THE NATIONAL UNIVERSITY OF LESOTHO

DEPARTMENT OF BIOLOGY

B108: INTRODUCTORY BIOLOGY
INTRODUCTORY PLANT DIVERSITY

Introduction to plant taxonomy

Taxonomy

- Taxonomy is the science of classification of organisms.
- Taxonomy is concerned with naming and classifying the diverse forms of life.
- Classification in biology is arrangement of organisms into groups with common characteristics.
- Taxonomy has two branches – nomenclature (naming of organisms) and systematics (placing of organisms into groups).
- Systematics is done on the basis of similarities and differences.

Systems of Classification

- There are two types of classification; artificial and natural.
- An artificial classification is based on one or a few easily observable characteristics and is usually designed for practical purposes with emphasis on convenience and simplicity.
- Natural classification uses natural relationships between organisms. It considers more evidence than artificial classification, including internal as well as external features.
- Similarities of embryology, morphology, anatomy, physiology, biochemistry, cell structure and behavior are all relevant and considered.
- Most classifications used today are natural and phylogenetic. A phylogenetic classification is one based on evolutionary relationships. In such a system, organisms belonging to the same groups are believed to have a common ancestor. The phylogeny (evolutionary history) of a group can be shown by means of a family tree.
- Another way to classify organisms is to use a phenetic classification. Phenetic means "that which is seen". If there is very little/no fossil evidence phylogenetic (evolutionary relationships) classification can be difficult and controversial to establish, thereby making it difficult to employ.
- Phenetic classification is based on observable characteristics (phenetic similarities). All characters used are considered of equal importance.
- Masses of data are collected and the degrees of similarities between different organisms are calculated, usually by computer programs because the calculations are completely complex. The use of computers in taxonomy is called numerical taxonomy.

NB. Coincidentally, phenetic classification often resembles phylogenetic classification.

Specimen identification keys

- A key is a convenient method of enabling a biologist to identify an organism.
- It involves listing the observable characteristics of the organism and matching them with those features that are diagnostic of a particular group.

- Most of the characteristics used in identification are based on easily observable features such as shape, colour and number of appendages, segments and so on.
- Identification is artificial and phenetic since it relies purely on the phenotype of the organism. Despite this, most diagnostic keys enable organisms to be identified into a group which is part of a natural phylogenetic hierarchical classification system.
- There are various types of diagnostic keys but the simplest is called dichotomous key. This is made up of pairs of contrasting and mutually exclusive statements called leads, numbered 1, 2, 3, and so on, where each lead deals with a particular observable characteristic. The characteristics used in keys should be readily observable morphological features and may be qualitative or quantitative.
- The characteristics must be constant for that species and subject to variation as a result of environmental influences.

Homology and analogy

Similarity due to shared ancestry is called homology and similarity due to convergent evolution is called analogy. Analogous structures that arose independently are called homoplasies.

Five kingdoms

- In the past organisms used to be grouped into two kingdoms (plants and animals) based on nutrition. Animals are heterotrophic while plants are autotrophic.
- Cellular organisms fall into two groups which are prokaryotes and eukaryotes.
- Margulis and Schwartz (1982) proposed a system which uses five kingdoms, the prokaryotae and four eukaryotae kingdoms. These groups include Prokaryotae (Monera), Protoctista, Fungi, Plantae and Animalia.
- This has been widely accepted and currently recommended by the Institute of Biology.

Taxonomic hierarchy

Organisms are classified into hierarchical groupings with the largest group at the top of the hierarchy.

Species → genus → family → order → class → phylum → kingdom → Domain

In some cases there are intermediate categories such as subfamilies, subphyla, subclasses, suborders etc. Each level on the hierarchy is called a taxon (taxa-plural). Each group possesses features that are unique to that particular group (diagnostic features). Similarities increase on moving down the hierarchy while differences increase on moving up the hierarchy e.g. members of the same genus have more similarities than members of the same family or order.

acris → Ranunculus → Ranunculaceae → Ranunculales → Dicotyledones → Anthophyta → Plantae

camara → Lantana → Verbenaceae → Lamiales → Magnoliopsida → Embryophyta → Plantae

NB. There are three domains: Eukrya, Bacteria and Archaea

Scientific naming

- Biological nomenclature is based on the bionomial system of nomenclature.
- Each organism has two names: a generic name beginning with uppercase (capital) letter and a specific name beginning with a lower case letter e.g. *Brachystegia spiciformis*,

Julbernadia globiflora, Vitex payos. The genus is *Brachystegia* and the species is *spiciformis*.

- Italics are used to indicate Latin names (scientific names) or the words can be underlined e.g. *Brachystegia spiciformis* or <u>Brachystegia spiciformis</u>.
- Generic name + specific epithet = species name. The genus name may be abbreviated to one letter e.g. *B. spiciformis*.
- The Latin (scientific) names are internationally agreed upon and avoid the confusion as a result of variations in local common names.

Species

A species is a population or group of closely related organisms which can potentially interbreed with each other to produce fertile offspring. Each species possesses its own distinct structural, behavioural and ecological characteristics. We cannot have a precise definition of a species.
NB. Species evolve (can change over time). Natural selection results in species changing. If populations of the same species become isolated from each other by e.g. ecological or physical barriers the different populations may evolve differently until they cease to be capable of interbreeding thereby becoming different species.

Algae

Characteristics

- There is a great range of size and form, including unicellular, filamentous, colonial and thalloid forms. However, they are mainly thalloid (i.e. not differentiated into true roots, stems, leaves and lack a true vascular system)
- They are grouped according to their photosynthetic pigments, green and brown algae
- Eukaryotic and mainly unicellular.
- Specialised for aquatic (both marine and freshwater) existence
- Mainly non-motile.
- Photosynthetic – have chlorophyll a, b, c and fucoxanthin.
- The common groups are phylum Chlorophyta (green algae), Phylum Phaeophyta (brown algae) and Phylum Euglenophyta (euglenoids)

Phylum Chlorophyta (Green algae)

- Dominant photosynthetic pigment is chlorophyll (chl. a and b); therefore green in appearance
- Store carbohydrate as starch (insoluble)
- Mostly freshwater
- Range from unicellular, filamentous, colonial to thalloid types
- Examples include Chlorella (unicellular and non-motile), *Chlamydomonas* (unicellular and motile), *Spirogyra* (filamentous), *Ulva* (marine and thalloid) and *Euglena*.

Phylum Phaeophyta (Brown algae)

- Dominant photosynthetic pigment (brown) is fucoxanthin but chlorophylls a and c are also present
- Store carbohydrate as soluble laminarin and mannitol but also store fat

- Nearly all marine (very few (three) freshwater genera only)
- Filamentous or thalloid, often large
- Examples include *Fucus* (thalloid and marine) and *Laminaria* (large thalloid and marine)

Economic importance

- Major primary producers in aquatic systems, also ecologically important
- They are used for food e.g. seaweed (Porphyra, red seeweed) in Asia. In Japan and Korea, Laminaria (large brown seeweed) is used in soups. Marine algae are rich in iodine and other essential minerals. Algin and agar are used for the manufacture of thickeners for such processed food as puddings and salad dressing, and as lubricants in oil drilling.
- Medicine – some medicines are derived from algae
- Energy source – biofuel e.g. ethanol fuel, biodiesel etc
- Fertilizers and soil conditioners
- The algae can be harvested occassionally and processed for animal fodder
- Filters in water purification
- Sewage treatment (microbial life of sewage works) to remove inorganic nutrients and toxins e.g. open oxidation pods
- Algae produce natural pigments that are used as alternatives to chemical dyes and colouring agents.
- Production of cosmetics
- Agar is also used in preparation of microbiological culture media.

Kingdom Plantae

Plants are autotrophic eukaryotes which have become adapted to life on land. Evolution of plants mainly considers gradual improving adaptation to life on land.

Plant diversity

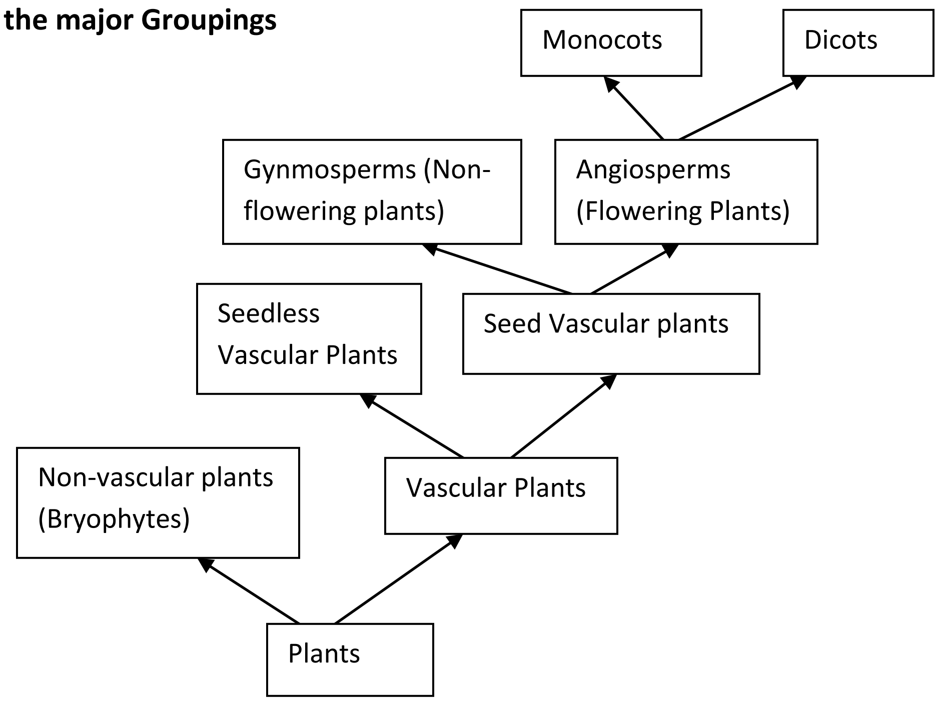
- One way to distinguish plants is by whether or not they have an extensive system of vascular tissue, cells joined into tubes that transport water and nutrients throughout the plant body.
- Most plants have a complex vascular tissue system and are therefore called vascular plants.
- Plants without vascular tissue are called non-vascular plants. These are also called bryophytes.

Major groups of plants and estimated number of species

Group of plants	Common name	Estimated number of species
Non-vascular Plants (bryophytes) Phylum Hepatophyta Phylum Anthocerophyta Phylum Bryophyta	 Liverworts Hornworts Mosses	 9,000 100 15,000
Vascular Plants		

Seedless Vascular Plants		
Phylum lycophyta	Lycophytes	1,200
Phylum Pterophyta	Pterophytes	12,000
Seed Plants		
Gymnosperms		
Phylum Ginkgophyta	Ginkgo	1
Phylum Cycadophyta	Cycads	130
Phylum Gnetophyta	Gnetophytes	75
Phylum Coniferophyta	Conifers	600
Angiosperms		
Phylum Anthophyta	Flowering Plants	250,000

Plant Tree Diagram showing the major Groupings



Bryophytes

They are represented by phyla of small herbaceous plants. These include Phylum Hepatophyta (liverworts), Phylum Anthocerophyta (Hornworts) and Phylum Bryophyta (Mosses). They are the simplest land plants. They are thought to have evolved from algae.

General characteristics of bryophytes

- They show alternation of generation in which the gametophyte generation is dominant.
- No vascular tissue i.e. no xylem or phloem
- Body is thallus or differentiated into simple “leaves” or “stems”
- Strengthening or conducting tissues absent or poorly developed.
- No true roots, stems, or leaves; the gametophyte is anchored by filamentous rhizoids.

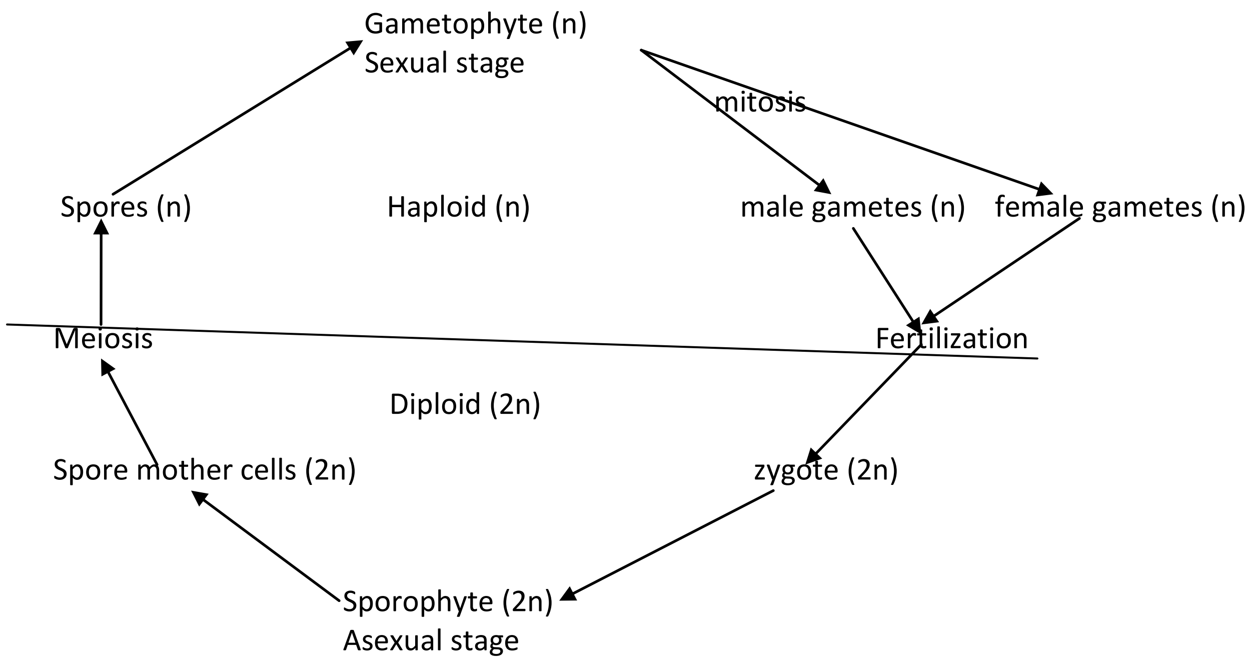
- Sporophyte is attached to, and depended upon, the gametophyte for its nutrition.
- Spores are produced by the sporophyte in a spore capsule on the end of a slender stalk above the gametophyte.
- Live mainly in damp shady places.
- Water and mineral salts can be absorbed by the whole surface of the plant
- Lacks cuticle or have a very delicate one so no barrier against loss or entry of water
- The plants are low-growing (short)
- Produce flagellated sperm

Alternation of Generations

Bryophytes, like all other plants, show alternation of generations. A haploid gametophyte generation and diploid sporophyte generation alternate in the life cycle. The haploid generation is called the gametophyte because it undergoes sexual reproduction to produce gametes. Production of gametes involves mitosis so the gametes are also haploid. The gametes fuse to form a diploid zygote which grows into the next generation, sporophyte generation. It is called sporophyte because it undergoes asexual reproduction to produce spores. Production of spores involves meiosis and so there is a return to the haploid condition. The haploid spores give rise to the gametophyte generation. One of the two generations is always conspicuous and occupies a greater proportion of the life cycle; this is said to be the dominant generation. In bryophytes the gametophyte generation is dominant while in all other plants the sporophyte generation is dominant. It is customary to place the dominant generation in the top half of the life cycle diagram.

General life cycle of a plant showing alternation of generations

The gametophyte is always haploid and produces gametes by mitosis. The sporophyte is always diploid and always produces spores by meiosis. This life cycle occurs in all plants including the most advanced flowering plants.



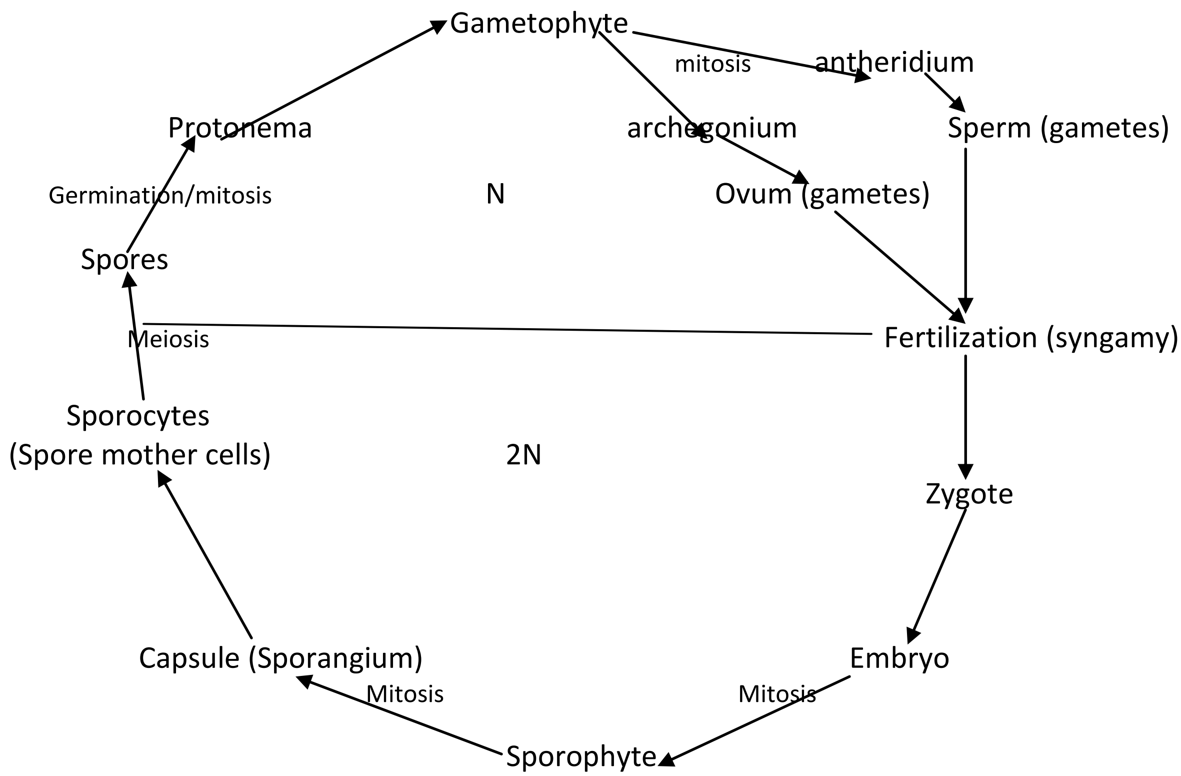
Phylum Hepatophyta (Liverworts)
They are more simple is structure than other bryophytes. They are more confined to damp and shady habitats. They are found on the banks of streams, on damp rocks and in wet vegetation. They have a flattened and liver-shaped gametophyte. **"Leaves" are in 3 ranks along the "stem"**. Rhizoids are unicellular. Capsules of sporophyte split into four valves for spore dispersal and elaters aid dispersal. They can be thallus (rare), "leafy" with "stem" majority and intermediate lobed types. Examples include 1) *Marchantia*, a thallus liverwort with antheridia and archegonia on stalked structures above the thallus; 2) *Pellia*; 3) *Lophocolea*, a leaf liverwort, common on rotting wood.

Phylum Anthocerophyta (Hornworts)
Have a long tapered shaped sporophyte. Sporophyte can grow to about 5cm high. The sporophyte lacks a seta and consists only of a sporangium. The gametophyte, usually 1-2cm in diameter, grows mostly horizontally and often have multiple sporophytes attached.

Phylum Bryophyta (Mosses)
They are more differentiated than liverworts. The gametophyte is "leafy" with "stem". Sporophytes elongated with height ranging up to 20cm. Gametophyte ranges from 1mm to 15cm in height. Though green and photosynthetic when young, the capsule turns tan or brownish when ready to release spores. Rhizoids are multicellular. Produce light weight spores that are dispersed by wind. Water is essential for fertilization. When the surface of the plant is wet, mature antheridia absorb water and burst, releasing the male gametes (sperm) each with two flagella onto the surface which then swim towards the archegonia. Examples include *Funaria*, *Mnium* and *Sphagnum*.

Bryophyte gametophyte
The gametophyte is larger and longer-living than the sporophyte. When bryophyte spores are dispersed to a favourable habitat, such as moist soil or tree bark, they germinate and grow into gametophyte. Gametophytes are anchored by delicate rhizoids, which are long, tubular single cells (in liverworts and hornworts) or filaments of cells (in mosses). Rhizoids are just for anchorage and not for water and mineral absorption. Mature gametophyte forms gametangia that produce gametes and are covered by protective tissue. A gametophyte may have multiple gametangia. Eggs are produced singly in the pear-shaped archegonium, whereas the antheridium produces many sperm. Some bryophyte gametophytes are bisexual, but in mosses the archegonia and antheridia are typically carried on separate female and male gametophytes. Flagellated sperm swim through a film of water toward eggs, entering the archegonia in response to chemical attractants. Eggs are not released but instead remain within the bases of the archegonia. After fertilization embryos are retained within the archegonia. Layers of placental cells help transport nutrients to the embryos as they develop into sporophytes. Bryophyte sperm require a film of water to reach the eggs.

Bryophyte sporophyte
Though usually green and photosynthetic when young, bryophyte sporophyte cannot live independently. They remain attached to their parental gametophytes, from which they absorb sugars, amino acids, minerals and water. Bryophytes have the smallest sporophytes among plants. A typical bryophyte sporophyte consists of a foot, a seta, and a sporangium. Embedded in the archegonia, the foot absorbs nutrients from the gametophyte. The seta (plural-setae) or stalk conducts these materials to the sporangium, also called a capsule. In most mosses the seta becomes elongated, enhancing spore dispersal by elevating the capsule.
Life cycle of a moss



Sperm must swim through a film of moisture to reach the egg and fertilization occurs in the archegonium.

NB. Bryophytes depend on water for two main reasons:
1. Antheridia only burst to release sperm in the presence of water
2. Sperm need a film of moisture (water) in order to swim to the archegonia.

Importance of bryophytes
- Help retain nitrogen in the soil e.g. mosses
- Form peat which inhibit decay of mosses and other organisms due to low temperatures, pH and oxygen levels. Peat refers to extensive deposits of partially decayed organic material.
- The peat they form is a source of fuel e.g. in Europe, Asia, Ireland and Canada
- Moss peat is useful as a soil conditioner. Bryophytes can be used for packaging plant roots during shipment.

- Peat is a good storage for organic carbon and this helps to stabilize atmospheric carbon dioxide.
- Bryophytes contribute significantly to community structure and ecosystem functioning.
- In arctic regions, they are important in maintaining permafrost.
- They help in water retention.
- They form a huge biomass in tropical montane forests.
- They are also important in maintaining the soil crust.
- They also control soil erosion.
- Help in accumulation of humus
- They provide food and habitat for other organisms such as arthropods.
- Used in water filtering as an absorption agent for the treatment of water and effluents from factories with acid and toxic discharges with heavy metals, organic substances acids, detergents and dyes.
- They can be used as an absorbing agent for oil spills.
- It is used in babies' nappies because of their absorptive properties.
- Indicators of surface water

Adaptations of Bryophytes to life on land

- Mode of spore dispersal depends on drying out of the capsule
- Dispersal of small light spores by wind
- The gametes develop in protective structures, the antheridia and archegonia
- Have rhizoids for anchorage on solid substratum

Early Tracheophytes (Seedless Vascular Plants)

Can be divided into Lycophytes (club mosses and their relates) and Pterophytes (ferns and their relatives)

Phylum Filicinophyta (Ferns)
General characteristics of ferns

- Alternation of generation in which the sporophyte generation is dominant.
- Vascular tissue is present (xylem and phloem) in the sporophyte. These tissues are concerned with translocation (transport) of water and nutrients around the plant body. Xylem carries mainly water and minerals salts, whereas phloem carries mainly organic solutes in solution such as sugar.
- Gametophyte is reduced to a smaller generation and is more susceptible to desiccation (drying) than in the bryophyte generation. It is called prothallus and produces sperm which must swim to reach the female gametes as in bryophytes.
- Sporophyte generation possesses well-developed true roots, stems and leaves.
- Leaves are relatively large and are called fronds.
- Spores are produced in sporangia which are usually in clusters called sori.
- Usually restricted to damp shady habitats.
- Vascular tissue is only found in the sporophyte generation and this is one reason why the sporophyte generation becomes conspicuous in all vascular plants. Vascular tissues has two important properties, 1) forms transport system around the multi-cellular body

and thus allowing the development of large, complex bodies; 2) these can be supported because xylem also contains lignified cells and they are of great strength and rigidity. Lignified vascular tissue permitted plants to grow tall (stems are strong enough for support). Non-vascular plants which rarely grow above 20cm in height can be shaded.

- These are common in tropical forests where temperature, light and humidity are favourable.
- Despite advances in adapting to a land environment which are associated with the sporophyte generation, in ferns there remains a major problem with the gametophyte.

Evolution of roots and leaves

Almost all vascular plants have developed roots which absorb water and nutrients from the soil. Roots also provide anchorage and so allow the shoot to grow taller.

Leaves increase surface area of the plant body and serve as the primary photosynthetic organs of vascular plants. In terms of size and complexity, leaves can be classified as either microphylls or megaphylls. All the lycophytes (oldest vascular plants) have microphylls – small, usually spine-shaped leaves supported by a single strand of vascular tissue. Almost all other vascular plants have megaphylls – leaves with highly branched vascular system. These have a greater surface area for photosynthesis than microphylls.

Sporophylls and spore variation

Evolution of plants saw the emergence of sporophylls – modified leaves that bear sporangia. Fern sporophylls produce clusters of sporangia known as sori (single – sorus), usually on the underside of the sporophylls. In many lycophytes and gymnosperms, groups of sporophylls form corn-like structures called strobili. Most seedless vascular plant species are homosporous i.e. they have one type of sporangium that produces one type of spores, which typically develops into bisexual gametophyte as in most ferns. In contrast, heterosporous species have two types of sporangia and produce two kinds of spores. Megasporangia on megasporophylls produce megaspores, which develop into female gametophyte; microsporangia on microsporophylls produce microspores, which develop into male gametophytes.

Homosporous spore production

Sporangium on sporophyll → Single type of spore → Typically a bisexual gametophyte → eggs / sperm

Heterosporous spore production

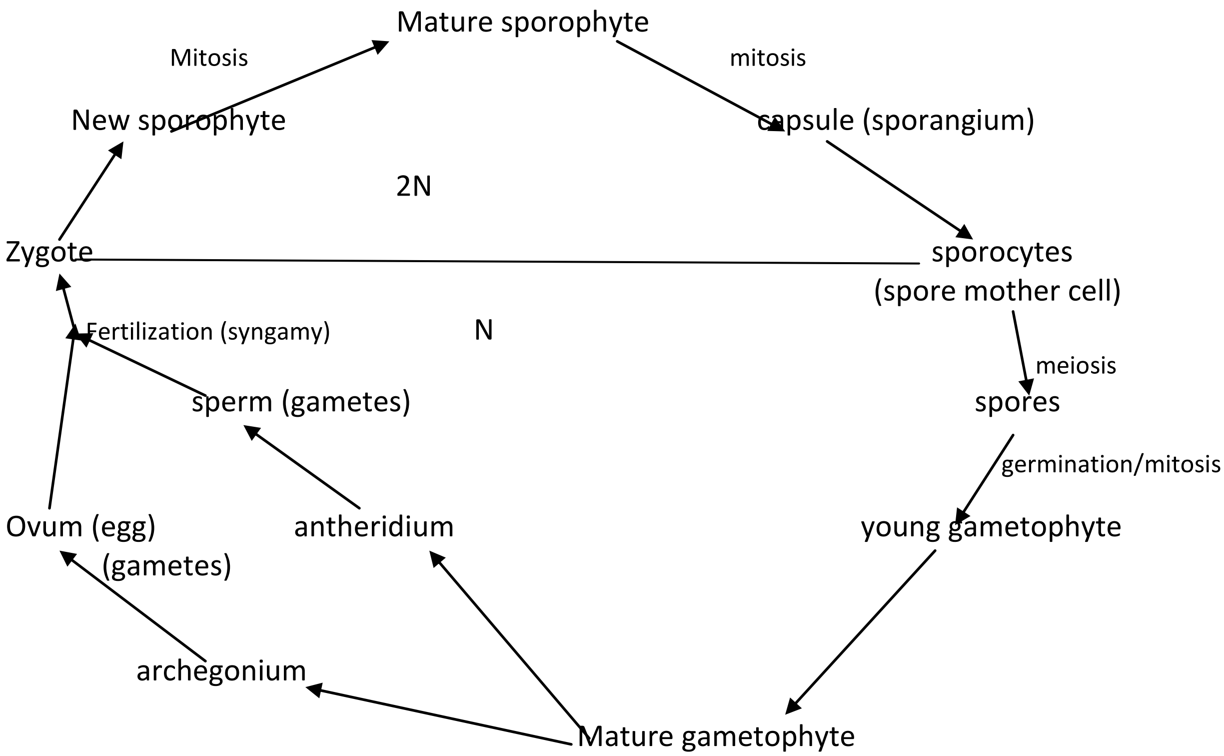
Megasporangium on sporophyll → Megaspore → Female gametophyte → Eggs

Microsporangium on microphyll → Microspore → Male gametophyte → Sperm

NB. All seed plants and a few seedless vascular plants are heterosporous.

Today, ferns are by far the most widespread seedless vascular plants with more than 12,000 species. These are most diverse in the tropics.

Life cycle of a fern



Adaptations of ferns to life on land

- Presence of vascular tissue
- True roots, stems, leaves in the sporophyte
- Gametophyte is reduced
- Rhizoids in gametophyte
- Large leaves called fronds

Importance of seedless vascular plants (Ferns)

- With the evolution of vascular tissue, roots and leaves, these plants accelerated their rate of photosynthesis, dramatically increasing the removal of carbon dioxide from the atmosphere.
- The seedless vascular plants that formed the first forests eventually became coal.
- Primitive seed plants grew along with seedless vascular plants i.e. seedless vascular plants promoted growth of seed plants.
- Seedless vascular plants dominated the earliest forest.
- Their growth may have helped produce the major global cooling that characterised the end of the carboniferous period.

Seed bearing plants

Seed plants evolved about 360 million years ago. These are the most successful group of land plants. A seed consists of an embryo and its food supply, surrounded by a protective coat. Seeds are a key adaptation that helped seed plants to be dominant producers on land and to make the vast majority of plant diversity today. Seeds resulted in domestication of seed plants.

There are two main groups of seed-bearing plants: Gymnosperms (conifers) and angiosperms (flowering plants). In conifers ovules (later seeds) are located on the surfaces of specialized scale leaves called ovuliferous scales. These are arranged in cones. In angiosperms, ovules and therefore seeds are enclosed, giving more protection.

General Characteristics of seed-bearing plants

- Sporophyte is the dominant generation; gametophyte generation is severely reduced.
- Sporophyte produces two types of spores i.e. heterosporous. The two types are microspores and megaspores (microspore – pollen grain; megaspore – embryo sac).
- The embryo sac (megaspore) remains completely enclosed in the ovule megasporangium; a fertilized ovule is a seed.
- Water is not needed for sexual reproduction because male gametes do not swim (except in a few primitive members); they are conveyed to the ovum by a pollen tube to effect fertilization.
- They have complex vascular tissues in roots, stems and leaves.

Adaptations of seed bearing plants to life on land

- The gametophyte generation is very much reduced and always protected inside a sporophyte, and is totally dependent on the sporophyte.
- Fertilization is not dependent on water. The male gametes are non-motile and carried in pollen grains dispersed by insects or wind and finally by pollen tube.
- The fertilized ovule (seed) is retained for some time on the parent gametophyte from which it obtains protection and food before dispersal.
- Many seed plants show secondary growth with production of large amount of wood which offers support, e.g. trees and shrubs are able to compete effectively for light and other resources.
- True roots provide anchorage and enable water in the soil to be reached.
- Presence of waxy cuticle to minimize water loss
- Presence of stomata for gaseous exchange
- Plants can show a variety of adaptations to hot dry environments

NB. Seeds and pollen grains are key adaptations for life on land.

Adavantages of reproduction by seed

- The plant is independent of water for sexual reproduction and therefore better for a land environment
- The seed protects the embyo
- The seed contains food for the embyo (either in cotyledons or in the endosperm)
- The seed is usually adapted for dispersal
- The seed can remain dormant and survive adverse conditions
- The seed is physiologically sensitive to favourable conditions and sometimes must undergo a period of after-ripening so that it will not germinate immediately

Disadvantages of reproduction by seed

- Seeds are relatively large structures because of the extensive food reserves. This makes dispersal more difficult than by spores
- Seeds are often eaten by animals for their food reserves
- There is a reliance on external agents such as wind, insects and water for pollination. This makes pollination (and hence fertilisation) more dependent on chance, particularly wind pollination
- There is a large wastage of seeds because the chances of survival of a given seed are limited. The parent must therefore invest large quantities of material and energy in seed production to ensure success
- The food supply in a seed is limited; whereas in vegetative reproduction food is available from the parent plant until the daughter plant is fully established
- Two individuals are required in dioecious species, making the process more dependent on chance than reproduction in which only one parent is involved. However, dioecious plants are relatively rare.

Gymnosperms

These are the plants with naked seeds.

General characteristics

- Usually produce cones on which sporangia, spores and seeds develop.
- Seeds are not enclosed in an ovary i.e. they are "naked"
- Seeds lie on the surface of specialized leaves called ovuliferous scales in structures called cones.
- Sporophylls are arranged in strobili
- No fruit because there is no ovary.
- There are four phyla of gymnosperms: Cycadophyta, Ginkgophyta, Gnetophyta and Coniferophyta.

Phylum Coniferophyta (Conifers)

- Phylum Coniferophyta is by far the largest gymnosperm phylum, consisting of about 600 species of conifers.
- Many have large trees such as cypresses and redwoods. Conifers are a successful group of plants of worldwide distribution, accounting for about one third of the world's forests.
- They are trees or shrubs, mostly evergreen, with needle-like leaves.
- Most of the species are found in higher altitudes and further north than any other trees.
- They include pines and larches
- *Pinus* and other conifers have a roughly conical appearance
- The lower branches die and drop off as the tree grows, leaving the mature trees bare for some distance up their trunk.
- They show unlimited growth.
- The leaves are needle-like, reducing surface area available for water loss.

- They are covered with thick, waxy cuticle and have sunken stomata. These xeromorphic features ensure conservation of water since the plants are evergreen. The tree is the sporophyte generation.
- Male and female cones are produced on the same tree in spring (heterospory).
- They take about three years to complete their life cycle.
- Fertilized ovules become winged seeds.

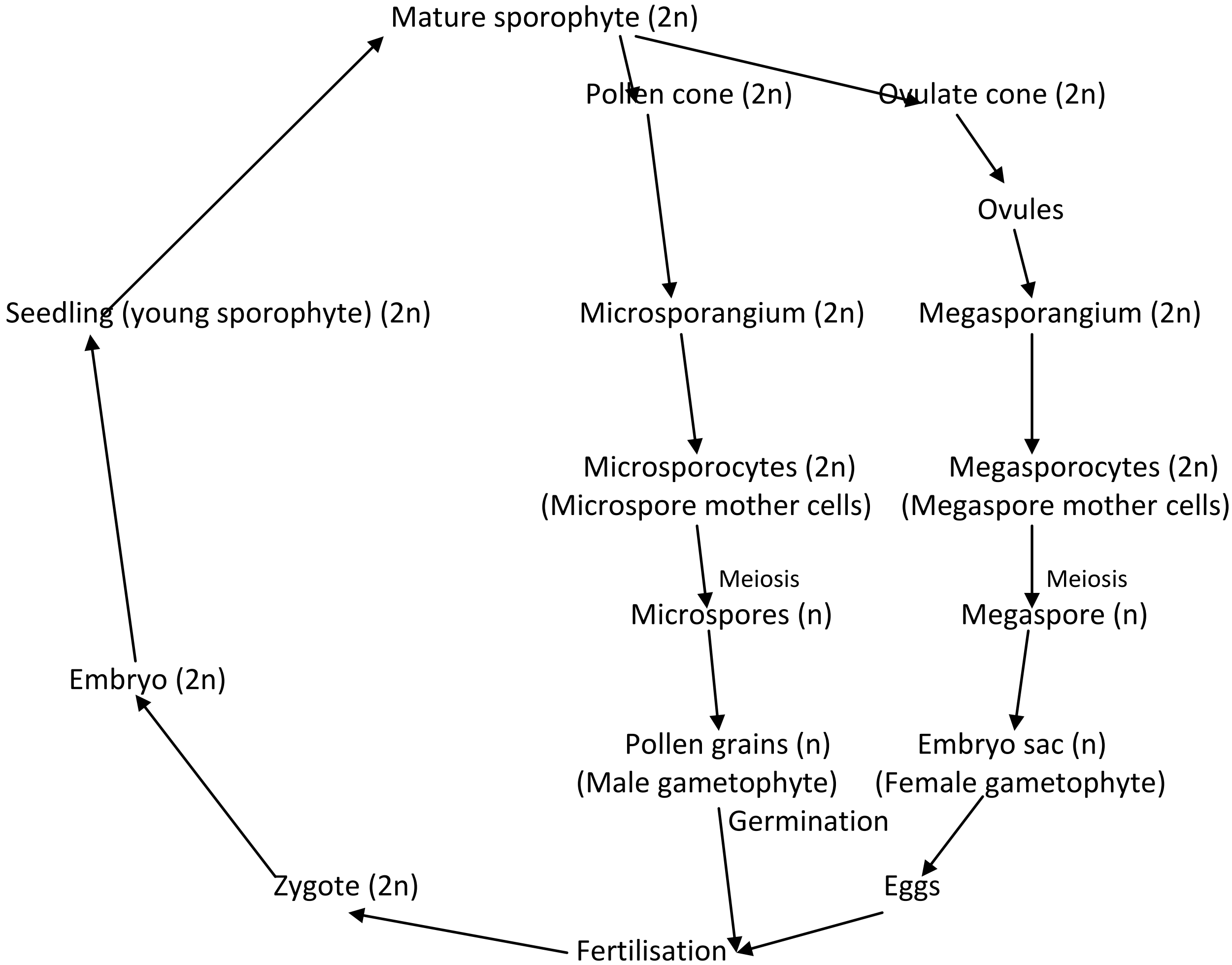
Reproduction

- The pine tree is the sporophyte; its sporangia are located on scale-like structures packed densely in cones.
- Like all seed plants, Conifers are heterosporous.
- In conifers two types of spores are produced by separate cones: small pollen cones and large ovulate cones. In most pine species, each tree has both types of cones. In pollen cones, microsporocytes (microspore mother cell) undergo meiosis producing haploid microspores. Each microspore develops into a pollen grain containing a male gametophyte. In pines and other conifers the yellow pollen is released in large amounts and carried by wind, dusting everything in its path.
- In ovulate cones, megasporocytes (megaspore mother cell) undergo meiosis and produce haploid megaspores inside the ovule. Surviving megaspores develop into female gametophytes, which are retained within the sporangia.
- From the time young pollen and ovulate cones appear on the tree it takes nearly three years for male and female gametophytes to be produced and brought together and for mature seeds to form from fertilized ovules. The scales of each ovulate cone then separate and the seeds are dispersed by wind. A seed that lands in a suitable environment then germinate into embryo and subsequent pine seedling.

Economic Importance of Gymnosperms

- They are soft woods and are used for timber, resins, turpentine.
- They are used as fuel (source of energy).
- Some are used for ornament e.g. *Pinus sylvestris*
- Sources of wood
- Wood pulp
- Construction material – the world’s most widely used construction material.

Life cycle of a pine



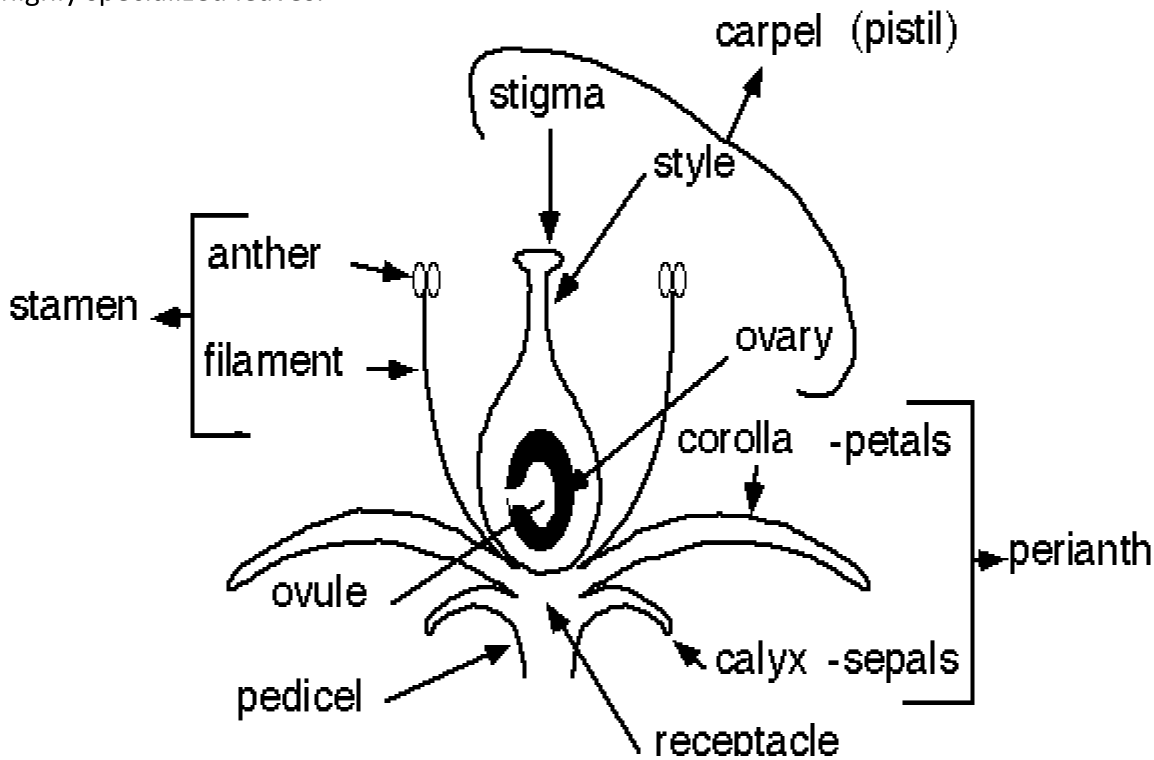
Angiosperms Phylum Anthophyta
General Characteristics

- These are the most diverse and widespread of all plants with more than 250,000 species (about 90% of all plant species).
- These are flowering plants.
- They produce flowers in which the sporangia, spores and seeds develop.
- Ovules (later seeds) are enclosed in an ovary.
- After fertilization, the ovary develops into a fruit.
- Angiosperms are better adapted to life on land than any other plants.
- There is double fertilisation.
- They have flowers instead of cones as the reproductive structures.
- The flower enabled plants to utilize insects and occasionally birds as agents of pollination.

- In order to attract these agents, flowers are usually brightly coloured, scented and offer pollen or nectar as food. In some cases the evolution of insects and flowering plants has become closely linked and there are many highly specialised, mutually dependent relationships. The process is more reliable than wind pollination. Insect pollinated flowers produce less pollen than wind pollinated ones. Many flowers are specialized for wind pollination.
- Two major morphological characteristic features of angiosperms are the flower and fruit.

Flower

A flower is a specialized shoot that can have up to four rings of modified leaves (sporophylls) called floral organs: sepals, petals, stamens and carpels. Flowers are regarded as collections of highly specialized leaves.



A collection of flowers borne on the same stalk is called inflorescence e.g. sunflower. A collection of flowers may be more attractive to pollinating agents than a small solitary flower. Receptacle is the top of the flower stalk (pedicel) from which the flower parts arise. The perianth consists of two whorls of structures called perianth segments. In monocots the two whorls are usually similar. In dicots the two whorls are usually different, consisting of an outer whorl of sepals called the calyx and an inner whorl of petals called corolla. The calyx is the collection of sepals. Sepals are usually green and leaf-like structures and enclose and protect the flower buds. Occasionally, they are brightly coloured and petal-like, serving to attract insects. In wind-pollinated flowers they are usually reduced in size and green or may be entirely absent. The corolla is the collection of petals. In insect pollinated flowers the petals are brightly coloured, serving to attract insects.

The androecium is the collection of stamens, forming the male reproductive organs of the flower. Each stamen consists of an anther and a filament. The anther contains pollen sacs in which pollen is made. The filament contains the vascular bundle that carries food and water to the anther.

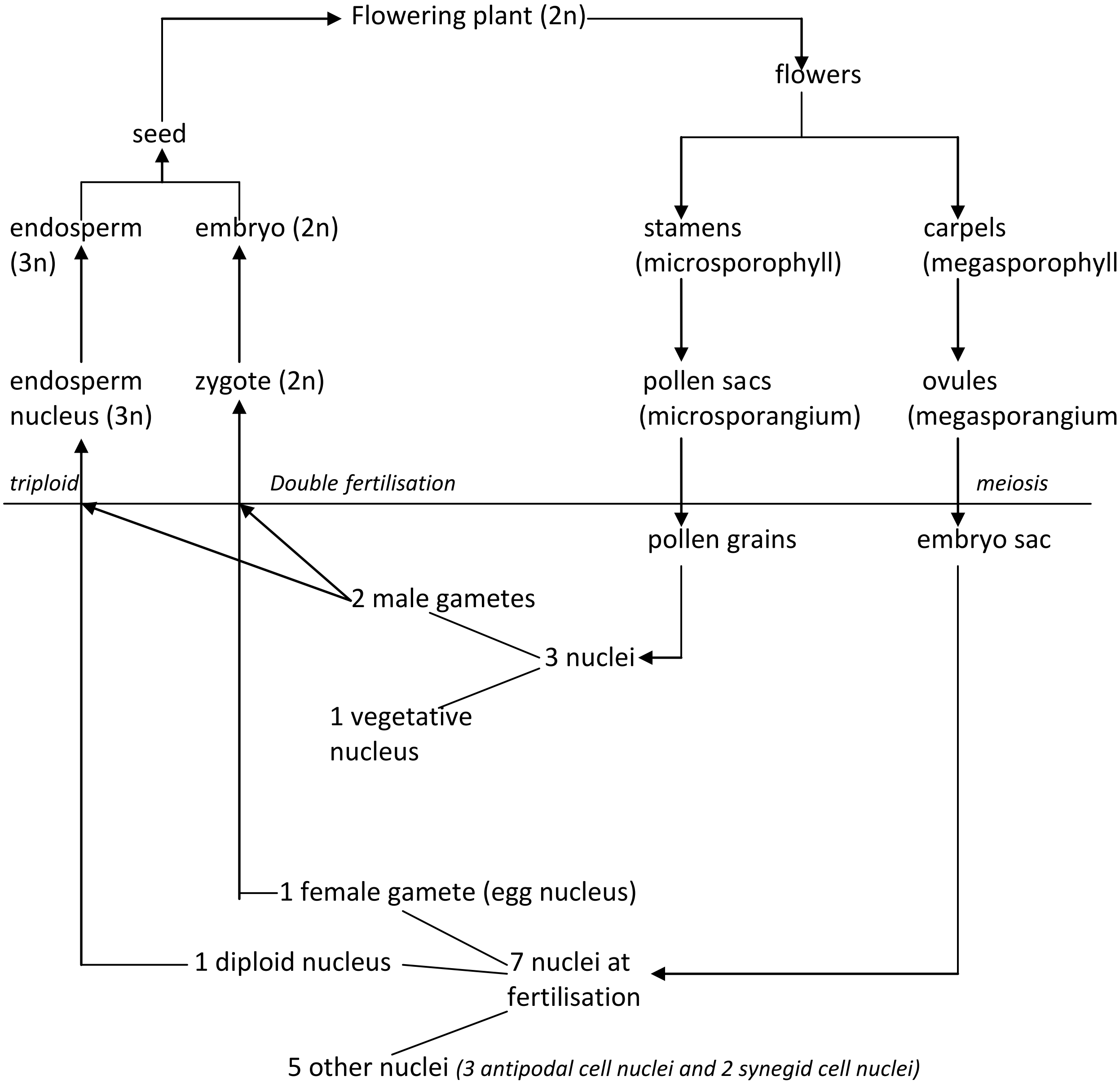
The gynoecium is the collection of carpels; forming female reproductive organs of the flower. A carpel consists of a stigma, style and ovary. The stigma receives pollen grains during pollination and the style bears the stigma in a suitable position in the flower to receive the pollen. The ovary is the swollen, hollow base of the carpel and contains one or more ovules. Ovules are the structures, in which the embryo sacs develop and which, after fertilization, become seeds. Each ovule is attached to the ovary wall by a short stalk called funicle and the point of attachment is called the placenta. The carpels of a flower may be separate and free e.g. in buttercup, or fused to form a single structure e.g. white deadnettle. The styles of flowers with fused carpels may be fused or separate. The receptacle and flower are described as hypogynous if the stamens and perianth are inserted below the gynoecium, epigynous if stamens and perianth are inserted above the ovary and perigynous if the receptacle is flattened or cup-shaped with the gynoecium at the centre and the stamens and perianth attached around the rim. A superior ovary is an ovary located above the other flower parts on the receptacle (hypogynous flower). An inferior ovary is an ovary located below the other flower parts on the receptacle, i.e. the ovary of an epigynous flower. The nectarines are glandular structures that secrete nectar, a sugary fluid that attracts agents of pollination, usually insects and birds.
The following terms are applied to whole plants and flowers:

- Hermaphrodite (bisexual) plants – male and female sex organs borne on the same plant
- Dioecious (unisexual) plant – male and female sex organs borne on separate plants, i.e. plants are either male (staminate) or female (pistillate) e.g. willow, yew, poplar, holly.
- Monoecious plants – separate male and female flowers borne on the same plant, such as oak, beech sycamore. Such plants are hermaphrodite.

Complete flowers have all four floral organs (sepals, petals, stamens and carpels). Some species have incomplete flowers, lacking one of sepals, petals, stamens or carpels, e.g. most grass flowers lack petals. Some incomplete flowers are infertile, lacking functional stamens or carpels. Flowers also vary in size, shape, colour, odour, organ arrangement and time of opening.

Reproduction in angiosperms
The flower of the sporophyte produces microspores that form male gametophytes and megaspores that form female gametophytes. The male gametophytes are in the pollen grains, which develop within microsporangia in the anthers. Each male gametophyte has two haploid cells: a generative cell that divides, forming two sperm and a tube cell that produces a pollen tube. Each ovule, which develops in an ovary, contains a female gametophyte, also known as an embryo sac. The embryo sac consists of only a few cells, one of which is the egg.

Life cycle of angiosperms



After its release from the anther, the pollen is carried to the sticky stigma at the tip of the carpel. Self pollination occurs in some flowers. However, most plants have mechanisms that promote cross-pollination – in angiosperms; it is the transfer of pollen from the anther of a flower on one plant to the stigma of a flower on another plant of the same species. Cross-pollination enhances genetic variability.

The pollen grain germinates after it adheres to the stigma of a carpel. The pollen grain's male gametophyte extends a pollen tube that grows down within the style of the carpel. After reaching the ovary, the pollen tube penetrates through the micropyle, a pore in the integuments of the ovule, and discharges two sperm cells into the female gametophyte (embryo sac). One sperm fertilizes the egg, forming a diploid zygote. The other sperm cell fuses with a diploid nucleus in the large central cell of the female gametophyte producing a triploid cell. Here, one fertilization event produces a zygote and the other produces a triploid cell to form an endosperm (food supply). This is described as **double fertilization** and is unique to angiosperms. After fertilization, the ovule matures into a seed. The zygote develops into a sporophyte embryo with a rudimentary root, and one or two seed leaves called cotyledons.

The fertilized nucleus of the central cell of the female gametophyte divides repeatedly and develops into endosperm, a tissue rich in starch and other food reserves that nourish the developing embryo. Another type of double fertilization ccurs in some gymnosperm species belonging to the phylum Gnetophyta. However, double fertilization in these species gives rise to two embryos rather than to an embryo and an endosperm as in angiosperms.
NB. A seed consists of the embryo, endosperm and seed coat derived from the integuments. An ovary develops into fruit as its ovules become seeds.

Fruits
A fruit typically consists of a mature ovary, although it can include other parts of a flower. The walls of the ovary thicken as seeds develop from ovules after fertilization. Fruits protect dormant seeds and aid in their dispersal. Mature fruits can either be fleshy (ovary becomes fresh during ripening) e.g oranges, mangoes, peaches, grapes etc; or dry (ovary becomes hard and dry during ripening) e.g. beans, nuts, grains etc. There are three types of fruits; simple fruit – a fruit derived from a single ovary and may be fleshy e.g. cherry or dry e.g. soyabean pod, aggregate fruit – fruit derived from a single flower that has several separate carpels e.g. blackberry, and multiple fruit – fruit derived from inflourescence, a group of separate flowers tightly clustered together e.g. pineapple. Fruits show a variety of adaptations which aid in seed dispersal.
Recording flower structure
The structure of a flower can be recorded by means of a **half flower diagram**, **floral formula** and **floral diagram**. In studying the structure of any flower it is important to determine the number of whorls present and the number of members in each of them. This basic information can be conventionally summarized by means of a floral formula.

Floral formula
Floral formula is a convenient shorthand method of recording flower sex, floral symmetry, number of parts, insertion, and ovary position. It is a method of expressing floral sex, floral symmetry, number and arrangement of the four whorls of a flower using symbols, letters and numbers. It summarizes the basic data which must be accumulated before the structure of a flower can be illustrated. It is coded description of floral structure. To write this, the types of floral leaves are each denoted by a capital (uppercase) letter (**K** for calyx, **C** for corolla, **P** for perianth, **A** for androecium, and **G** for Gynoecium) and the number of parts in each of them is written as a subscript after the appropriate letter, e.g. C_5 for a corolla of five petals. When there are more than twenty members in a whorl the sign ∞ is used to denote numerous. Fusion between members of the same whorl is shown by enclosing the appropriate number in brackets, e.g. $K_{(5)}$ means a calyx of five fused sepals. Fusion between members belonging to

different categories of floral whorl is represented by an overhead bracket linking the relevant letters together, e.g. $\overset{\frown}{C_{(5)}A_5}$ means that five stamens are joined to a corolla tube of five fused petals. The position of the ovary is recorded by drawing a horizontal line below or above the figure for the number of carpels, so that the line below denotes a superior ovary (either hypogynous or, by convention, a perigynous flower), whereas a line above indicates an inferior ovary (an epigynous flower). The floral symmetry is also given.
From left to right, a floral formula consists of flower sex, floral symmetry, calyx (K), corolla (C), androecium (A) and gynoecium (G).

Symbols used

Sex : ♂ Male flower ♀ Female flower ⚥ Bisexual flower

Symmetry: ⊕ actinomorphic (regular) flower 0|0 zygomorphic (irregular) flower

Calyx (K): e.g. K_5 – 5 free sepals, $K_{(5)}$ – 5 fused sepals, $K_{(3)+2}$ – 3 fused & 2 free sepals

Corolla (C): e.g. C_5 – 5 free petals, $C_{(5)}$ – 5 fused petals, C_{3+2} – unfused but different petals
P = perianth

Androecium (A): e.g. A_5 – 5 stamens, $A_{(5)}$ – 5 fused stamens, A_∞ - more than 20 stamens

Gynoecium (G): e.g. $G_{\overline{3}}$ – 3 carpels; inferior ovary, $G_{\underline{3}}$ – 3 carpels; superior ovary

Joining of different parts, e.g. $\overset{\frown}{K \quad C}$ – adnation (calyx joined to corolla)

NB. If calyx and corolla cannot be differentiated, use the letter P (perianth)

For example: ⊕ ⚥ $\overset{\frown}{K_5 \quad C_{(5)}}$ A_5 $G_{\underline{1}}$

Regular bisexual flower with 5 sepals and 5 fused petals that are adnated (joined) to the sepals, 5 stamens and 1 carpel; the ovary is superior.

Example Questions:

1. Provide the floral formula for the flower with the following description: Regular bisexual flower with 5 sepals and 5 fused petals that are adnated (joined) to the sepals, 5 stamens and 1 carpel; the ovary is superior

   ⊕ ⚥ $\overset{\frown}{K_5 \quad C_{(5)}}$ A_5 $G_{\underline{1}}$

2. Describe the flower with the following floral formuale:
   a. ⊕ ⚥ K_{20} $C_{(5)}$ A_5 $G_{\underline{1}}$

   b. 0|0 ♂ $P_{(15)}$ A_{18}

Answers

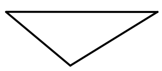
a. Bisexual actinomorphic (regular) flower with 5 sepals and 5 fused petals joined to the sepals, 5 stamens and 1 carpel, superior ovary.
b. Male zygomorphic (irregular) flower with 15 fused perianth segments and 18 stamens

Half flower diagram and floral diagram

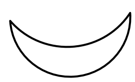
To give them some spatial meaning to a floral structure recording, it is necessary to make two drawings, a floral diagram and a half flower drawing. These two drawings correspond to an architect's plan and elevation of a building. A half flower diagram is a longitudinal section through a flower. A floral diagram is a kind of ground-plan of a flower showing the position of the whorls of a flower. A floral diagram is a stylized cross-section of a flower that represents floral whorls as viewed from above. Like a floral formula, a floral diagram is used to show symmetry, sex, number of parts, the relationship of the parts to one another etc.

Symbols used

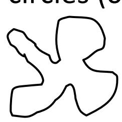
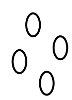
Pedicel - 0 small circle at the top of the diagram

Bract  triangle at the bottom of the diagram

Calyx (sepals) – same as bract (triangle) but separated from it

Corolla (petals) – semicircle /half moon 

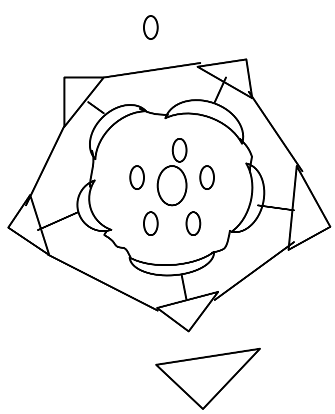
Androecium (stamens) – circles (0) or star (*)

Carpels (gynoecium) –  , if fused;  if free

Example: Draw the floral diagram for the flower with the following floral formula:

$\oplus$ ⚥ $\widehat{K_{(5)}\quad C_{(5)}}$ A_5 $G_{\underline{1}}$

Answer:



Dicotyledons and monocotyledons

- Angiosperms are divided into two major groups (classes). This is based partly on the number of cotyledons or seed leaves in the embryo.
- Species with one cotyledon are called monocotyledons, and those with two are called dicotyledons.
- Angiosperms may be herbaceous (non-woody) or woody.
- Woody plants can be shrubs or trees. They grow a large amount of secondary xylem (wood) that offers support as well as being the conducting tissue and is produced as a result of the activity of the vascular cambium. The cambium is a layer of cells found between the xylem and phloem in stems and roots. These retain the ability to divide and the new xylem produced is called secondary xylem.
- Herbaceous plants or herbs rely on turgidity and smaller quantities of mechanical tissue such as collenchyma, sclerenchyma and xylem for support and are consequently smaller plants.
- They either lack cambium or if present, is of limited activity.
- Many herbaceous plants are annuals, completing their life cycle in one year or one season. Some herbaceous plants produce organs of perennation such as bulbs, corms and tubers by means of which they overwinter or survive periods of adverse conditions such as drought. They may then be biennial (produce their seeds and die in their second year) or perennial (survive from year to year, i.e. more than two years). Shrubs and trees are perennial and may be evergreen or deciduous.

Comparison of dicots and monocots

	Class Dicotyledoneae	**Class Monocotyledoneae**
Examples	Pea, Tomato, orange, rose, buttercup, dandelion	Grasses, iris, orchids, lilies
Leaf morphology	Net-like pattern of veins (reticulate vennation) Lamina (blade) and petiole (leaf stalk) Dorsal and ventral surfaces differ	Veins are parallel (parallel vennation) Typically long and thin grass-like Identical dorsal and ventral surfaces
Stem anatomy	Ring of vascular bundles Vascular cambium usually present giving rise to secondary growth	Vascular bundles scattered Vascular cambium usually absent, so no secondary growth (exceptions occur e.g. palms)
Root morphology	Primary root (first root from seed persists as a tap root that develops laterals roots (secondary roots)	Adventitious roots from the base of the stem take over from the primary root, giving rise to a fibrous root system.
Root anatomy	Few groups of xylem (2-8) Vascular cambium often present, giving rise to secondary growth	Many groups of xylem (commonly up to 30) Vascular cambium usually absent; no secondary growth
Seed	Embryo has two cotyledons (seed	Embryo has one cotyledon

morphology	leaves)	
Flowers	Parts mainly in fours and fives Usually distinct petals and sepals Often insect pollinated	Parts usually in threes No distinct petals and sepals. These structures are combined to form "perianth segments" Often wind pollinated
Pollen	Pollen grain with three opening	Pollen grain with one openings

Differences between wind-pollinated and insect-pollinated flowers

Typical wind-pollinated flower	Typical insect-pollinated flower
Small petals that are not brightly coloured (usually green, or petals absent; flowers therefore inconspicuous	Large coloured petals; flowers therefore conspicuous. If flowers are relatively inconspicuous they may be gathered together in inflorescences
Not scented	scented
Nectaries absent	Nectaries present
Large branched and feathery stigma hanging outside flower to trap pollen	Small stigma, sticky to hold pollen and enclosed within flower
Stamens hanging outside flower to release pollen	Stamens enclosed within flower
Anthers attached only at midpoints to tip of filament so that they swim freely in air currents	Anthers fixed at their bases or fused along their backs to the filaments so that they are immovable
Large quantities of pollen owing to high wastage	Less pollen produced
Pollen grains relatively light and small; dry, often smooth, walls	Pollen grains relatively heavy and large. Spiny walls and stickiness help attachment to insect body
Flower structure relatively simple	Complex structural modifications for particular insects often occur
Flowers borne well above foliage on long stalks (e.g. grasses) or appear before leaves (e.g. many British trees)	Position and time of appearance variable in relation to foliage, though often borne above it for increased conspicuousness

Major adaptations of angiosperms to life on land

- The production of the flower as the reproductive structure which has more efficient mechanisms for pollination and fertilisation
- The production of seeds and fruits to nourish and protect the embryo plants and to help in their dispersal. Seeds survive better than spores and can be transported long distances.
- The absence of swimming male gametes. Male gametes are carried inside pollen grains to the female parts of the plant, a process called pollination. This is followed by the production of a pollen tube carrying male nuclei to the female gamete. Pollen grains and pollen tube make water unnecessary for fertilization.

- The extreme reduction of the gametophyte generation, which is poorly adapted to life on land in simpler plants like bryophytes. The microscopic male and female gametophytes (n) are nourished and protected by the sporophyte (2n)

Economic importance of angiosperms

- Food – most of our food comes from angiosperms e.g. wheat, rice, maize, potatoes, cassava, sweet potatoes, etc.
- Livestock feeds – used as food for livestock. It takes 5-7 kg of grain to produce 1kg of grain-fed beef.
- Crops that we have today are products of genetic change following artificial selection of flowering plants.
- Beverages – two of world's most popular beverages come from tea leaves and coffee beans, e.g. cocoa and chocolate.
- Spices are derived from various plant parts such as flowers, fruits, seeds, leaves and even bark.
- Sources of wood
- Fuel
- Wood pulp
- Construction material.
- Medicine – both modern and traditional herbal remedies, e.g. aspirin is a synthesized derivative of willow plant.