstylous, an aggregate, or not an aggregate. Fruit dehiscent, or indehiscent; a capsule, or a berry, or a nut. Capsules loculicidal, or circumscissile, or splitting irregularly.

Common Plants
Convolvulus arvensis
Ipomoea batatas
Ipomoea tricolor
Cuscuta pedicellata
Cressa cretica

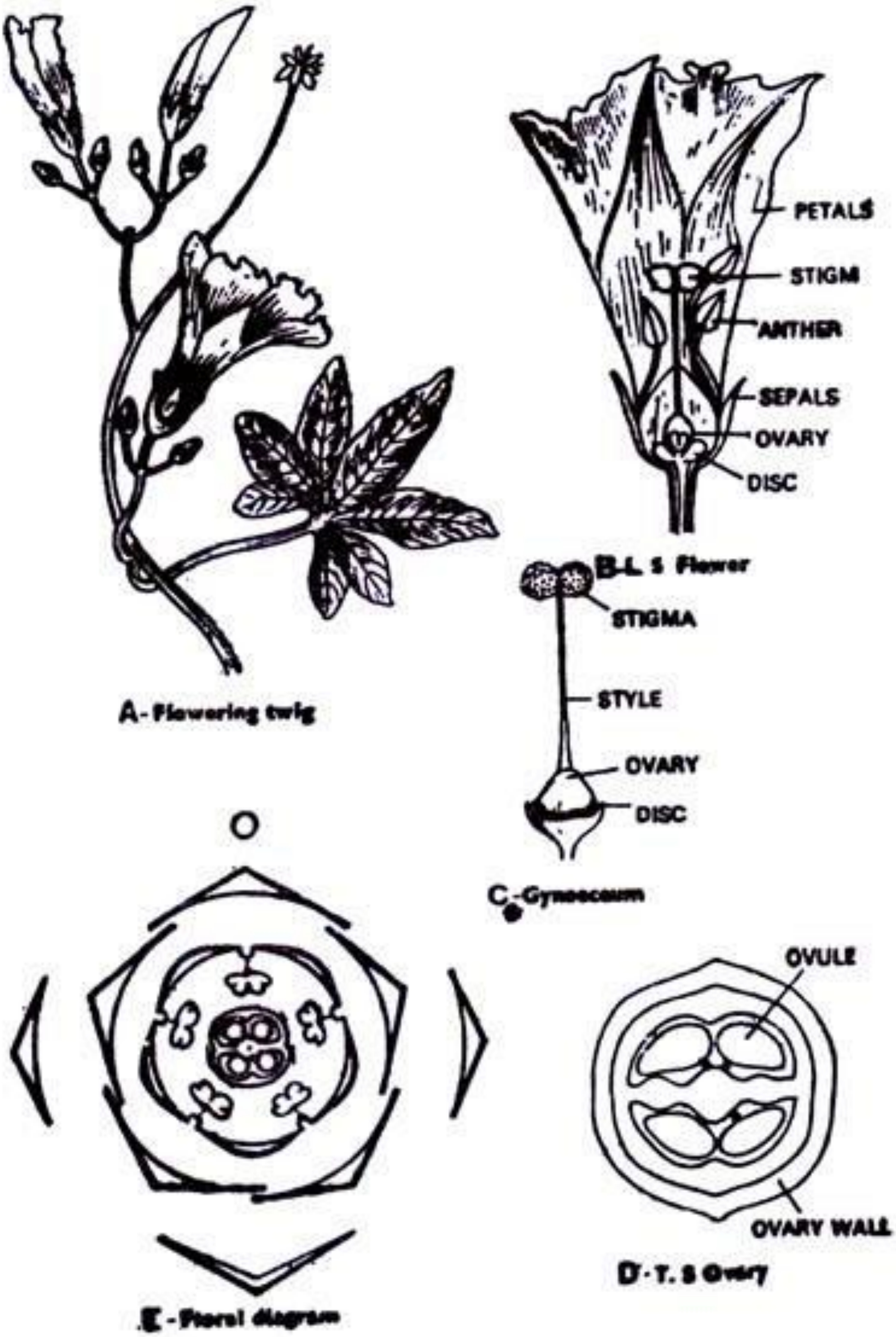


Fig. 77.1. *Ipomoea palmata.*

2. Family: Lamiaceae (Labiatae) - The Mint Family

Inflorescence and flower.

Flowers solitary, or aggregated in 'inflorescences' in heads, or in spikes, or in cymes, or in panicles. The terminal inflorescence unit cymose. Inflorescences terminal, or axillary. Flowers minute to medium-sized; zygomorphic; tetracyclic. Floral receptacle developing a gynophore, or with neither androphore nor gynophore.

Perianth with distinct calyx and corolla; 4–10; 2 whorled; isomerous, or anisomerous (or only dubiously interpretable). Calyx 2, or 3, or 4, or 5 (basically 5, but often with the bilabiate condition superimposed, and 2-lobed; 1 whorled. Corolla 5 or 4;1 whorled; gamopetalous; imbricate; bilabiate (usually, the lower lip typically threelobed, the upper commonly bilobed).

Androecium

2, or 4(–5) . Androecial members adnate; all equal. Stamens 2, or 4.

Gynoecium

2 carpelled. Carpels reduced in number relative to the perianth; syncarpous; superior. Ovary 2 locular. Styles 1. Stigmas 2, or 1; 2 lobed.

Placentation

basal. Ovules 2 per locule, or 1 per locule.

Fruit

usually non-fleshy, or fleshy; more or less a schizocarp. Mericarps 2-4; comprising nutlets.

Common Plants

Salvia splendens
Ocimum basilicum
Mentha sativa
Rosmarinus officinalis
Organum vulgare
Thymus vulgare

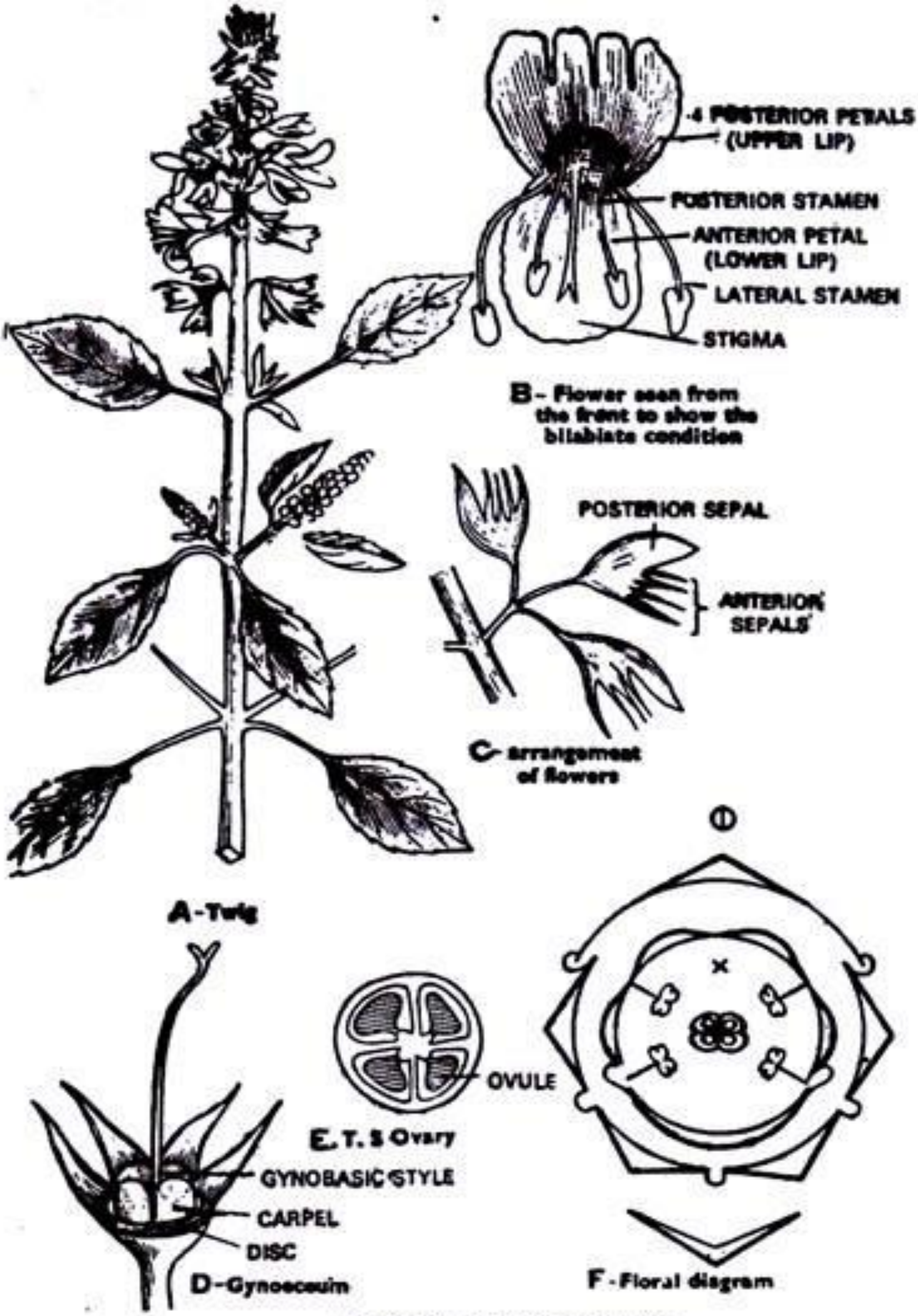


Fig. 85.1. *Ocimum sanctum*.

Order: Personatae

1. Family: Solanaceae - The Nightshade Family

Inflorescence and flower. Flowers solitary, or aggregated in 'inflorescences'. The terminal inflorescence unit apparently cymose. Inflorescences terminal, or axillary, or leaf-opposed.
Perianth with distinct calyx and corolla; 10 , or 8, or 11–14; 2 whorled; Calyx (4–)5(–7); 1 whorled; gamosepalous. Corolla (4–)5(–7); 1 whorled; gamopetalous.
Androecium 5 , or 3–4 , or 6–7. Stamens 5 or 2, or 4. Anthers connivent
Gynoecium 2 carpelled. Carpels reduced in number relative to the perianth. Gynoecium syncarpous; ovary 2 locular (but sometimes complicated by secondary divisions). Gynoecium oblique. Styles 1. Placentation axile. Ovules 1–50 per locule .
Fruit fleshy, or non-fleshy; dehiscent, or indehiscent; a capsule, or a berry, or a drupe. Capsules septicidal , or loculicidal, or valvular, or circumscissile.
Geography, cytology. Temperate to tropical. Absent only from cold regions, but with greatest diversity in Central and South America. X = 7–12(+).

Common Plants
Solanum tuberosum
Solanum nigrum
Solanum melongena
Solanum lycopersicum

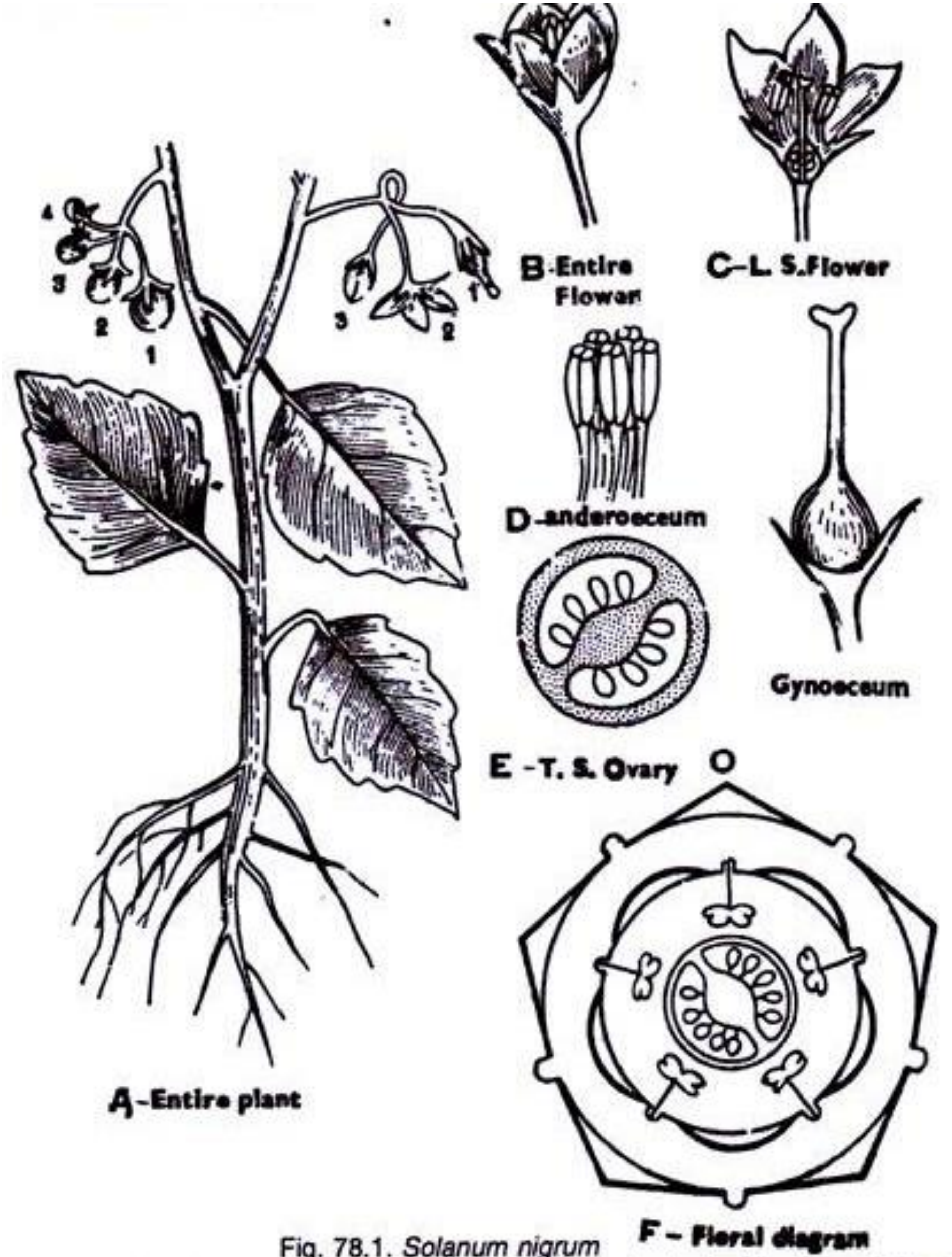


Fig. 78.1. *Solanum nigrum*

Order: Asterales

1. Family: Asteraceae (Compositae)

The Sunflower Family

Inflorescence and flower.

Flowers aggregated in 'inflorescences'; in heads. The terminal inflorescence unit racemose (but the primary capitula sometimes in cymose secondary heads). Inflorescences nearly always Indeterminate heads, but sometimes primary 'heads' reduced to single florets are grouped into secondary heads. Flowers bracteate, regular, or irregular.

Perianth with distinct calyx and corolla; (1–)3–35; 1 whorled, or 2 whorled. Calyx when present, (1–) 2–30 (of scales, awns or bristles constituting the 'pappus'); represented by bristles , or not represented by bristles; 1 whorled. Common inflorescence types: Radiate - mix of disc (center) and ray (periphery) Corolla 1–3 (ligulate florets), or (4–)5 (disk florets); 1 whorled; gamopetalous; valvate.

Androecium 3–5. Androecial members adnate; coherent; 1 whorled. Stamens 3–5; oppositisepalous. Anthers cohering basifixed; dehiscing via longitudinal slits; usually appendaged.

Gynoecium 2 carpelled. Gynoecium syncarpous; inferior. Ovary 1 locular. Styles 2; partially joined; attenuate from the ovary. Stigmas 2. Placentation basal. Ovules inthe single cavity 1.

Fruit

non-fleshy; indehiscent; a cypsella or a drupe. The drupes with one stone. Geography, cytology. Frigid zone, temperate, sub-tropical, and tropical.

Common Plants

Lactuca sativa
Cynara scolymus
Cotula cinerea
Gnaphalium luteo-album

Fig. 68.1. *Helianthus annuus.*

Class 2: Monocotyledoneae

Order: Glumiflorae

1. Family: Poaceae (Gramineae) - The Grass Family
Inflorescence and flower.
Flowers aggregated in ‘inflorescences in ‘spikelets’. The terminal inflorescence unit (the spikelet) or racemose (e.g. Pooideae). Inflorescences terminal, or axillary; with 1–50 florets and vestiges grouped into characteristic ‘spikelets’ in association with specialised bracts termed ‘glumes’, ‘lemmas’ and ‘paleas’, the spikelets variously gathered into simple or compound panicles, racemes, spikes, heads or fascicles; with involucral bracts, or without involucral bracts; spatheate, or espatheate.
Androecium (1–)2–3, or 4 , or 6. Stamens (1–)2–3, or 4, or 6–120. Anthers basifixed (sagittate).
Gynoecium theoretically 2(–3) carpelled. Gynoecium syncarpous; superior. Ovary 1 locular. Styles 1, or 2(–3). Stigmas (1–)2–3; dry type; papillate, or non-papillate.
Placentation basal to parietal. Ovules in the single cavity.
Fruit non-fleshy, or fleshy; indehiscent; a caryopsis or capsular-indehiscent , or achene-like, or a nut, or a berry.

Common Plants
Avena fatua
Echinochloa colunum
Cynodon dactylon
Triticum vulgare

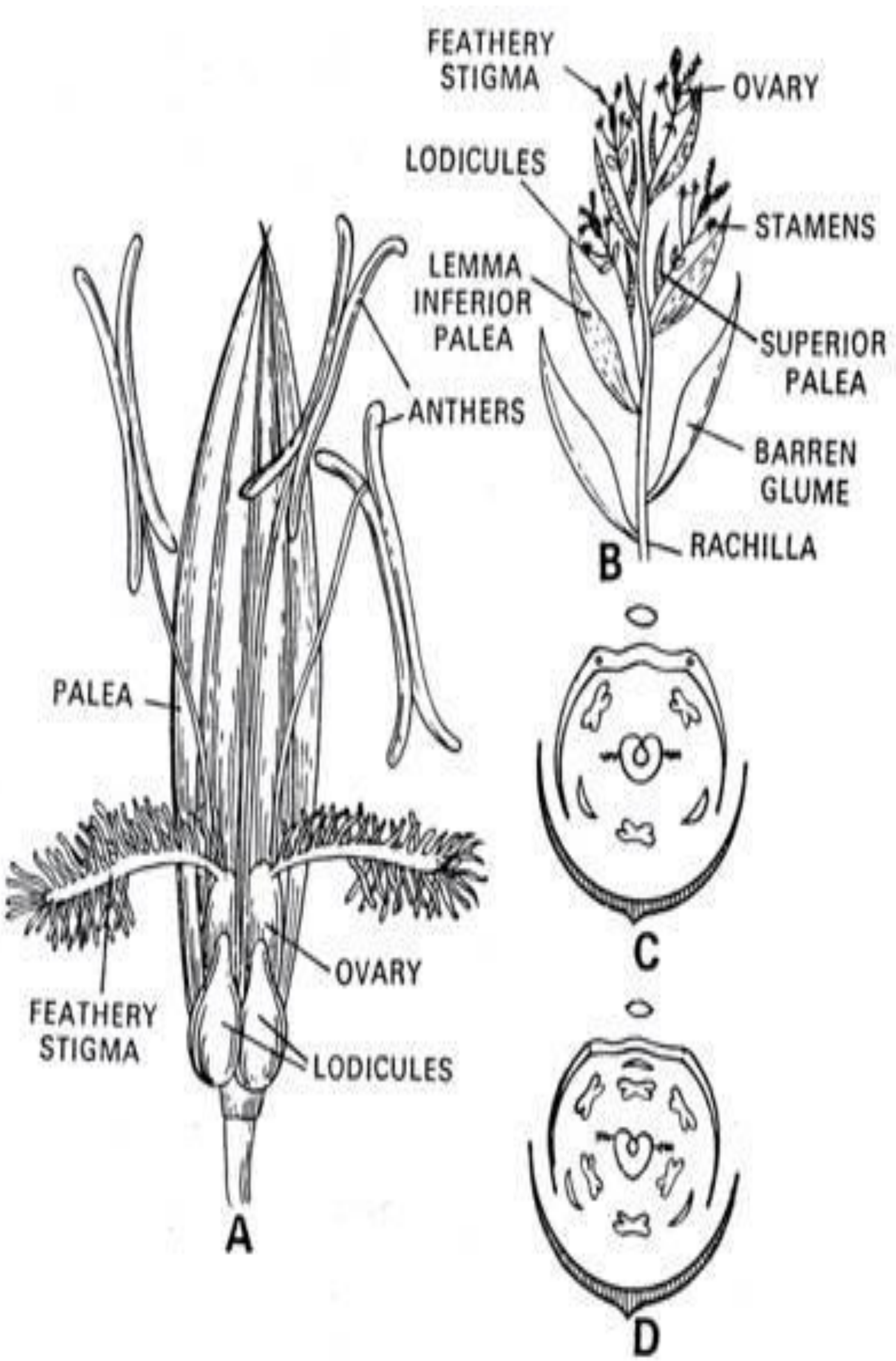


Fig. 30.1. Gramineae (Poaceae)–A, a spikelet of *Festuca* sp., after the removal of the glumes showing lodicules, ovary, anthers, stigma, etc; B, spikelet of a grass; C, floral diagrm of a grass; D, floral diagram of *Bambusa*.

Order: Spadiciflorae

1. Family: Arecaceae (Palmae) - the Palm Family

Inflorescence and flower.

Flowers aggregated in 'inflorescences'; in panicles. Inflorescences axillary , or terminal; usually complex panicles; usually spatheate. Flowers small; more or less regular; 3 merous; cyclic , or partially acyclic.

Perianth

with distinct calyx and corolla, or of 'tepals', or vestigial to absent ; 6 , or 4; free, or joined; 2 whorled (usually 3+3, occasionally 2+2), or 1 whorled ; sepaloid, or petaloid, or sepaloid and petaloid.

Androecium

3, or 6, or 9, or 10–900; 1 adelphous ; 2 whorled, or 3 whorled.

Stamens

3, or 6, or 9, or 10–900. Anthers dehiscing via longitudinal slits.

Gynoecium

3(–10) carpelled. Carpels isomerous with the perianth, or increased in number relative to the perianth. Gynoecium apocarpous, or syncarpous. Ovary when syncarpous 1 locular or 3(–10) locular. Styles 1, or 3(–10). Stigmas dry type; papillate. Placentation sub apical, or basal. Ovules 1 per locule; non-arillate.

Fruit

fleshy, or non-fleshy; an aggregate , or not an aggregate. The fruiting carpel when apocarpous, indehiscent; drupaceous. Fruit indehiscent , or dehiscent ; nearly always a berry, or a drupe (sometimes with a fibrous mesocarp).

Common Plants

Phoenix dactylifera
Hyphaene thebaica
Oredoxa regia
Washingtonia robusta
Livistonia chinensis
Cocos nucifera

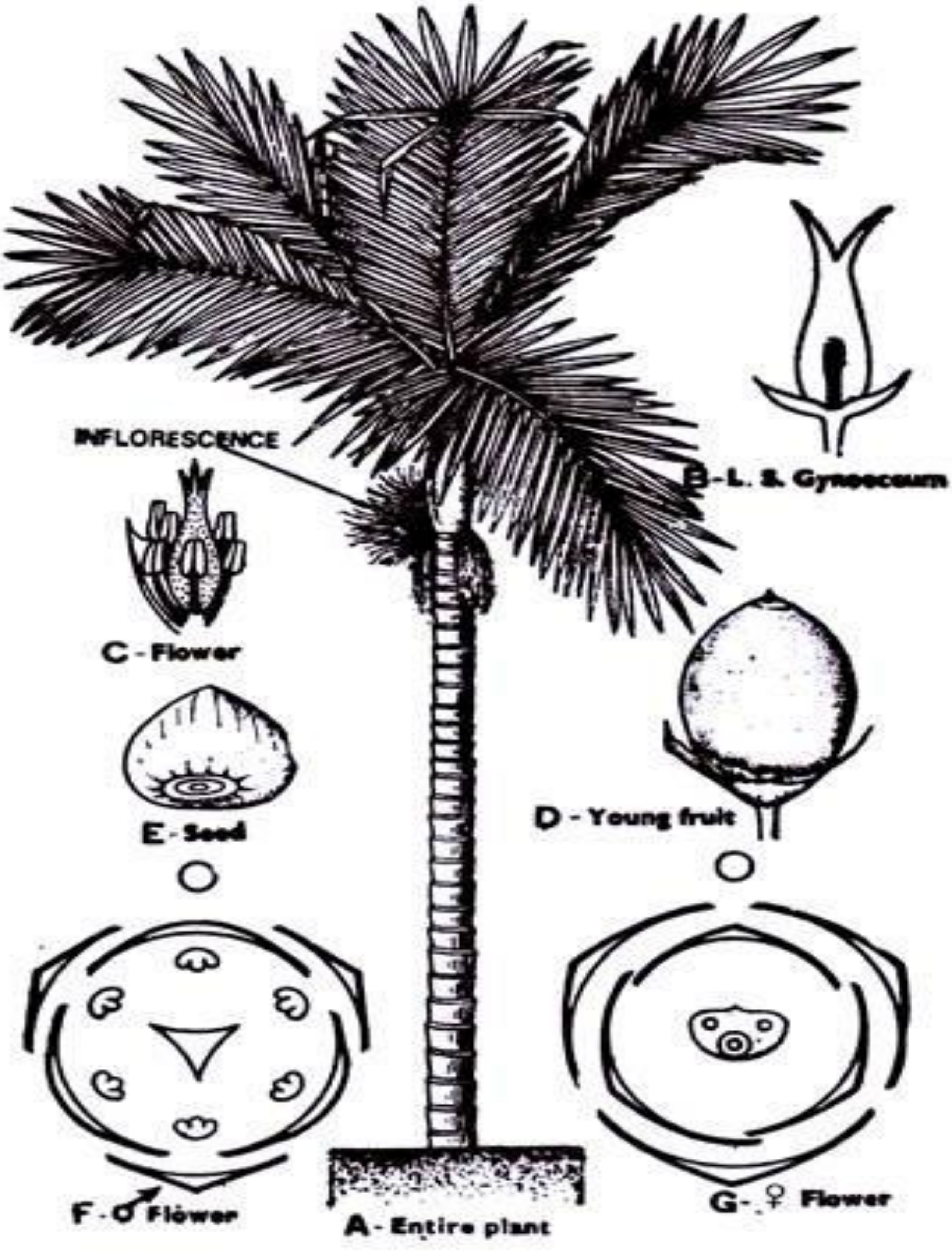


Fig. 111.1. *Areca catechu.*

Order: Liliflorae

1. Family: Liliaceae - The Lily Family

Inflorescence and flower.

Flowers solitary, or aggregated in 'inflorescences'; in racemes, or in umbels, or in panicles. The terminal inflorescence unit racemose. Flowers bracteate, or ebracteate.

Perianth of 'tepals',

or with distinct calyx and corolla; 6; free; 2 whorled; isomerous; petaloid, or sepaloid and petaloid; similar in the two whorls, or different in the two whorls; colour variable.

Androecium

6. Androecial members free of the perianth; all equal; free of one another; 2 whorled (3+3). Androecium exclusively of fertile stamens. Stamens 6; diplostemonous; alterniperianthial. Anthers basifixed or dorsifixed.

Gynoecium 3 carpelled. Carpels isomerous with the perianth. Gynoecium syncarpous. Ovary 3 locular. Styles 1; attenuate from the ovary, or from a depression at the top of the ovary; apical. Stigmas 1, or 3; dorsal to the carpels; wet type, or dry type; papillate.

Placentation

axile. Ovules 5–50 per locule.

Fruit

non-fleshy; dehiscent; a capsule. Capsules loculicidal.

Common Plants

Allium cepa
Allium sativum
Allium porrum
Allium currat

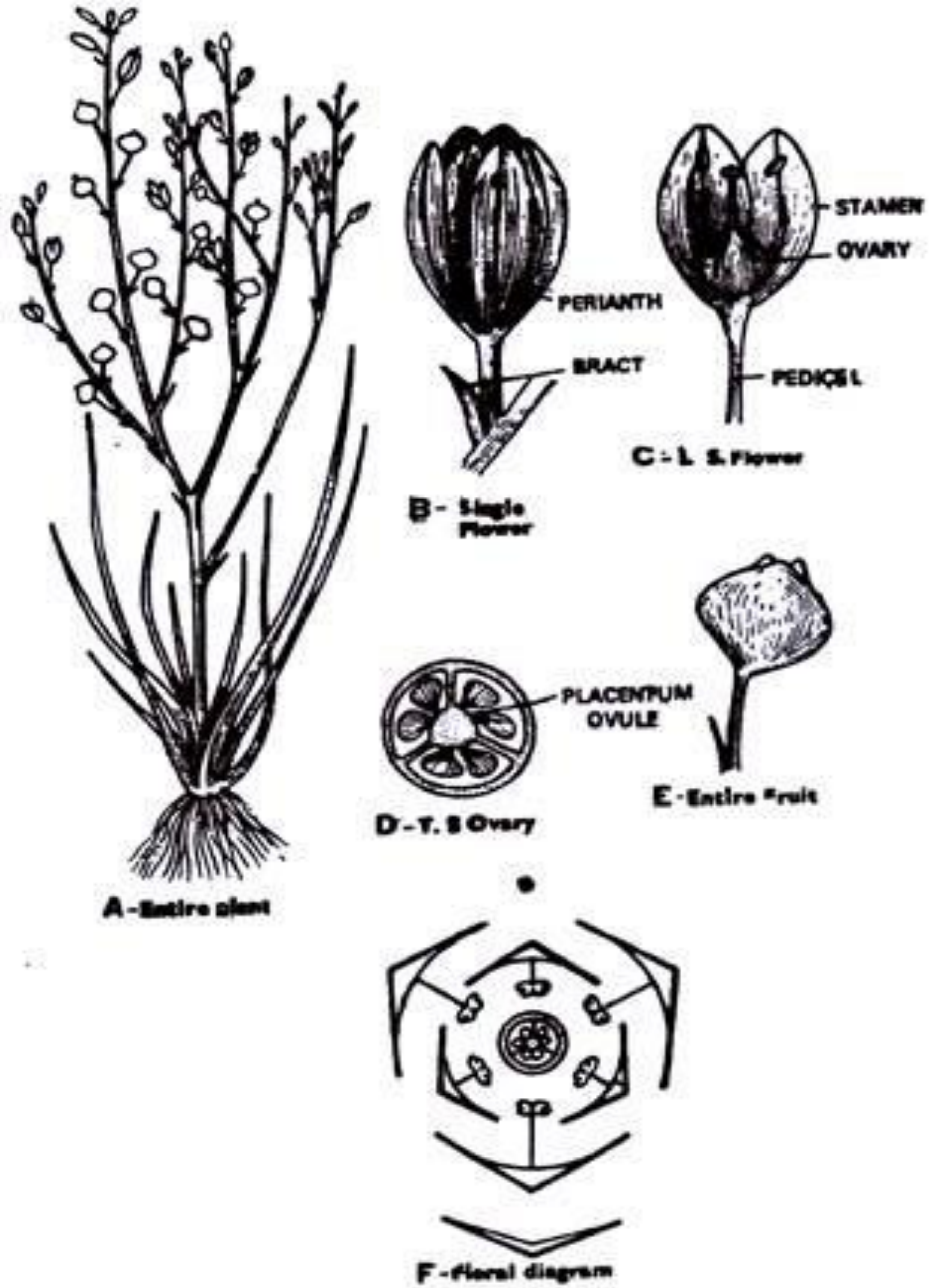


Fig. 107.1. *Asphodelus tenuifolius.*