BOTANY

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BOTANY

Manual for foreign students

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PREFACE

This manual is intended for teaching the discipline of “Botany” to the bachelors of the pharmacy faculty.

The manual is written in compliance to the educational program.

The manual provides concise description of basic sections of “Botany” discipline: Cytology, Anatomy, Morphology, Systematics.

The sections of Cytology and Anatomy include laboratory work which will help to substantiate theoretical knowledge.

The section of Systematics does not include all groups of herbal organisms. However, this section investigates Fungi, Algae, High Class Sporadic and Seed Plants.

The knowledge of “Botany” discipline is very important for training pharmacologist - specialists, in order to facilitate the process of learning fundamentals of Pharmacognosy (science about herbal plants) in future.

We have described the professional peculiarities of herbal plant families applied in modern medicine. Besides the plants, which grow in the territory of the Republic of Armenia, this section also includes tropical, subtropical and many other regional valuable herbal plants.

We kindly express our gratitude in advance for all the remarks and proposals with regard to this manual.

The main branches of Botany are:

1. Plant systematics - classification and naming of plants
2. Plant morphology - structure and form of plants
3. Plant anatomy - structure of plant cells and tissues
4. Plant embryology - development of generative and embryological structures
5. Plant cytology - cell structure and functions
6. Plant physiology - life functions of plants
7. Plant biochemistry - chemical processes of metabolism
8. Plant genetics - genetic inheritance in plants
9. Plant geography - the study of plant distributions
10. Plant ecology - role and function of plants in the environment
11. Ethnobotany -practical use of plants and plant products
12. Paleobotany - study of fossil plants and plant evolution
13. Palynology – all about pollen and spores
14. Pomology – all about fruits and nuts
15. Algology – all about Algae
16. Mycology – all about Fungi
17. Lichenology – all about Lichens
18. Bryology – all about Mosses, Liverworts, Hornworts
19. Pteridology – all about Ferns
20. Dendrology - study of woody plants, shrubs, trees, lianas.

Human and Animal Dependence on Plants

Our dependence on green organisms to produce the oxygen in the air we breathe and to remove the carbon dioxide we give off doesn`t stop there. Plants are also the sources of products that are so much a part of human society that we largely take them for granted. We know, of course, that rice, corn, potatoes and other vegetables are plants, but all the foods, including meat, fish, eggs, cheese and milk, to mention just a few, owe their existence to plants. Condiments, such as spices, and luxuries, such as perfumes are produced by plants, as are some dyes, adhesives, digestible surgical stitching fiber, food stabilizers, beverages and emulsifiers. Our houses are constructed with the lumber from trees, which also furnish cellulose for paper, cardboard and synthetic fibers. Some of our clothing, camping equipment, bedding, drapery and other textile goods are made from fibers of many different plant families. All medicines and drugs at one time came from plants, fungi or bacteria and many important ones, including most of the antibiotics, still do. Microscopic organisms play a vital role in recycling both plant and animal wastes and aid in the building of healthy soil. Others are responsible for human diseases and allergies.

Evolutionary History of Plants

The evolution of plants has resulted in widely varying levels of complexity, from the earliest algal mats, through bryophytes, lycopods and ferns, to the complex gymposperms and angiosperms of today.

Evidence for the appearance of the first land plants occurred in the Ordovician, about 450 million years ago, in the form of fossil spores. Land plants began to diversify in the Late Silurian, about 430 million years ago. By the middle of Devonian, many of the features recognised in plants today were present including roots and leaves. Late Devonian free-sporing plants such as Archaeopteris had secondary vascular tissue that produced wood and formed forests of tall trees. The first land plants were non-vascular bryophytes, represented today by mosses, hornworts, and liverworts. These plants, lacking circulatory tissues, were quite short. They could only survive in very moist areas where their spores could be dispersed easily. Lacking a protective coating, spores are relatively fragile and prone to drying out. Appearance of flowering plants began in the Triassic (~200 million years ago), and their later diversification in Paleogene. The latest major group of plants to evolve were the grasses (about 40 million years ago). The grasses, as well as many other groups, evolved new mechanisms of metabolism to survive the low CO_2 and warm, dry conditions of the tropics over the last 10 million years.

The earliest megafossils of land plants were thalloid organisms. They could only survive when the land was waterlogged.

Early plants had to develop woody tissue that provided support and water transport. The fruit plants to develop secondary growth (with the help of vascular cambium) and a woody habit, were apparently the ferns, and as early as the middle Devonian one species, Wattieza, had already reached heights of 8m and a tree-like habit.

The dominant groups today are the gymnosperms, which include the coniferous trees, and the angiosperms, which contain all fruiting and flowering trees. Both groups arose from within the pteridosperms, probably as early as the Permian.

The first spermatophytes ("seed plants"), the first plants to bear true seed – are called pteridosperms ("seed ferns"). Their foliage consisted of fern-like fronds, although they were not closely related to ferns. Most of gymnosperms incase their seeds in a woody cone or fleshy aril (ex. yew), but none of them fully enclose their seeds. The angiosperms are the only group to fully enclose the seed in a flower carpel. Seeds increased the success rate of fertilized gametophytes. The nutrient store could be "packaged" in with the embryo. The process of double fertilization is unique and common to all angiosperms.

Taxonomic Ranks of Botany are:

1. Empire or Domain
2. Superkingdom
3. Kingdom
4. Phylum (Division)
5. Class
6. Order
7. Family
8. Genus
9. Species

Macrosystems of Living Organisms

The entire organic world can be divided into two empires:

I. Empire Acellular Organisms - Noncellulata

II. Empire Cellular Organisms – Cellulata

Empire Noncellulata consists of only one Kingdom Vira (Viruses), but many scientists believe viruses are not real organisms, as it is not capable of independent metabolism.

Empire Cellulata is divided into two netcarta:

1.non-nuclear (or prokaryotes),

2.nuclear (or eukaryotes).

Prokaryotes do not have morphologically decorated nucleus and organelles. In prokaryotes there are no mitosis, meiosis, sexual process. Prokaryotes, unlike eukaryotes, are capable of multiplying very rapidly.

Prokaryotes consist of two kingdoms:

1.Archaebacteria

2.Eubacteria (Bacteria).

The difference between them is the presence of double layer lipid membranes in Bacteria.

Eukaryotes are divided into three kingdoms:

1.Plants (Plantae or Vegetabilia),

2.Mushrooms (Fungi),

3.Animals (Animalia).

The special ending of Taxa

Chapter 1

PLANT CELLS

Cell Structure and Communication

All living things are composed of cells. The plants cell wall is a protective layer outside the cell membrane that also provides support for the cell's structure. It surrounds the **protoplasm**, which consists of all the living components of a cell. These living components are bounded by a membrane called the *plasma membrane.* All cellular components between the plasma membrane and a relatively large body called the *nucleus* are known as **cytoplasm**. Within the cytoplasm is a soup-like fluid called *cytosol*, in which various bodies called *organelles* are dispersed. Organelles are persistent structures of various shapes and sizes with specialized functions in the cell; most, but not all, are bounded by membranes.

The Cell Wall

The plant cell wall acts as a gatekeeper, because it determines what can come in and out of the cell in order to keep the cell protected. It protects the plant from pathogens, insects. There are holes all over the cell wall called *plasmodesmata*, which allows nutrients to enter and waste to exit the cell. In plants the main structural component of cell walls is *cellulose.* In addition to cellulose (strong fibers of carbohydrate polymer), cell walls typically contain a matrix of *hemicellulose* (a glue-like substance that holds cellulose fibrils together), *pectin* (the organic material that gives stiffness to fruit jellies), and *glycoproteins* (proteins that have sugarb associated with their molecules). The plant cell wall consists of 3 sections: *middle lamella, primary cell wall and secondary cell wall.*

. **middle lamella** – outer cell wall layer that contains polysaccharides called pectins.

. **primary cell wall** – layer between middle lamella and plasma membrane. It is composed of cellulose microfibrils contained within a gel-like matrix of hemicellulose fibers and pectin polysaccharides. This part provides the strength and flexibility of the cell.

. **secondary cell wall** – layer formed between the primary cell wall and plasma membrane. It can contain lignin, which strengthens the cell wall and aids in water conductivity in plant vascular tissue cells.

Plant Cellular Components

Plant cells contain many membrane bounded cellular structures. These organelles carry out specific functions necessary for survival and normal operation like producing hormones, enzymes, and all metabolic activities of the cell. Most chemical reactions that take place in cells occur in the protoplasm, as part of a dynamic series of events that make the plant a living entity. Each organelle within the protoplast has a primary function, and the flow of *metabolites* (products of chemical synthesis or breakdown).

The Plasma Membrane

While the plasma membrane may inhibit movement of some substances, it can otherwise allow free movement and can even control movement of other substances into and out of the cell. The plasma membrane is also involved in the production and assembly of cellulose for cell walls.

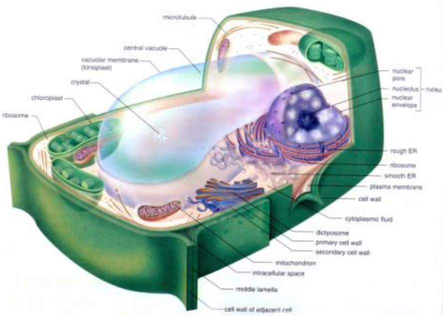


Fig.1. The plant cell structure

The plasma membrane and other cell membranes are composed of *phospholipids* arranged in two layers, with proteins interspersed throughout (fig.1).

The Nucleus

The nucleus is the control center of the cell. In some ways, it functions like combination of a computer program and a dispatcher that sends coded messages or “blueprints” originating from DNA in the nucleus with information that will ultimately be used in other parts of the cell. In other words, the DNA in the nucleus provides the original information needed to fulfill the cell’s needs. This nuclear information contributes toward growth, differentiation, and the myriad activities of the complex cell “factory”. The nucleus also stores information, passing from cell to cell, as new cells are formed. In living cells the nucleus may appear as a grayish, spherical to ellipsoidal lump, sometimes lying against the plasma membrane, to one side of the cell or toward a corner. Certain fungi and algae have numerous nuclei within a single branched cell, but the cells of more complex plants usually have a single nucleus.

The Endoplasmic Reticulum (ER)

The outer membrane of the nucleus is connected with the endoplasmic reticulum. The endoplasmic reticulum facilitates cellular communication and channeling of materials. The ER is an enclosed space consisting of a network of flattened sacs and tubes that form channels through the cytoplasm.

Ribosomes may be distributed on the outer surface (i.e. the surface is in contact with the cytoplasm) of the ER. Such endoplasmic reticulum is said to be rough and is primarily associated with the synthesis, secretion, or storage of proteins. This contrasts with smooth ER, which has few, if any, ribosomes lining the surface, and is associated with lipid secretion. Both types of ER can occur in the same cell.

Ribosomes

Ribosomes are tiny bodies that are visible with the aid of an electronic microscope. They are typically roughly ellipsoidal in shape. Each ribosome is composed of two subunits that are composed of RNA and proteins. They initiate protein synthesis. Unlike other organelles, ribosomes have no bounding membranes, and because of this, some scientists prefer not to call them organelles.

Dictyosomes

Dictyosomes constituting the Golgi apparatus occur in protein-secreting animal cells and a few plant cells with similar function.

Plastids

Most living plant cells have several kinds of plastids, the **chloroplasts, chromoplasts** and **leucoplasts**.

Chloroplast is a type of plastid, characterized by its high concentration of green pigment chloriphyll. Other plastid types, such as the leucoplast and the chromoplast, contain little amount of chlorophyll and do not carry out photosynthesis. The green colour results from the presence of two pigments: *chlorophyll a* and *chlorophyll b*. A function of those pigments is to absorb light energy.

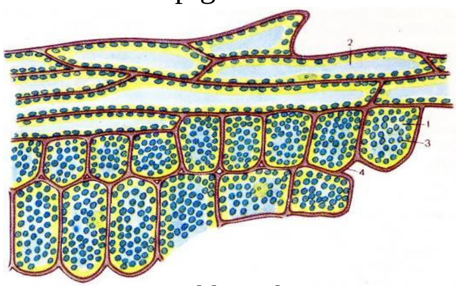


Fig.2. Chloroplasts

In plants chloroplasts occur in all green tissues, though they are concentrated particularly in parenchyma cells of the leaf mesophyll. With the help of chloroplasts photosynthesis occurs, a process by which light energy is converted to chemical energy, resulting in the production of oxygen and energy-rich organic compounds. Chloroplasts are disc-shaped organelles found in cytosol of a plant cell. It consists of a double membrane with outer and inner layers, between which is a gap called the *intermembrane space*. A third, internal membrane characterized by the presence of closed disks (thylakoids) is known as the *thylakoid membrane*. The space between the inner membrane and the thylakoid membrane is filled with stroma, a matrix containing dissolved enzymes, starch granules and copies of the chloroplast genome (fig. 2).

Chromoplasts are another type of plastid found in some cells of more complex plants. They vary considerably in shape. They sometimes develop from chloroplasts through internal changes that include the disappearance of chlorophyll. Chromoplasts are yellow, orange or red in color due to the presence of carotenoid pigments, which they synthesize and accumulate. They are most abundant in the yellow, orange, or some red parts of plants, such as ripe tomatoes, carrots, or red peppers. The main evolutionary purpose of chromoplasts is to attract animals and insects to pollinate the flowers and disperse seeds (fig.3-1).

Leucoplasts are another type of plastids common to cells of higher plants. They are essentially colorless, non-pigmented and are located in non-photosynthetic tissues of plants, such as roots, bulbs and seeds. They may be specialized for storage of starch, lipid or protein and are then known as *amyloplasts* (which synthesize starches), *elaioplasts* (which synthesize oils) and *aleuroplasts* (which synthesize proteins). In some cell types at certain stages of development leucoplasts are clustered around the nucleus. In general, they are often described as amoeboid. After several hour - exposure to light the leucoplasts can be transformed into chloroplasts (fig. 3-2).

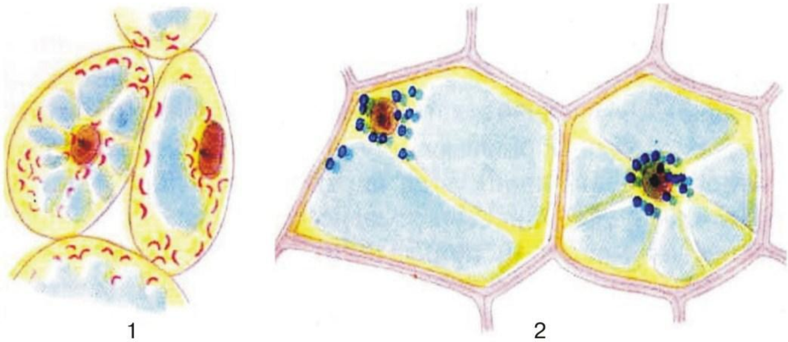


Fig.3. Chromoplast (1), Leucoplasts (2)

Plastids of all types develop from **proplastids**, which are small, pale green or colorless organelles present in meristematic cells. Depending upon the organs and presence or absence of light, proplastids undergo transformation and develop into either colorless leucoplasts or colored chromoplasts including green chloroplasts.

Mitochondria

The **Mitochondria** are double membrane bound organelle found in all eukaryotic organisms. They can be considered the power generators of the cell, converting oxygen and nutrients into adenosine triphosphate (ATP). ATP is the chemical energy "currency" of the cell that powers the cell's metabolic activities. This process is called **aerobic respiration**. Mitochondria typically are shaped like cucumbers, paddles, rods, or balls.

Vacuoles

In a mature living plant cell, as much as 80% or more of the volume may be taken up by one or two large central vacuoles that are bound by **vacuolar membranes (tonoplasts)**. The vacuole evidently received its name because of a belief that it was just an empty space; hence its name has the same Latin root as the word *vacuum* (from *vacuus*-meaning "empty"). Vacuoles, however, are filled with a watery fluid called **cell sap**, which contains dissolved substances, such as salt, sugar, organic acids, and small quantities of soluble proteins. It also contains water soluble pigments, called *anthocyanins*, which are responsible for many of the red, blue, or purple colors of flowers and some reddish leaves.

The primary vacuole functions include:

1.maintaining the fluid balance;

2.exporting the unwanted and toxic substances;

3.acting as a cellular pump;

4.maintaining the cell's acidic internal pH;

5 determining relative cell size and shape (they can help the cell elongate rapidly).

Ergastic (Reserve) Substances

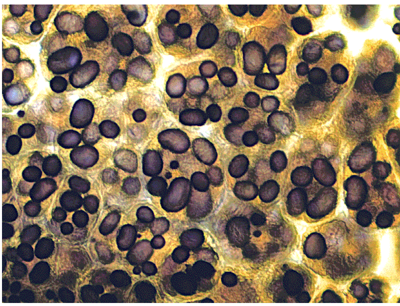
Ergastic substances are non-protoplasm materials found in plant cells. Ergastic substances may appear in the protoplasm, in vacuoles or in the cell wall. They are usually either organic or inorganic substances that are products of metabolism and include crystals, oil droplets, gums, tannins, resins and other compounds that can aid the organism in defense, maintenance of cellular structure, or just substance storage.

Carbohydrates - Cellulose and starch are the main ergastic substances of the plant cells. Cellulose is the chief component of the cell wall, and starch occurs as a reserve material in the protoplasm. Starch as starch grains, arises almost in plastids, especially leucoplasts and amyloplasts. Starch grains are found in storage organs of plants, in a larger amount e.g., seeds, fruits, rhizomes etc. Each starch grain has a central area called *hilum*. Starch is deposited around hilum in the form of layers. Depending upon the position of hilum, a starch grain may be *concentric* or *eccentric*. The primary function of the starch grain is to provide carbohydrate energy to the plant.

Aleurone Grains - They represent the storage proteins which are generally insoluble and occur inside the special leucoplasts called *aleuroplasts*. Depending upon their internal structure, the aleurone grains are of four types:

- *Amorphous;*
- *Protein matrix containing crystalloid;*
- *Protein matrix with globoid;*
- *Protein matrix with both crystalloid and globoid.*

Fat droplets - Fat droplets occur abundantly inside the seeds, either in endosperm (e.g. coconut), or cotyledons (e.g. mustard) (fig. 4).

a) 

b) 

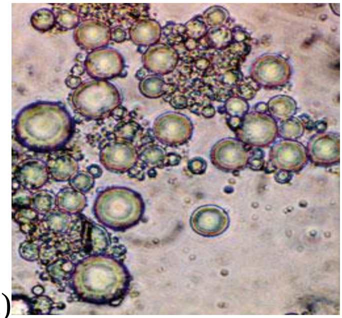
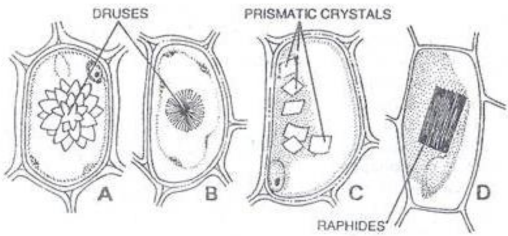
c) 

Fig.4. a) starch grains, b) aleurone grains, c) fat droplets

INORGANIC (MINERAL) MATERIALS

The accumulation of inorganic materials within the plant and their cells mostly takes place in the form of calcium salts or anhydrous silicate salts. Calcium oxalate is common in plants of many families. Their crystalline particles are of various shapes such as prismatic, needle-shaped, diamond shaped, etc. Very often the crystals occur as compound aggregates called *druses.* Elongated crystals are called *styloids and raphides.* Raphides occur in the form of bundles. Some crystals occur in a special type of cells called *idioblast cells*. Calcium carbonate is also found in some plants (e.g. Ficus leaves). Silica particles as *crystal sand* are found in petiole of Atropa (fig. 5).



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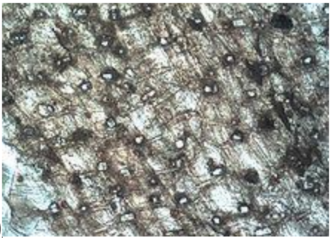
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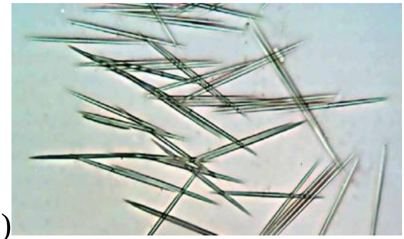
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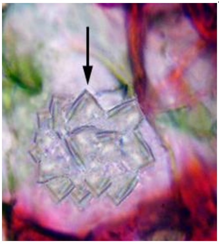
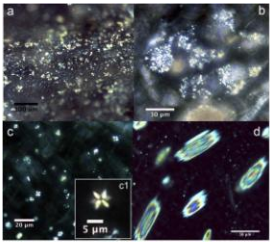



Fig.5. a)styloids, b)druses, c)raphides, d)crystal sand

Chapter 2

PLANT TISSUES

Most plants have three or four major groups of organs-**roots, stems, leaves,** and in some instances, **flowers**. Each of these organs is composed of tissues, which are defined as "group of cells performing similar function". Any plant organ may be composed of several different tissues; each tissue is classified according to their structure, origin, or function.

MERISTEMATIC TISSUES

Unlike animals, plants have permanent regions of growth called **meristems**, or *meristematic tissues*, where cells are actively divided. As new cells are produced, they typically are small, each with a large nucleus, usually near the center, and with tiny vacuoles or no vacuoles at all. As the cells mature, the vacuoles increase in size, often occupying more than 90% of the volume of the cell.

Apical Meristems

Apical Meristems are meristematic tissues found at, or near apices or the tips of roots and shoots, which increase in length as the apical meristems produce new cells. This type of growth is known as *primary growth*. Three *primary meristems*, as well as embryo leaves and buds, develop from apical meristems. These primary meristems are called **protoderm, ground meristem,** and **procambium**. The tissues they produce are called **primary tissues**.

Lateral Meristems

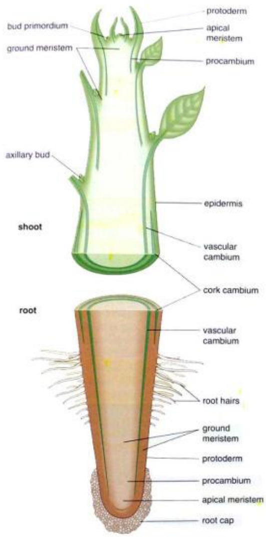


Fig.6. Lateral meristems

The *vascular cambium* and *cork cambium* are **lateral meristems** (fig. 6), which produce tissues that increase the growth of roots and stems. Such growth is termed as *secondary growth*.

Intercalary Meristems

Intercalary meristems are capable of cell division, and they allow for rapid growth and regrowth of many monocots. Intercalary meristems at the nodes of bamboo allow for rapid stem elongation.

Floral Meristems

When plants begin the developmental process known as flowering, the shoot apical meristem is transformed into an inflorescence meristem, which goes on to produce the floral meristem, which produces the sepals, petals, stamens and carpels of the flower. Their future growth is limited.

Simple Tissues

Parenchyma

Parenchyma tissue is composed of parenchyma cells, which are the most abundant of the cell types and are found in almost all major parts of higher plants. They are spherical in shape when they are first produced, but when all the parenchyma cells push up against one another, they assume various shapes and sizes. They tend to have large vacuoles and may contain starch grains, oils, tannins, and crystals.

More often parenchyma cells have spaces between them; in fact, in water lilies and other aquatic plants, the intracellular spaces are quite extensive and form a network throughout the entire plant. This type of parenchyma tissue with extensive connected air spaces is referred to as *aerenchyma* (fig. 7).

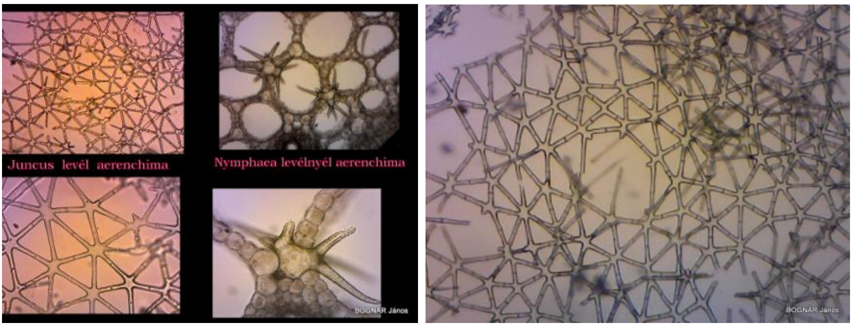


Fig.7. Aerenchima

Parenchyma cells containing numerous chloroplasts (as found in leaves) are collectively referred to as *chlorenchyma* tissue. Chlorenchyma tissue's function mainly is photosynthesis, while parenchyma tissue's without chloroplasts function mostly is *food or water storage*. For example, the soft, edible parts of most fruits and vegetables consist largely of parenchyma.

Prosenchyma is a type of parenchyma where cells are elongated with tapering ends.

Vascular parenchyma is the parenchyma, which is found associated with the vascular tissues xylem and phloem. Accordingly, it is distinguished into xylem parenchyma and phloem parenchyma.

Medullary parenchyma is the parenchyma, which is found radially arranged in between the vascular bundles in the stem. It is meant for storaging reserve food.

Conjunctive parenchyma is the parenchyma, which occurs in the root system. It is specially meant for water storage.

Many parenchyma cells live long; in some cacti, for example, they may live to be over 100 years old.

When a plant is damaged or wounded, the capacity of parenchyma cells to multiply is specially important in repair of tissues.

Collenchyma

Collenchyma cells, like parenchyma cells, have living cytoplasm and may remain alive a long time. Their walls generally are thicker and more uneven in thickness than those of parenchyma cells. The unevenness is due to extra primary wall in the corners. Collenchyma cells provide flexible support for both growing organs and mature organs, such as leaves and floral parts (fig. 8).

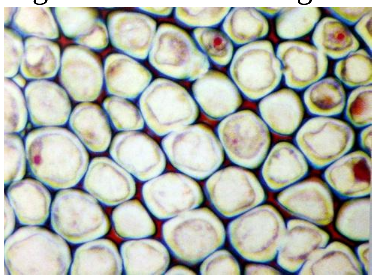


Fig.8. Collenchyma

Sclerenchyma

Sclerenchyma tissue consists of cells that have thick, tough, secondary walls, normally impregnated with **lignin**. Most sclerenchyma cells are dead and function in support. Two forms of sclerenchyma occur: **sclereids** and **fibers.** Sclereids may be randomly distributed in other tissues. For example, the slightly gritty texture of pears is due to the presence of groups of sclereids, or **stone**

cells, as they are sometimes called. The hardness of nut shells and the pits of peaches and other stone fruits are due to sclereids.

Fibers may be found in association with a number of different tissues in roots, stems, leaves, and fruits. They are usually much longer than they are wide. At present, fibers from more than 40 different families of plants are in commercial use in the manufacture of textile goods, ropes, strings, canvas, and similar products. Archaeological evidence indicates that humans have been using plant fibers for at least 10,000 years (fig. 9).

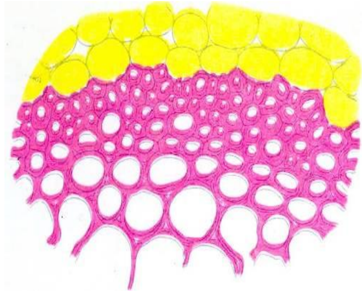


Fig.9. Sclerenchyma

CONDUCTING (VASCULAR) TISSUES

Most of the tissues we have discussed thus far consist of one kind of cell, but a few important tissues are always composed of two or more kinds of cells and are sometimes referred to as *complex tissues*. Two of the most important complex tissues in plants, *xylem* and *phloem*, function primarily in the transport of water, ions, and soluble food (sugar) throughout the plant. Some complex tissues are produced by apical meristems, but most complex tissues in woody plants are produced by the vascular cambium.

Xylem

Xylem tissue is an important component of the "plumping" and storage systems of a plant and is the chief conducting tissue throughout all organs for water and minerals absorbed by the roots. Xylem consists of a combination of

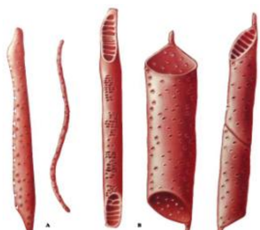


Fig.10. Xylem

parenchyma cells, fibers, *vessels, tracheids*, and *ray cells*. **Vessels** are long tubes composed of individual cells called **vessel elements** that are open at each end (fig. 10).

Tracheids, like vessel elements, are dead at maturity and have relatively thick secondary cell walls. They allow water to pass from cell to cell.

In cone-bearing trees and certain other non-flowering plants, the xylem is composed almost entirely of tracheids. The walls of many tracheids, as well as vessel elements, have spiral thickenings on them that are easily seen with the light microscope. The lateral (sideways) conduction takes place in the **rays**. Ray cells also function in food storage. In woody plants, the rays radiate out of the center of stems and roots like the spokes of a wheel.

Types of vessel elements are:

. *annular vessels* - in which the secondary thickenings are in the form of rings;

. *spiral vessels* – in which the secondary thickenings are present in the form of a helix or coil;

. *scalariform* – in which the secondary thickenings appear in the form of cross bands resembling the steps of a ladder.

. *reticulate vessels* – in which the secondary thickenings are irregular and appear in the form of a network.

. *pitted vessels* – in which the secondary thickenings result in the formation of depressions on the primary wall called pits.

Phloem

In plant anatomy, sieve tube elements are a specialized type of elongated cell in the phloem tissue of flowering plants. The ends of these cells are connected with other sieve tube members. The main function of the sieve tube is transport of carbohydrates in the plant (from the leaves to the fruits and roots). Unlike the water-conducting xylem vessel elements that are dead when mature, sieve elements are living cells.

At the interface between two sieve tube members in angiosperms are sieve plates, pores in the plant cell walls that facilitate transport of materials between them. Each sieve tube element is normally associated with one or more nucleated companion cells, to which they are connected by *plasmodesmata* (channels between the cells). Sieve tube members have no cell nucleus, ribosomes, vacuoles. They depend on companion cells to provide proteins. In leaves, companion cells help move the sugar that is produced by photosynthesis from the mesophyll tissue into the sieve tube elements (fig. 11).

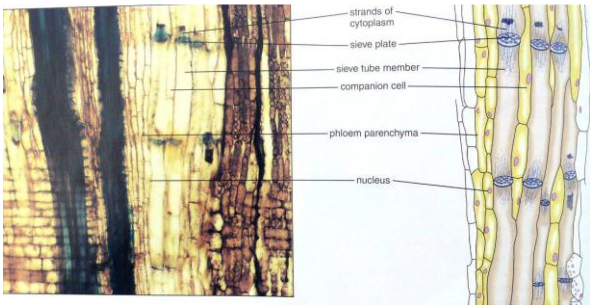


Fig.11. Longitudal view of part of the phloem of a black locust tree (Robinia pseudo-acacia). x1,000

Types of Vascular bundles in Plants

In the primary structure of stem, root and leaves the conductive tissue xylem and phloem are grouped together. A group of xylem and phloem form a vascular bundle.

Vascular bundles can be:

1. *Collateral*. In this type, xylem and phloem are arranged side by side on the same radius. This bundle may be either open or closed. Usually xylem is seen towards the inner side and phloem towards the outer side.

a) Collateral open: Between xylem and phloem cambium is present (Ex: Dicot stem).

b) Collateral closed. Between xylem and phloem there is no cambium. (Ex: Monocot stem)

2. *Bicollateral*. Here two patches of phloem and one patch of xylem are in the middle (Ex: f. Solanaceae), (fig. 12).

3. *Concentric*. One vascular element surrounds the other from all sides.(Ex. Yucca, Selaginella).

4. *Radial*. Xylem and phloem are seen as patches and they alternate each other, and occupy the different radii on the axis separated by nonconductive tissue (Ex. dicot and monocot roots).

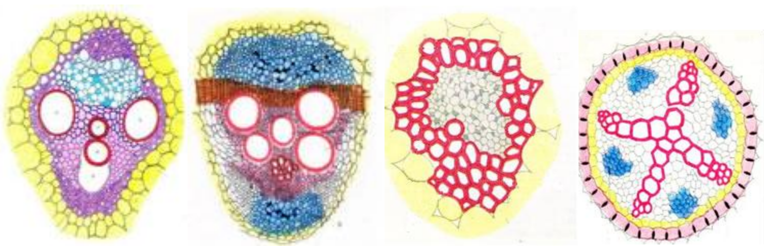


Fig.12. Vascular Bundles*: a.*Collateral, b.Bicollateral open, c.Concentric, d.Radial

COVERING TISSUES

Epidermis

The outer-most layer of cells of all young plant organs is called the **epidermis** (fig. 17). Most epidermal cells secrete a fatty substance called **cutin** within and on the surface of the outer walls. Cutin forms a protective layer called the cuticle. The thickness of the cuticle (or, more importantly, wax secreted on top of the cuticle by the epidermis) to a large extent determines how much water is lost through the cell walls by evaporation. The cuticle is also exceptionally resistant to bacteria and other disease organisms.

Epidermal cells of roots produce tubular extensions called *root hairs*. The root hairs greatly increase the absorptive area of the surface.

Leaves also have numerous small pores, the **stomata**, bordered by pairs. Guard cells differ from other epidermal cells in shape; they also differ in chloroplasts which are present within them. Some epidermal cells may be modified as **glands** that secrete protective or other substances (fig. 13).

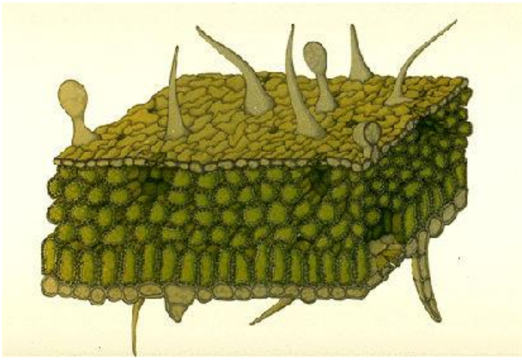


Fig.13. Epidermis

Secondary Dermal Tissue

Periderm

Plants such as monocots show only primary growth, while plants like conifers and woody dicots undergo primary as well as secondary growth. The primary growth is responsible for the extension of the length of plant parts, whereas secondary growth is responsible for the increase in the growth and size of plant laterally.

Secondary growth takes place at two lateral meristems – the vascular cambium and the cork cambium. These cells are meristematic in nature and are capable of dividing and producing new cells throughout their life time. The vascular cambium produces tissues of secondary xylem and secondary phloem. The cork cambium is responsible for the formation of periderm which is protective material that line the outer side of woody plants.

Periderm commonly replaces the epidermis in stems and roots having secondary growth. The fundamental tissues which compose the periderm are the phellogen, phelloderm and phellem.

The phellogen (cork cambium) is the meristematic portion of the periderm and consists of one layer of initials.

The phelloderm is a living parenchymal tissue. They have photosynthesizing chloroplasts and cellulosic walls.

The phellem or cork cells are phellogen derivative formed outwards. It is non-living tissue which has walls that are heavily suberized at maturity.

In stems and roots containing periderms, lenticels are formed to allow for the escape of carbon dioxide and the entrance of oxygen. They allow exchange of gases between the interior of the stem and atmosphere (fig. 14).

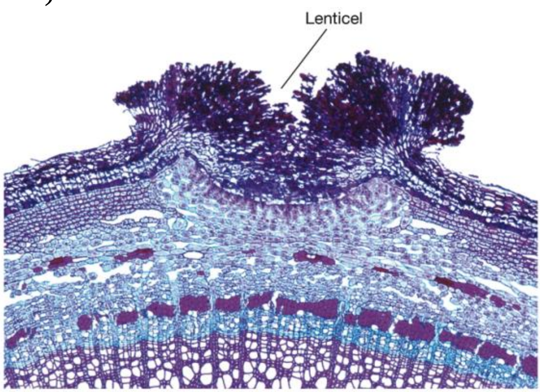


Fig.14. Periderm

Bark

Bark is the outer-most layer of stems and roots of woody (trees, woody vines, shrubs) plants. It consists of inner bark and the outer bark. The inner bark which in older stems is a living tissue, includes the inner-most area of the periderm.

From the outside to the inside of a mature woody stem, the layers include:

1. Phellem (Cork)
2. Phellogen (Cork cambium)
3. Phelloderm
4. Cortex
5. Phloem
6. Vascular cambium
7. Xylem.

The bark includes 1 through 5 said -above, and is composed of periderm and phloem and cells that produce these tissues. As the stem ages and grows, changes occur that transform the surface of the stem into the bark. Due to the thickening cork layer these cells die, because they do not receive water and nutrients. This dead layer is the rough corky bark that forms around tree trunks and other stems.

SECRETORY CELLS AND TISSUES

All cells secrete certain substances that can damage the cytoplasm, if allowed to accumulate internally. Such materials either must be isolated from the cytoplasm of the cells in which they originate or moved outside of the plant body. The substances consist of waste products that are of no further use to the plant, but some substances, such as nectar, perfumes, and plant hormones, are vital to normal plant functions.

Secretory cells may function individually or as part of a **secretory tissue**. Secretory cells or tissues, which often are derived from parenchyma, can occur in a wide variety of places in a plant. Among the most common secretory tissues are those that secrete nectar in flowers; oils in citrus, mint, and many other leaves; mucilage in the glandular hairs of sundews and other insect-trapping plants; latex in members of several plant families; and resins in coniferous plants, such as pine trees. Latex and resins are usually secreted by cells lining tube-like ducts that form networks throughout certain plant species. Some plant secretions, such as pine resins, rubber, mint oil, and opium, have considerable commercial value.

External secretory tissues

External secretory tissues are epidermal hairs, hydathodes and nectaries.

Epidermal hairs of many plants are secretory or glandular, such hairs commonly have a head composed of one or more secretory cells borne on a stalk (ex. Stinging Nettle). If one touches the hair, its tip breaks off, the sharp edge penetrates the skin, and the poisonous secretion is released.

Nectaries are glands, secreting a sugary liquid – the nectar, in flowers, pollinated by insects, are called nectaries. Nectaries may occur on the floral stalk or on any floral organ; sepal, petal, stamen or ovary.

The *hydathode* structures discharge water – a phenomenon called guttation through openings in margins of leaves. The water flows through the xylem to its endings in the leaf and then through the intercellular spaces of the hydathode tissue toward the openings in the epidermis.

Internal secretory tissues

Generally there are three types of internal secretory tissues:

1. Schizogenous cavities;
2. Lysigenous cavities;
3. Laticiferous cavities.

1. *Schizogenous cavities* are formed by the enlargement of intercellular spaces in the tissues. The cavity is surrounded by epithelial layers, which are composed of glandular cells. The

epithelial cells secrete their products (such as resins, tannins etc.) into the cavities.

2. *Lysigenous cavities* arise through dissolution of entire cells. These secretory cells have big vacuole and protoplasm. The vacuole stores secretory products. After disintegration the products are relayed into the cavity. The cavity acts as a reservoir. The lysigenous cavities in Citrus fruits and leaves of Eucalyptus store essential oils.

3. *Laticiferous tissues* consist of thin walled, greatly elongated and much branched ducts containing a milky or yellowish colored juice known as latex. Laticiferous ducts, in which latex is found, are two types (fig. 15 a):

1. Latex cell or non-articulate latex ducts;
2. Latex vessels or articulate latex ducts.

Latex cells are independent units which extend as branched structures for long distances in the plant body. They originate as minute structures, elongate quickly and by repeated branching ramify in all directions but do not fuse together.

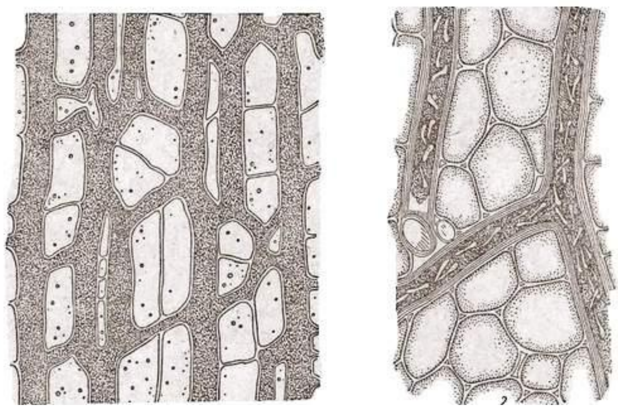
Latex vessels are the result of anastomosing of many cells together. They grow as parallel ducts, which form a complex network by means of branching. Latex vessels are commonly found in many angiosperm families – Papaveraceae, Compositae, Euphorbiaceae, etc.

Glandular tissues

A gland may consist of isolated cells or small group of cells with or without a central cavity. They contain some secretory or excretory products. These glands are:

1. oil secreting glands (essential oils – orange, lemon);
2. mucilage secreting glands (Piper betel leaf);
3. gums, resin and tannin secreting glands (gymnosperms-Pine);
4. digestive glands (enzymes or digestive agents-Drosera);
5. water secreting glands (at the tip of leaf veins-Dionaea) (fig. 15 b).

a)



b)

Fig.15. a) Glandular hairs, b) milky ways

Homologous and Analogous organs

Homologous organs have the same evolutionary origin and different functions. In plants, all the stem modifications or all the root modifications are homologous with each other. Such structures serve different functions like support, food storage, etc.

Analogous organs have different evolutionary origin, but the same function. For example, leaf tendril and stem tendril. They both perform the function of coiling or support (fig. 16).

a)

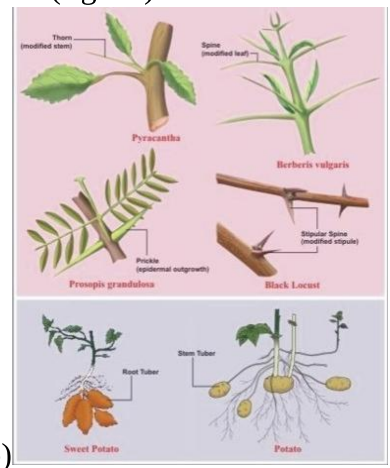

b)


Fig.16. a) Homologous organs, b) Analogous organs

Embryogenesis and Organogenesis

Plant embryogenesis is the process that produces a plant embryo. It occurs naturally as a result of sexual fertilization and the formation of the zygotic embryos. The embryo along with other cells from the mother plant develops into the seed or the next generation, which, after germination, grows into a new plant.

Plant organogenesis is simply the process of forming new organs, occurs continuously and only stops when the plant dies.

In the shoot, the apical meristem regularly produces new lateral organs (leaves or flowers) or lateral branches.

Chapter 3

PLANT ORGANS

Organs of plants can be divided into vegetative and reproductive. Vegetative plant organs are roots, stems and leaves. The reproductive organs are variable. In flowering plants they are represented by the flower, seed and fruit. In conifers, the organ that bears the reproductive structures is called a cone. In other divisions of plants, the reproductive organs are called strobili (in Lycopodiophyta), or simply gametophores (in Mosses).

ROOTS

Roots anchor trees firmly in the soil, usually through an extensive branching network that constitutes about one-third of the total dry weight of the plant. The roots of the most plants do not usually extend more than 3 to 5 meters down into the earth. The roots of a few plants, such as alfalfa, however, often grow more than 6 meters. Some plants, such as cacti, form very shallow root systems, but these systems still effectively anchor the plants with a densely branching mass of roots radiating out in all directions up to 15 meters from the stem.

Root systems

In general, the plant root system consists either of a **taproot** system (with primary root) or **fibrous** root system (adventitious roots).(fig.17).

When a seed germinates, the tiny, rootlike **radicle**, a part of the embryo within it, grows out and develops into a thick, tapered **taproot**, from which thinner branch roots arise (e.g. Dandelions).

Adventitious roots are those that do not develop from another root but develop instead of a stem or leaf. **A fibrous** root system, which may have large numbers of fine roots of similar diameter, develops from the adventitious roots. Many mature plants have a combination of taproot and fibrous root systems.

Root hairs greatly increase the total surface area of the root.

Many plants such as peas and carrots, whose seeds have two seed leaves – commonly referred to as dicots –have taproot systems with one, primary roots from which secondary roots develop. Monocotyledonous plants (e.g. corn and rice, whose seeds have one seed leaf, commonly referred to as monocots), on the other hand, have fibrous roots system. Adventitious and other types of roots may develop in both dicots and monocots.

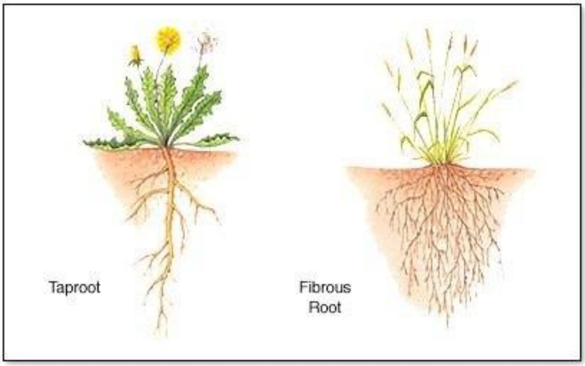


Fig.17. a) taproot, b) fibrous root

FUNCTIONS OF THE PLANT ROOT

The functions of the plant root system include:

1**. Anchorage and support**. The plant root system anchors the plant body to the soil and provides physical support. In general, taproot system provides more effective anchorage.

2. **Absorption and conduction.** The plant root system absorbs water, oxygen and nutrients from the soil in mineral solution, mainly through the root hair. From the root, these move upward.

3. **Storage**. The root serves as a storage organ for water and carbohydrates as in the modified swollen roots of carrot, sweet potato. Fibrous roots generally store less starch than taproots.

4. **Photosynthesis**. Some roots are capable of performing photosynthesis, as in the epiphytic orchids and aerial roots of mangrove trees.

5. **Aeration**. Plants that grow in watery places have modified roots called *pneumatophores* to which oxygen diffuses from the air.

6. **Movement**. In many bulb- and corm-forming plants, *contractile* roots pull the plant downward into the soil where the environment is more stable.

7. **Reproduction.** The plant root system also serves as a natural means of perpetuating species. In mature horsetail tree (Casuarina equisetifolia) and certain plants, clonal seedling or offshoots are commonly seen growing profusely around the trunk from horizontally growing roots. Likewise, new plants emerge from left-over tuberous roots after harvest in fields grown to sweet potato (Ipomaea batatas) and yam been (Pachyrhizus eroses). As a rule, plants with a fibrous root system are easier to transplant than those with tap roots.

ROOT STRUCTURE

Young roots usually reveal four regions or zones. Three of the regions are not sharply defined at their boundaries. The cells of each region gradually develop the form of those of the next region, and the extent of each region varies considerably, depending on the species involved. These regions are called (1) the root cap, (2) the region of cell division, (3) the region of elongation, and (4) the region of maturation.

The Root Cap

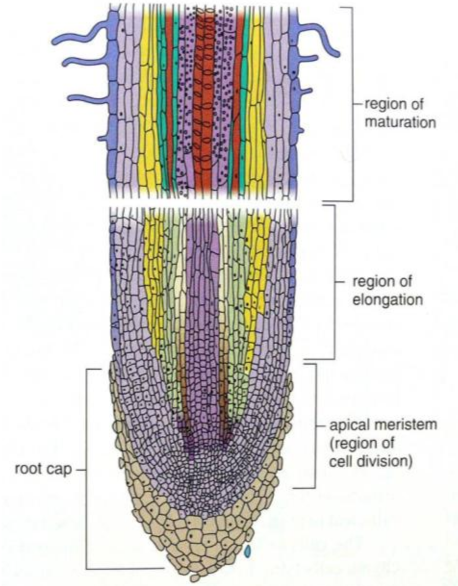


Fig.18. Root regions

The root cap is composed of a thimble-shaped mass of parenchyma cells covering the tip of each root. It is quite large and obvious in some plants, while in others, it is nearly invisible. One of its functions is to protect from damage the delicate tissues behind it as the young root tip pushes through often angular and abrasive soil particles. The root cap has no equivalent in stems. The dictyosomes of the root cap's outer cells secrete and release a slimy substance that lodges in the walls and eventually passes to the outside.

The root cap, whose cells have an average life of less than a week, can be slipped off or cut from a living root, and when this is done, a new root cap is produced. The root cap also functions in the perception of gravity. It is known, that amyloplasts (plastids containing starch grains) act as gravity sensors, collecting on the sides of root-cap cells facing the direction of gravitation force (fig. 18).

The Region of Cell Division

Cells in the **region of cell division**, which is composed of an apical meristem (a tissue of actively dividing cells) in the center of the root tip, produce the surrounding root cap. Here the cells divide every 12 to 36 hours, while at the base of the meristem, they may divide only once every 200 to 500 hours. Cells in this region are mostly cubical with large nuclei and very small vacuoles.

Both in roots and stems, the apical meristem soon subdivides into three meristematic areas (1) the **protoderm** gives rise to an outer layer of cells, the *epidermis*; (2) the **ground meristem**, to the inside of the protoderm, produces parenchyma cells of the cortex; (3) the **procambium**, which appears as a solid cylinder in the center of the root, produces *primary xylem* and *primary phloem*.

The Region of Elongation

The region of elongation, usually extends about 1 centimeter or less from the tip of the root. This is the area of root lengthening. The cells that were produced in the meristematic region grow in this zone. No new cells are produced here, but this is the area that actually creates the growth of the root.

The Region of Maturation

Most of the cells mature, or differentiate, into the various distinctive cell types of the primary tissues in the region, which is sometimes called the region of differentiation, or root hair zone. Root hairs absorb water and minerals and greatly increase the total absorptive surface of the root.

The root hairs are not separate cells; they are tubular extensions of specialized epidermal cells. They are so numerous. A single plant occupying less than 0.6 cubic meter soil is found to have more than 14 billion root hairs.

The cuticle which may be relatively thick on the epidermal cells of stem and leaves is thin enough on the root hairs and epidermal cells of roots allow water to be absorbed but still sufficient to protect against invasion by bacteria and fungi.

ROOT ANATOMY

ANATOMY OF A TYPICAL MONOCOT ROOT

A transverse section passing through the monocot root reveals the following details:

- Epiblema
- Cortex
- Endodermis
- Stele
- Pericycle
- Conjunctive tissue
- Pith
- Vascular bundles.

Epiblema is outer-most covering of the root formed by a single layer of compactly arranged, barrel-shaped parenchyma cells. The cells are characteristically thin-walled since they are involved in absorption of water. A cuticle and stomata are absent. Some of the epiblema cells are produced into long unicellular projections called **root hairs**.

Cortex is a major component of the ground tissue of the root. It is represented by several layers of loosely arranged parenchyma cells. Intercellular spaces are prominent. The cortex is mainly meant for storage of water. The cells also allow a little amount of water into the xylem vessels.

Endodermis is the inner-most layer of cortex formed by compactly arranged barrel-shaped cells. Some of the cells are thin-walled and are known as passage cells. They allow water to pass into the xylem vessels. The other cells are characterized by the presence of thickening on their radial walls. These thickenings are known as "casparian thickenings". They are formed by the deposition of a waxy substance called suberin. These thickenings play an important role in creating and maintaining a physical force called root pressure.

Stele is the central cylinder of the root consisting of pericycle, conjunctive tissue, pit and vascular bundles.

Pericycle is the outer-most covering of the stele represented by a single layer of parenchima cells.

Conjunctive tissue is represented by loosely arranged parenchyma cells found in between the bundles. The cells are specialized for water storage.

Pith is the inner-most region of the root representing the central axis. It is composed of a few loosely arranged parenchyma cells.

Vascular bundles are radial in arrangement (fig. 19).

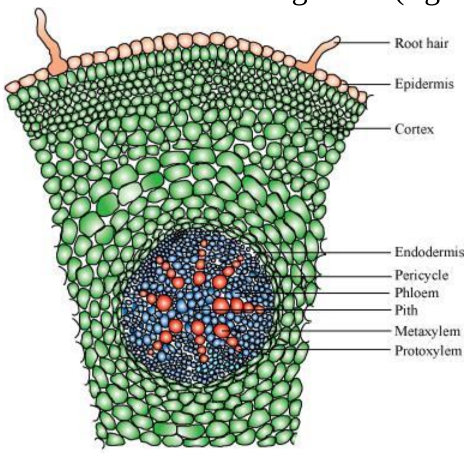


Fig.19. Monocot root

ANATOMY OF TYPICAL DICOT ROOT

A transverse section passing through the root of sunflower reveals the following details:

- Epiblema
- Cortex
- Endodermis
- Stele
- Pericycle
- Conjunctive Tissue
- Vascular bundles
- Pith.

Epiblema is the outer-most covering of the root formed by a single layer of compactly arranged, barrel-shaped, parenchyma cells. The cells are thin-walled since they are involved in absorption of water. A cuticle and stomata are absent. Some of the epiblema cells are produced into long unicellular projections called **root hairs.**

Cortex is a major component of the ground tissue of root. It is represented by several layers of loosely arranged parenchyma cells. Intercellular spaces are prominent. The cortex is mainly meant for storage of water. The cells also allow a little amount of water into the xylem vessels.

Endodermis is the inner-most layer of cortex formed by compactly arranged barrel-shaped cells. Here some of the cells are thin-walled and are known as "passage cells". These cells allow water to pass into the xylem vessels. The other cells are characterized by the presence of thickening on their radial walls. These thickenings are known as "casparian thickenings" and are formed by the deposition of a waxy substance called suberin.

Stele consists of pericycle, cojunctive tissue and vascular bundles.

Pericycle is the outer-most layer of stele composed of one layer of parenchymatous cells. At the time of secondary growth, it produces secondary cambium or phellogens.

Conjunctive tissue is represented by a group of radially arranged parenchyma cells found in between the vascular bundles. The cells are specialized for water storage.

Vascular bundles – they are 2-8 in number, radial or arranged in ring.

Pith is centrally located. It consists of thin walled, parenchyma cells with intercellular spaces. It helps in storage of food materials (fig. 20,21).

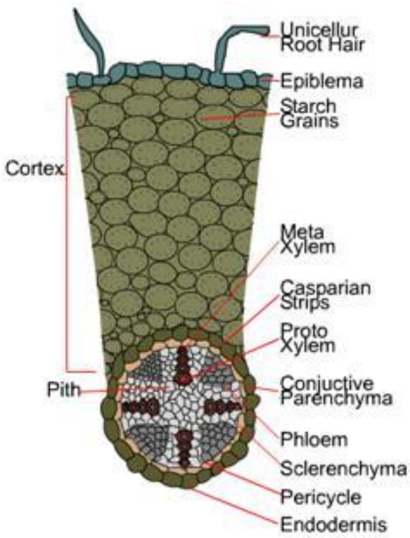


Fig.20. Dicot root

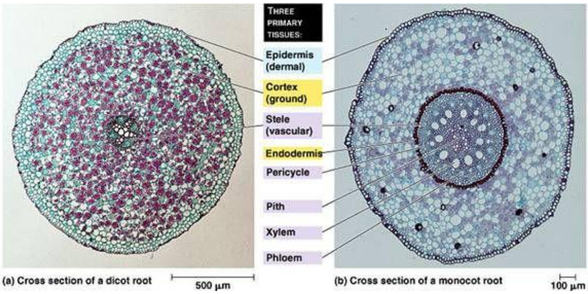


Fig.21. Cross section of dicot and monocot roost

SPECIALIZED ROOTS

Some plants, however, have roots with modifications that adapt them for performing specific functions as well as the absorption of water and minerals in solution.

Food-storage Roots

Fig.22. Food-storage roots

Most roots and stems store some food, but in certain plants, the roots are enlarged and store large quantities of starch and other carbohydrates, which may later be used for extensive growth. In carrots, beets, turnips, and radishes, the food-storage tissues are actually a combination of root and stem. Although the external differences are not obvious, approximately 2 centimeters at the top of an average carrot is derived from the stem tissue that merges with the root tissue below (fig. 22).

Water-storage Roots

Some members of the Pumpkin Family (Cucurbitaceae) produce huge water-storage roots. This is particularly characteristic of those that grow in arid regions or in those areas where there may be no precipitation for several months of the year. In certain manroots (Marah), for example, roots weighing 30 kilograms or more, are frequently produced, and a major root of one calabazilla plant (Cucurbita perennis) was found to weigh 72,12 kilograms. The water in the roots is apparently used by the plants when the supply in the soil is inadequate.

Propagative Roots

Many plants produce adventitious buds (buds appearing in places other than stems) along the roots that grow near the surface of the ground. The buds develop into aerial stems called suckers. The rooted suckers can be separated from the original root and grow individually. Cherries, apples, pears and other fruit trees often produce suckers. The adventitious roots of rice-paper plants (Tetrapanax papyrifera) and tree-of-heaven (Ailanthus altissima) can become a nuisance in gardens, often producing propogative roots 10 meters or more from the parent (fig. 23).

Fig.23. Propagative root

Pneumatophores

Some swamp plants, such as the black mangrove (Avicennia nitida) and the yellow water weed (Ludwigia repens), develop special spongy roots, called pneumatophores, which extend above the water's surface and enhance gas exchange between the atmosphere and the surface roots to which they are connected (fig. 24).

Fig.24. Pneumatophores

Aerial Roots

Velamen roots of orchids, prop roots of banyan trees, adventitious roots of ivies, and photosynthetic roots of certain orchids are among various kinds of aerial roots produced by plants. The epidermis of velamen roots, which is several cells thick, aided in the absorption of rain water. Some tropical plants, produce sizable prop roots extending for several feet above the surface of the ground or water.

Many of the tropical figs produce roots that grow down from the branches until they contact the soil. Once they are established, they continue secondary growth and look just like additional trunks.

The vanilla orchid, from which we obtain vanilla flavoring, produces chlorophyll in its aerial roots and, through photosynthesis, can manufacture food within them (fig. 25).

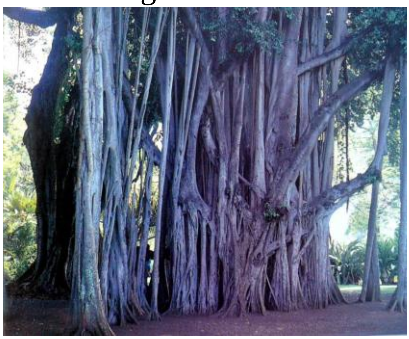


Fig.25. Aerial root

Contractile Roots

Some herbaceous dicots and monocots have contractile roots that pull the plant deeper into the soil. Many lily bulbs are pulled a little deeper into the soil each year as new sets of contractile roots develop (fig. 26).

Fig.26. Contractile root

Buttress Roots

Some tropical trees growing in shallow soil produce huge, buttress-like roots toward the base of the trunk, giving them great stability. Apart from their angular appearance, these roots look like a part of the trunk.

Parasitic Roots

Some plants, including dodders, broomrapes, and pinedrops, have no chlorophyll (necessary for photosynthesis) and have become dependent on chlorophyll-bearing plants for their nutrition. They parasitize their host plants via peglike projection called haustoria, which develop along the stem in contact with the host. The haustoria penetrate the outer tissue and establish connections with the xylem and phloem (fig. 27).

Fig.27. Parasitic root

Mycorrhizae

More than three-quarters of all seed plant species have various fungi associated with their roots. The association is mutualistic; that is, both the fungus and the root benefit from it and are dependent upon the association for normal development.

The fungus is able to absorb and concentrate phosphorus much better than it can be absorbed by the root hairs.

These “fungusroots”, or mycorrhizae are essential to the normal growth and development of forest trees and many herbaceous plants.

Root Nodules

Although almost 80% of our atmosphere consists of nitrogen gas, plants cannot convert the nitrogen gas to usable forms. New species of bacteria, however, produce enzymes with which they can convert nitrogen into nitrates and other nitrogenous substances readily absorbed by roots. The members of the Legume family, which includes peas, beans, form associations with certain soil bacteria that result in the production of numerous small swellings called root nodules that are clearly visible when such plants are uprooted. The nodules contain large numbers of nitrogen-fixing bacteria (fig. 28).

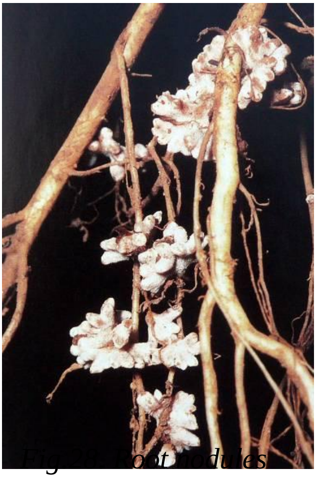


Fig.28: Root nodules

Chapter 4

PLANT ORGANS: THE PLANT STEM

The plant stem is a component of the shoot system, the portion of the plant body of angiosperms having phototropic response. Besides the stem, the plant shoot also consists of leaves and reproductive organs.

The stem has been described as a "central axis" to which all other parts are attached. The first stem, that develops from a seed, arises from the epicotyl, an embryonic shoot within the seed.

STEM SHAPES

The main stem shapes are: round, square, angular, oval, lens, triangular, hollow, winged, ribbed, milkysap, spines.

The stems of family Poaceae is called *straw*. It is a hollow stem, in which chloroplasts are absent, and the stems become woody. It gives the mature plant mechanical strength. Vascular bundles have chess-like location and are covered with sclerenchyma.

The stem supports the leaves; to conduct water and minerals to the leaves, where they can be converted into usable products by photosynthesis; and to transport these products from the leaves to other parts of the plant, including the roots. The stem conducts water and nutrient minerals from their site of absorption in the roots to the leaves by means of certain vascular tissues in the *xylem*. The movement of synthesized foods from the leaves to other plant organs occurs through other vascular tissues in the stem called *phloem.* Food and water are also frequently stored in the stem.

There are some plants that appear to be stemless. Actually these stems are just extremely short, the leaves appearing to rise directly out of the ground, these stems are called acaulescent (ground rosette,

e. g. some Viola species). All stems of angiosperms, including those which are highly modified, are recognizable from other plant organs by their presence of *nodes, internodes, buds* and *leaves.*

A *node* is a point on the stem from which leaves or buds arise. The portion between two successive nodes is the *internode*. Nodes can hold one or more leaves, as well as buds which can grow into branches (with leaves and flowers). Adventitious roots may also be produced from the nodes (fig. 29).

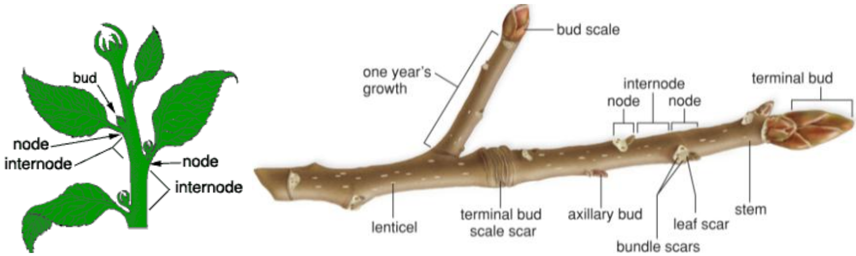


Fig.29. Node, internode, bud

STEM FUNCTIONS

The main functions of the stems are:

- transportation
- connect the roots with leaves
- storage of nutrients and water
- vegetative propagation
- photosynthesis (in green stems)
- modifications

ANATOMY OF STEM

A thin transverse section of a young stem reveals the internal structure when observed under the microscope:

Internal Structure of Monocot Stem

1.Epidermis - it is the outer-most layer of the stem, composed of square-shaped cells and interrupted by stomata. It is protective in nature.

2.Hypodermis - it lies below the epidermis. It consists of 2 or 3 layers of sclerenchymatous cells. It is mechanical in functions and provides support and strength to the stem.

3.Ground tissue - it consists of a mass of thin-walled parenchyma cells extending from below the hypodermis to the centre of the stem. It is not differentiated into definite tissues like cortex, endodermis, pericycle, etc., as in dicot stems. The cells of the ground tissue have intercellular spaces. The cells contain reserve food materials. Vascular bundles are scattered in the ground tissue.

4. Vascular bundles - they lie closer to periphery. The peripheral vascular bundles are smaller than the central ones. Each vascular bundle is surrounded by a sheath of thick-walled sclerenchyma cells called the bundle-sheath. It provides protection and gives strength to the vascular bundles. Vascular bundles are conjoint, collateral and closed. Each vascular bundle is composed of xylem and phloem.

In **woody dicot plants** the rings grow to make a complete ring around the stem. Xylem growth makes the "annual rings" used to tell the tree's age. In woody dicot plants, water and mineral movement occurs in the more recent years of xylem rings. Drought reduces the size of the annual rings (size of xylem tubes) and thus the potential for water and nutrient movement (fig. 30).

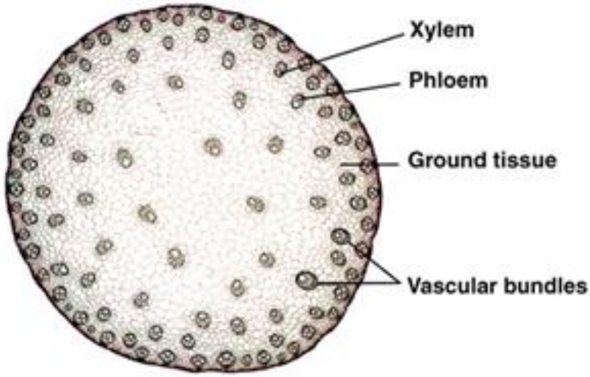


Fig.30. Monocot stem

Internal structure of Dicot stem

1. Epidermis- it forms the single-celled outer-most layer of the stem. The outer walls of epidermal cells are cutinized. It bears multi-cellular hairs and a few stomata. It is protective in nature.

2. Cortex- lies below the epidermis. It is differentiated into 3 zones:

a) Hypodermis; it is formed of 4 to 5 cell thick layer of collenchymatous cells. These cells are living and contain chloroplasts.

b) General cortex; it lies below the hypodermis, it consists of a few layers of thin-walled parenchymatous cells with intercellular spaces. Some of the cells have chloroplasts and they are known as chlorenchyma.

c) Endodermis; it is the inner-most layer of cortex. It is made up of single row of compact barrel-shaped cells without intercellular spaces. Since the cells of endodermis contain starch grains, it is also known as starch-sheath. Casparian strips are distinctly visible in endodermal cells.

3. Pericycle- it lies below the endodermis. Here the sclerenchyma cells are dead and they provide mechanical support to the plant and protect the vascular bundles.

4. Vascular bundles- they are many in number and arranged in ring inclosed by the pericycle. The vascular bundles are collateral and open. Each vascular bundle is composed of xylem, phloem and cambium.

<u>Xylem</u>- it is the inner-most layer of vascular bundles and lies towards the centre of the stem. Xylem consists of vessels, tracheids, wood fibers and wood parenchyma.

<u>Phloem</u>- it lies below the pericycle and is composed of sieve tubes, companion cells and phloem parenchima. The phloem cells store starch, protein and fats.

<u>Cambium</u>- it is a strip of thin-walled cells lying in between the phloem and xylem. The cambial cells consist of a single layer of meristematic cells.

5. Pith of medulla-it is the central part of the stem, composed of parenchymatous cells with intercellular spaces. Its main function is storage of food and transverse conduction of food materials (fig. 31).

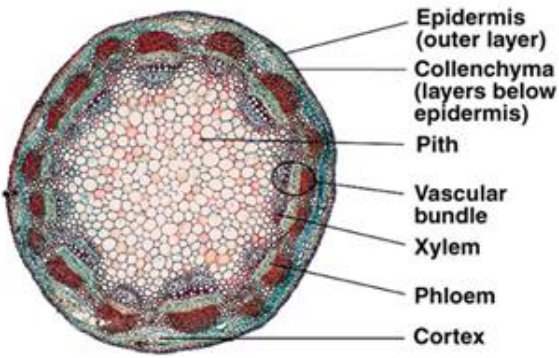


Fig.31. Dicot stem

Gymnosperm stems

All gymnosperms are woody plants. Their stems are similar in structure to woody dicots, except that most gymnosperms produce only tracheids in their xylem, not the vessels found in dicots. Gymnosperm wood also often contains resin ducts.

According to the height of the plant, we classify them into:

1. **Trees:** Plants with ligneous stems, with a superior height of 5 meters. In the case we call the stems trunks. They do not generally branch up to a considerable distance from the soil.
2. **Shrubs:** They are those plants with ligneous stems from 1 to 5 meters tall. In this case, branching begins at the soil level.
3. **Bushes:** Ligneous plants - shorter than 1 meter tall.
4. **Herbaceous plants:** They have non-woody short stem and generally they die back at the end of each growing season. Both grasses and forbs are herbs (fig. 32).

a b c d

Fig.32. a) tree,b) shrubs,c) bushes,d) herbacus plant

BUDS

A bud is an embryonic stem which has the potential for further plant growth. It may develop into a leaf, flower, or both. Such buds are called **leaf buds** (vegetative), **flower buds** (reproductive) and mixed buds, respectively. Many buds remain dormant within a certain duration or they may be embedded in the stem tissue as to become hardly visible. A single bud that is found at the apex of the stem is called terminal bud, while lateral buds or axillary buds occur in the leaf axils, they develop into leaves, lateral brunches or flowers. As a result of injury, adventitious buds may be formed also in the internode of the stems, in leaves or roots. The "eyes" of the potato tuber are buds**. Terminal bud** contains apical meristem, found at the tip of a stem. It increases the length of a stem**. Lateral buds** develop into a leaf or flower. Lateral and terminal buds are protected by **bud scales** which are modified leaves, they cover and protect the bud. It helps the bud survive climate changes; when the bud opens in the spring, the scales fall off leaving a bud scale scar.

Leaf scar is the remains of the leaf after it has fallen off the tree; it is just below the lateral bud.

Naked bud is a bud without a protective bud scale (e.g. Viburnum family).

Edible buds - some plants are cultivated because their buds are edible (Artichokes and Cabbage) (fig. 33).

a b

c

Fig.33.a) leaf buds, b) flower buds, c) artichoke

Dicot stems

Vascular bundles are arranged in a ring around the stem. In plants with secondary growth, vascular cambium begins to produce secondary phloem outside, and secondary xylem inside. The yearly additions of secondary xylem are commonly called “growth rings”. Rings can be counted visually.

The cambium forms two systems of vascular tissue, one vertically up the axis, and the other horizontally across the axis (called a ray system). Inward from the cambium, xylem rays are produced, and outwardly phloem rays are produced. Associated with the rays are gum ducts in dicots, which contain resins, oil, gums. Comparable to **gum ducts**, some conifers have **resin ducts.** Secondary xylem tissue, “wood”, may be composed of sapwood and heartwood. Sapwood consists of xylem components, active in the transport of water and mineral nutrients. The inner heartwood is composed of inactive xylem that stores secondary metabolites.

Monocot Stem. Monocots have no vascular or cork cambium and, therefore, no secondary growth. They exist in primary state of growth (herbaceous plants). In large plants bodies such as palms, thickening of the trunk occurs by multiple divisions of parenchyma cells.

TREE RINGS

Greek botanist Theophrastus (ca. 371- ca. 287 BC) first mentioned that the wood of trees has rings. Leonardo da Vinci was the first person to mention that trees form rings annually and that their thickness is determined by the condition under which they grew. Tree rings or annual rings, can be seen in a horizontal cross section cut through the trunk of a tree. Growth rings are the result of new growth in the vascular cambium, a layer of cells near the bark that is classified as a lateral meristem. It is known as a secondary growth. Visible rings result from the change in growth speed through the seasons of the year; thus, one ring generally marks the passage of one year in the life of the tree. The rings are more visible in temperate zones, where the seasons differ more markedly. In spring growth is comparatively rapid. Many trees in temperate zones make one growth ring each year, with the newest adjacent to the bark. Hence, for the entire period of a tree's life, a year-by-year record or ring pattern is formed that reflects the age of the tree and the climatic conditions in which the tree grew. Adequate moisture and long growing season result in a wide ring, while a drought year may result in a very narrow one (fig. 34).

Fig.34. Tree rings

Stem Modifications

In most plants stems are located above the soil surface, but some plants have underground stems.

There are three types of stem modifications:

1. Underground
2. Aerial
3. Subaerial

The **underground stems,** by being situated below the surface of the soil, protect themselves from weather and animal attacks, and serve as storehouses for food reserve and in vegetative propagation. Their stem nature can be distinguished by the presence of nodes and internodes, scale leaves at the nodes, axillary buds in axils of scale leaves and a terminal bud. The underground stems are of 4 types, namely:

- Rhizome
- Tuber
- Bulb
- Corm.

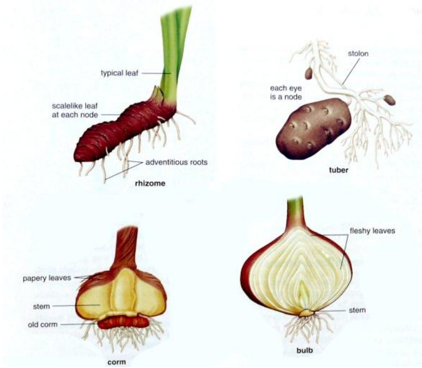


Fig.35. Underground stems

Stems may be of various forms to serve different functions, such as for food or water storage (fig. 35).

Bulb- the stem here is reduced and represented by a short disc. The lower surface of the stem produces many adventitious roots (e.g. Onion, Garlic). In bulbs of onion, the inner leaves are fleshy, while the outer ones are dry. This is called as *tunicated bulb.* The apical bud of the bulb produces the shoot. The axillary buds sometimes produce daughter bulbs, as in garlic.

Corm - A solid, bulb-like, underground stem without fleshy scales forms a corm. It has greatly shortened internodes. Examples are the food-storage, reproductive corms of *Gladiolus.*

Rhizome - is a thick horizontally growing stem, which usually stores food materials. It has nodes and internodes, scale leaves, axillary buds, adventitious roots and a terminal bud. Usually the growing points of the rhizome continue to remain underground causing an elongation of rhizome. Roots develop from the lower surface of rhizome (e.g. Ginger).

Tuber - is a swollen end of an underground branch which arises from the axil of a lower leaf. These underground branches grow horizontally outwards in the soil. Each tuber is irregular in shape due to the deposition of food materials (starch). On the surface of each tuber many leaf scars are seen. Each such leaf scar encloses an axillary bud, and it is called an "eye". These eyes of potato are capable of producing new plants by vegetative propagation (e.g. Potato).

Aerial stem modifications are:

1. stem tendril
2. stem thorn
3. phylloclade
4. bulbil
5. cladodes and cladophylls

Stem tendrils- the terminal bud gives rise to a tendril and the axillary bud becomes modified into a tendril in Passiflora (fig. 36).

Fig.36. Stem tendrils

Stem thorn- is a hard, straight, and pointed structure. In Bougainvillea and Duranta, the axillary bud is modified into a thorn. The thorn sometimes bears leaves, flowers and fruits as in Pomegranate. The thorns not only check the rate of transpiration, but also protect the plants from herbivore grazing (e.g. Citrus) (fig. 37).

Fig.37. Stem thorn

Phylloclade- is a flattened stem of several internodes functioning as a leaf. In Opuntia the stem is modified into a green flattened structure called *phylloclade*. On the surface of the phylloclade, clusters of spines are formed. These spines are the modified leaves of the axillary bud. These spines not only check the rate of transpiration but also protect the plant from herbivores. The phylloclade has distinct nodes and internodes (e. g. Opuntia) (fig. 38).

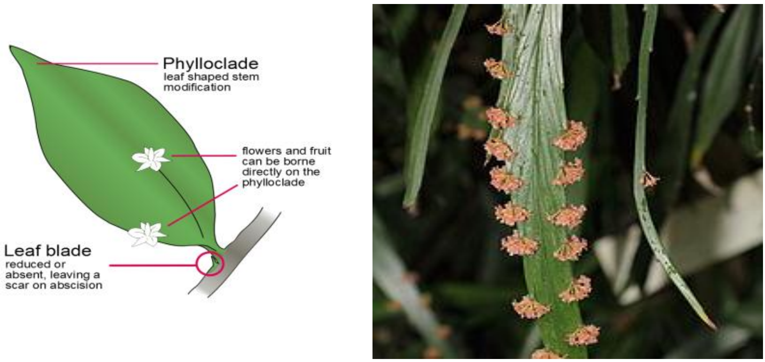


Fig.38. Phylloclade

Bulbil - is a modification of vegetative or floral bud. It is swollen due to the storage of food. It can function as an organ of vegetative propagation. In Agave the floral buds are modified into bulbils (fig. 39).

Fig.39. Bulbil

Cladodes and Cladophylls - a phylloclade of one or two internode is called a cladode. Cladophyll is a flattened leaf like stem arising in the axils of a minute, bract-like, true leaf (e. g. Asparagus) (fig. 40).

Fig.40. Cladodes and Cladophylls

Subaerial stem modifications are:

1. Runner
2. Offset
3. Stolon
4. Sucker

Runner- arises from the base of the stem as a lateral branch and runs along the surface of the soil. It develops distinct nodes and internodes. At each node the runner produces roots below and leaves above. In this way many runners are often produced by the mother plant and they spread out on the ground on all sides. If any accidental injury results in the separation of a runner, the severed parts are capable of leading an independent existence (e.g. Fragaria) (fig. 41).

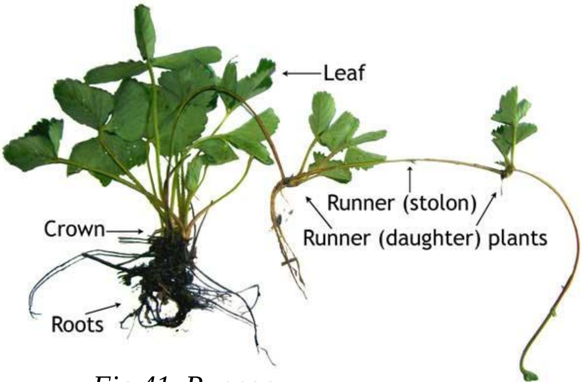


Fig.41. Runner

Offset- is a short thick runner like a branch which produces a new plant at its tip. The offsets grow in all directions from the main stem of the parent plant. If any injury results in the separation of these units, each is capable of leading an independent existence (e.g. Pistia) (fig. 42).

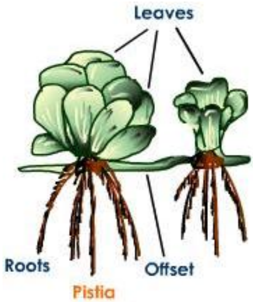


Fig.42. Offset

Stolon- here lateral branches called stolons originate from the underground stem. The stolons grow horizontally outwards for a varying distance in the soil. Ultimately their terminal bud emerges out of the ground and develops into a new plant. A runner, sucker or any basal branch which produces roots is called a stolon (e.g. Colocasia) (fig. 43).

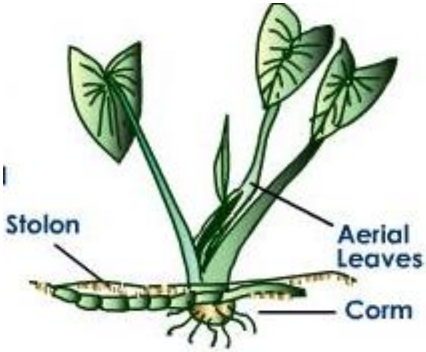


Fig.43. Stolon

Sucker- a lateral branch arising close to the ground level traveling underground for some distance, turning up at its end and producing a new plant is a sucker (e. g. Mint, Chrysanthemum) (fig. 44).

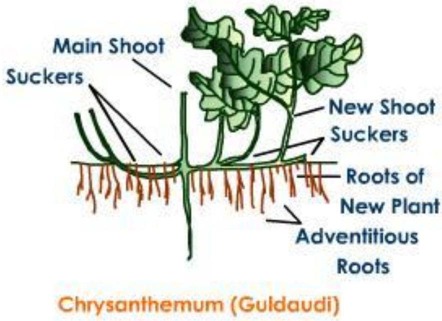


Fig.44. Sucker ()

Chapter 5

PLANT ORGANS: LEAVES

Regardless of their ultimate size or form, all leaves originate as primordia in the buds. In early spring, a leaf primordium may consist of fewer than 200 cells, but in response to changes in temperature, day-length, and availability of water, hormones are produced that stimulate these cells to begin dividing. Within a few days or weeks, the original 200 cells have been multiplied, differentiated, and expanded into a structure consisting of millions of cells. The first leaves produced may appear quite different in form from those produced later.

At maturity, most leaves have a stalk, called the petiole, and a flattened blade, or lamina, which has a network of veins (vascular bundles) (fig. 45). A pair of leaf-like, scale-like, or thorn-like appendages, called stipules, are sometimes present at the base of the petiole. Occasionally, leaves may lack petioles; when they do, they are said to be sessile. Leaves of deciduous trees normally live through only one growing season, and even those of evergreen trees rarely function for more than 2 to 7 years.

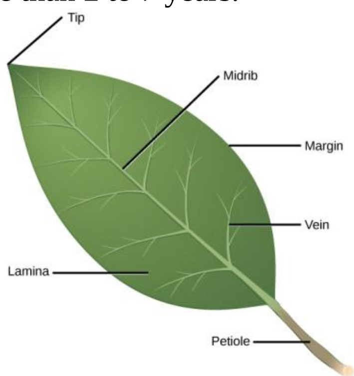


Fig.45. Leaves structure

Leaves of flowering plants are associated with leaf gaps, and all have an axillary bud at the base. Leaves may be **simple** or **compound**. A simple leaf has a single blade, while the blade of a compound leaf is divided in various ways into leaflets. Pinnately compound leaves have the leaflets in pairs along an extension of the petiole called a rachis, while palmately compound leaves have all the leaflets attached at the same point at the end of the petiole. Sometimes, the leaflets of a pinnately compound leaf may be subdivided into still smaller leaflets, forming a bipinnately compound leaf.

The flattened surface of leaves, which is completely covered with a transparent protective layer of cells, the epidermis, admits light to all parts of the interior. Many leaves twist daily on their petioles so that their upper surfaces are inclined at right angles to the sun's rays throughout daylight hours.

Green leaves capture the light energy available to them by means of the most important process for life on earth. This process is called **photosynthesis** (fig. 46). All the energy needs of living organisms ultimately depend on photosynthesis.

The lower surfaces of leaves (and in some plants, the upper surface as well) are dotted with tiny pores called stomata, which not only allow entry for the carbon dioxide gas needed for photosynthesis, but also play a role in the diffusion out of the leaf of oxygen produced during photosynthesis. The stomatal apparatus, which consists of a pore bordered by a pair of sausage-shaped guard cells, controls the water loss when the guard cells inflate or deflate, opening or closing the pore.

Leaves also perform other functions. For example, all living cells respire, and in the process of this and other metabolic activities, waste products are produced. These wastes accumulate in the leaves and are disposed of when the leaves are shed, mostly in the fall. Before dropping from the plant, the leaves are sealed off at the bases of their petioles. The following season, the discarded leaves are replaced with new ones.

Leaves play a major role in the movement of water absorbed by roots and transported throughout the plant. Most of the water reaching the leaves is evaporated in a vapor form into the atmosphere by a process known as transpiration. In some plants, there are special openings called **hydathodes** at the tips of leaf veins. Root pressure forces liquid water out of hydathodes, usually at night when transpiration is not occurring. The loss of water through hydathodes is called guttation.

Fig.46. Green leaves

Leaf Arrangement and Types

Fig.47. Leaf types

Many of the roughly 275,000 different species of plants that produce leaves can be distinguished from one another by their leaves. The variety of shapes, sizes, and textures of leaves seems to be almost infinite. The leaves of some of the smaller duckweeds are less than 1 millimeter (0.04 inch) wide.

The mature leaves of the Seychelles Island palm can be 6 meters (20 feet) long, and the floating leaves of a giant water lily, which reach 2 meters in diameter, can support, without sinking, weights of more than 45 kilograms.

In addition to flattened, variously shaped, colored, spine-like leaves and those of various textures, there are others that are tubular, feathery, cup-shaped, or needle-like. Leaves may be smooth or hairy, slippery or sticky, waxy or glossy, pleasantly fragrant or foul smelling, edible or poisonous. They also may be of almost every color of the rainbow and of exquisite beauty, especially when viewed with a microscope (fig. 47).

LEAF ARRANGEMENT: in botany phyllotaxis is the arrangement of leaves on a plant stem. Leaf arrangements are:

- Alternate
- Opposite
- Whorled
- Basal rosette
- Equitant

Alternate - a single leaf is attached at each node. The leaves may be arranged in straight rows or spiral around the stem (e.g. Cercis canadensis) (fig. 48).

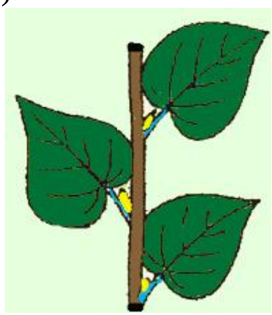


Fig.48. Alternate leaf

Opposite - a pair of leaves occur at each node (e.g. Cercidiphyllum japonicum) (fig. 49).

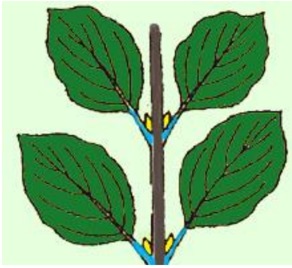


Fig.49. Opposite leaf

Whorled- three or more leaves arising from the same node to form whorls of leaves along the stem (e.g. Galium mollugo) (fig. 50).

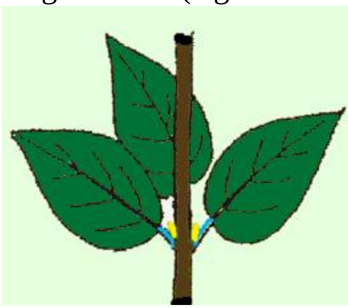


Fig.50. Whorled leaf

Equitant - leaves are overlapping as is typical in some Iris (e.g. Amaryllidaceae) (fig. 51).

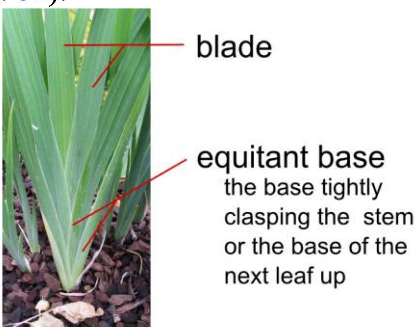


Fig.51. Equitant leaf

Basal rosette - all the leaves arise from the base of the plant (e.g. Dandelion). (fig. 52).

Fig.52. Basal rosette leaf

LEAF VENATION

The arrangement of veins in a leaf or leaflet blade (venation) may also be either **pinnate** (fig. 53) or **palmate** (fig. 54). In pinnately veined leaves, there is one primary vein called the midvein, which is included within an enlarged midrib: secondary veins branch from the midvein. In palmately veined leaves, several primary veins fan out of the base of the blade. The primary veins are more or less **parallel** (fig. 55) to one another in monocots. The branching arrangement of veins in dicots is called netted or **reticulate** (fig. 56) venation. In a few leaves (e.g., those of Ginkgo), no midvein or other large veins are present. Instead, the veins fork evenly and progressively form the base of the blade to the opposite margin. This is called **dichotomous** (fig. 57) venation.

Fig.53. Pinnate leaf venation

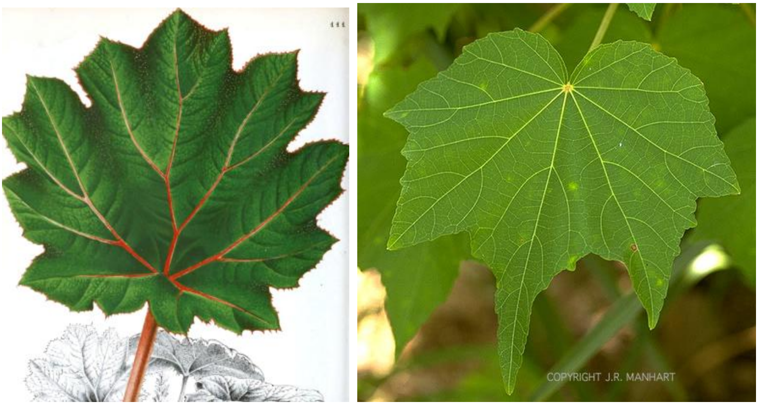


Fig.54. Palmate leaf venation

Fig.55. Parallel leaf venation

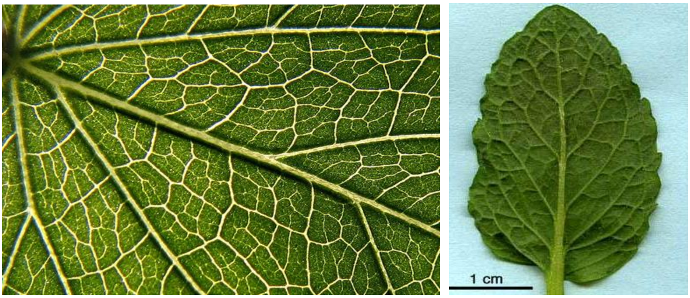


Fig.56. Reticulate leaf venation

Fig.57. Dichotomous leaf venation

Leaf margins

Leaves come in many sizes and shapes; they are often used to help identify plants. Leaf margins are:

entire**:** has a smooth edge with neither teeth nor lobes,

crispate: curved or ruffled,

sinuate: with a sinous margin,

undulate: having a wavy margin,

lobate: lobed,

pinnatifid: with pinnated divisions,

pinnatisect: with similar parts on each side of the central axis and sessile,

palmatifid: is a palmately lobed leaf,

crenate: the edge of the leaf has blunt, rounded teeth,

serrate: it has sharp “saw - like” teeth,

serrulate: it is similar to serrate, but has smaller, evenly-spaced teeth,

dentate: having a toothed margin,

ciliate: hair-like edge,

spinose: as above with the teeth point tipped,

runcinate: hairing incised margins with the lobes or teeth curved towards the base (dandelion L.),

incised: it has incised margin, deep, irregular teeth,

laciniate: margins cut into a ribbon-like segment,

dissected: they are deeply or repeatedly cut into many partitions, but not into individual leaflets (fig. 58).

Fig.58. Leaf margins

INTERNAL STRUCTURE OF LEAVES

Three types of internal structure of leaves occur:

- **dorsoventral**
- **isobilateral**
- **radial**

If a typical dorsoventral leaf is cut transversely and examined with the aid of a microscope, three regions stand out: epidermis, mesophyll, and veins (vascular bundles). The **epidermis** is a single layer of cells covering the entire surface of the leaf. The epidermis on the lower surface of the blade can sometimes be distinguished from the upper epidermis by the presence of tiny pores called stomata.

Except for guard cells, the upper epidermal cells for the most part do not contain chloroplasts. A coating of waxy cutin is normally present. In addition to the cuticle, many plants produce other waxy substances on their surfaces. The wax affords added protection to the leaves. Different types of glands may also be present in the epidermis. Glands often secrete sticky substances.

Stomata

The lower epidermis of most plants generally resembles the upper epidermis, but the lower is perforated by numerous tiny pores called stomata. Some plants (e.g., corn) have these pores in both leaf surfaces, while others have them exclusively on the upper epidermis. Each pore is bordered by two sausage-shaped cells that usually are smaller than most of the neighboring epidermal cells. These guard cells are part of the epidermis, but they, unlike most of the other cells of epidermis, contain chloroplasts.

The functioning of guard cells is aided by the photosynthesis that takes place within them. The primary functions include regulating gas exchange between the interior of the leaf and the atmosphere. When the guard cells are inflated, the stomata open; when the water content of the guard cells decreases, the cells deflate and the stomata close (fig. 59).

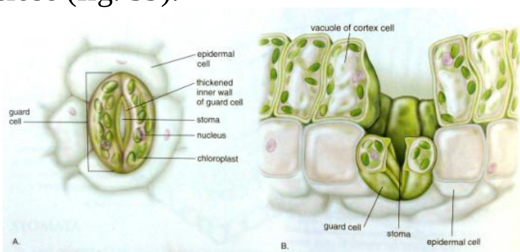


Fig.59. Stomata

Mesophyll and veins

Most photosynthesis takes place in the mesophyll between the two epidermal layers. The upper-most mesophyll consists of compactly stacked, barrel-shaped, or post-shaped parenchyma cells that are commonly in two rows. This region is called the palisade mesophyll and may contain more than 80% of the leaf's chloroplasts. The lower region, consisting of loosely arranged parenchyma cells with abundant air spaces between them, is called the spongy mesophyll. Its cells also have numerous chloroplasts.

Parenchyma tissue with chloroplasts is called **chlorenchyma**. Chlorenchyma tissue is found in stems of herbaceous plants as well as in leaves. Veins (vascular bundles) of various sizes are scattered throughout the mesophyll. They consist of xylem and phloem tissues surrounded by a jacket of thicker-walled parenchyma cells called the bundle sheath. The veins give the leaf its "skeleton". The phloem transports sugars and other carbohydrates throughout the plant. Water is brought up to the leaf by the xylem, which is part of a vast network of "plumbing" throughout the plant.

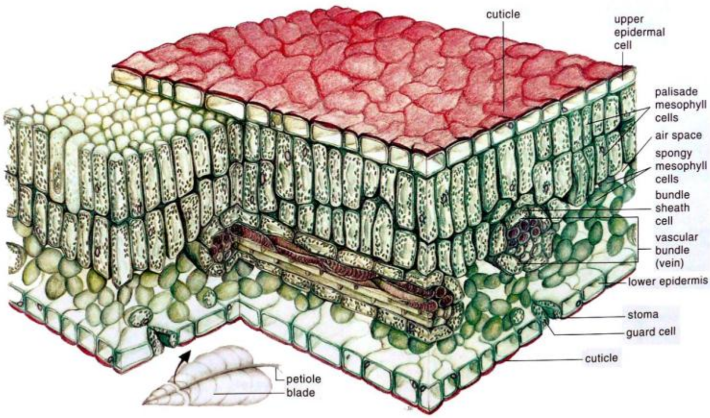


Fig.60. Mesophyll and veins in dorsoventral leaf

Monocot leaves, besides having parallel veins, usually do not have the mesophyll differentiated into palisade and spongy layers.

Some monocot leaves have large, thin-walled bulliform cells, which are large, bubble-shaped epidermal cells that occur in groups on the upper surface of the leaves of many monocots. They are generally present near the mid vein. They are empty and colorless. When these cells absorb water, they become turgid. The leaf straightens up. Whereas on the other hand, at the time of insufficient water supply, these cells lose water and become flaccid and they make the leaf curled. The curling minimizes water loss (fig. 60).

An isobilateral leaf is usually vertically oriented to expose both surfaces to the sun. They have equal numbers of stomata on both faces of the leaf.

Radial leaf- in the cross-section of Pine needle central vein contains two vessels. The phloem tubes have companion cells. The photosynthetic mesophyll cells are folded and are not differentiated into separate palisade and spongy mesophylls. The endodermis has Casparian strips. The needles have a small surface area to volume ratio. The stomata, which occur on all sides in vertical rows, are sunken. The waxy, waterproof cuticle is thick. Beneath the epidermis are one or more layers of strengthening fibrous sclerenchyma cells forming a **hypodermis.** These strengthen the needle and prevent it collapsing when dehydrated or frost-damaged (fig.61).

SPECIALIZED LEAVES

If the leaves of all plants could function normally under any environmental condition, various leaf modifications would provide no special benefits to a plant. But the form and structure of tropical rain-forest plants do not adapt them to thrive in a desert, and cacti soon die if planted in a creek because their structure, form and life cycles are attuned to specific combinations of environmental factors, such as temperature, humidity, light, water and soil conditions. The modifications of leaves occupying any single ecological niche may be very diverse, resulting in such a rich variety of leaf forms and specializations throughout the Plant Kingdom that only a few may be mentioned here.

Shade Leaves

A single tree may have leaves that superficially all appear similar, but close inspection may reveal various differences. For example, because leaves in the shade receive less total light needed for photosynthesis, they tend to be larger than their counterparts in the sun. In addition, since they receive less intense sunlight and heat, they are thinner, and have fewer well-defined mesophyll layers and fewer chloroplasts. They also do not have as many hairs (fig. 61).

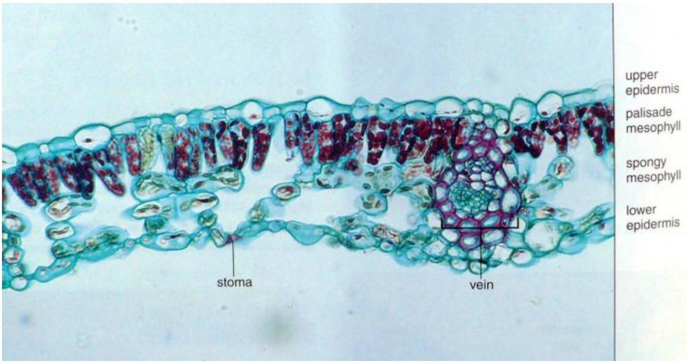


Fig.61. Shade leaves

Leaves of Arid Region

Leaf modifications are generally more pronounced in different climatic zones or habitats. Because of the limited availability of water, wide temperature ranges, and high light intensities, plants growing in arid regions have developed adaptations that allow them to thrive under such conditions. Many have thick, leathery leaves and fewer stomata, or stomata that are sunken below the surface in special depressions, all of which reduce loss of water through transpiration. They also may have succulent, water-retaining leaves or no leaves at all (with the stems taking over the function of photosynthesis), or they may have dense, hairy covering. Pine trees, whose water supply may be severely restricted in the winter when the soil is frozen, have some leaf modifications similar to those of desert plants. The modifications include sunken stomata, a thick cuticle, and a layer of thick-walled cells (the **hypodermis**) beneath the epidermis (fig. 62).

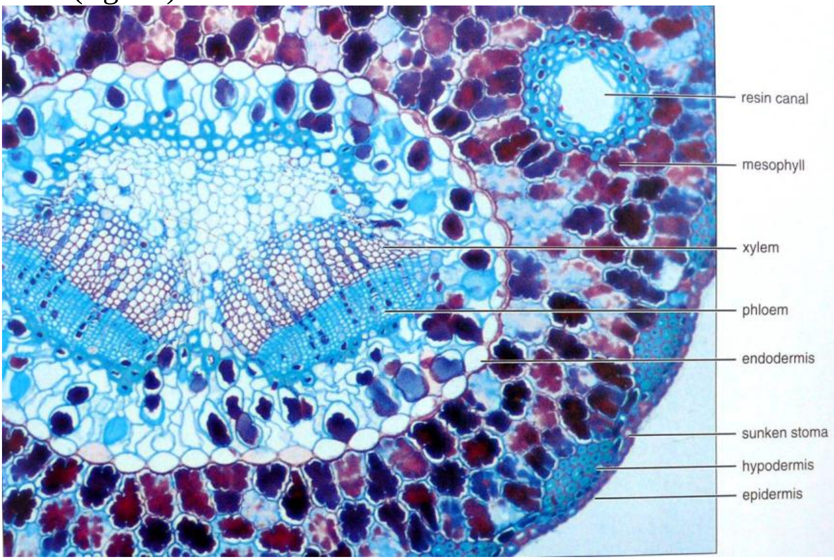


Fig.62. Leaves of Arid Region

Leaves of Aquatic Area

The submerged leaves of plants that grow in water usually have considerably less xylem than phloem, and the mesophyll, which is not differentiated into palisade and spongy layers, has large air spaces.

Leaf Modifications

Tendrils

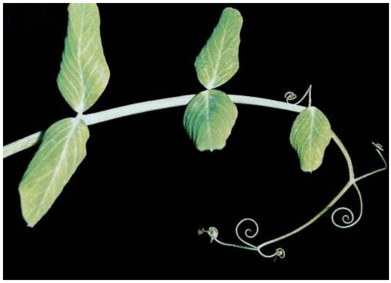


Fig.63. Tendrils

There are many plants whose leaves are partly or completely modified as **tendrils** (fig. 63). These modified leaves when curled tightly around more rigid objects, help the plant in climbing or in supporting weak stems.

As the tendrils develop, they become coiled like a spring. When contact with a support is made, the tip not curls around it, but the direction of the coil reverses; sclerenchyma and collenchyma cells then develop in the vicinity of contact. The sclerenchyma cells provide rigid support, while the collenchyma cells impart flexibility. This makes a very strong but flexible attachment that protects the plant from damage during the winds.

Spines, Thorns and Prickles

The leaves of many cacti and other desert plants are modified as **spines** (fig. 64). This reduction of leave surface reduces water loss from the plants, and the spines also tend to protect the plants from browsing animals. In such desert plants, photosynthesis, which would otherwise take place in leaves, occur in green stems. Most spines are modifications of the whole leaf, in which much of the normal leaf tissue is replaced with sclerenchyma. Like grape and other tendrils, many spine-like objects arising in axils of leaves of woody plants are modified stems rather than modified leaves. Such modifications could be referred to as **thorns** to distinguish them from true spines. The

Fig.64. Spines

prickles of roses and raspberries, however, are neither leaves nor stems but are outgrowths from the epidermis or cortex.

Storage Leaves

Desert plants may have *succulent leaves* (leaves that are modified for water retention). The adaptations for water storage involve large, thin-walled parenchyma cells without chloroplasts. These non-photosynthetic cells contain large vacuoles that can store relatively substantial amounts of water. If removed from the plant and set aside, the leaves will often retain much of the water for up to several months.

The fleshy leaves of onion, lily, and other bulbs store large amounts of carbohydrates, which are used by the plant during rapid growth early in the subsequent growing season (fig. 65).

Fig.65. Storage leaf

Reproductive Leaves

Some of the leaves of the walking fern are most unusual in that they produce new plants at their tips. Occasionally, three generations of plants may be found linked together. The succulent leaves of air plants have little notches along the leaf margins in which tiny plantlets are produced, complete with roots and leaves, even after a leaf has been removed from the parent plant. Each of the plantlets can develop into a mature plant if given the opportunity to do so (fig. 66).

Fig.66. Reproductive leave

Insect-Trapping Leaves

Highly specialized *insect-trapping leaves* have intrigued humans for hundreds of years. Almost 200 species of flowering plants are known to have these leaves. In swampy areas and bogs of tropical regions, certain needed elements, particularly nitrogen, may be deficient in the soil, or they may be in a form not readily available to the plants. Some of these elements are furnished when the soft part of insects and other small organisms trapped by the specialized leaves are broken down and digested. All the plants have chlorophyll and are able to make their food. It has been demonstrated that they can develop normally without insects if they are given the nutrients they need.

Pitcher Plants

The blades of leaves of many *pitcher plants* are flattened and function like those of any other leaves. Some of the leaves of these plants are larger and cone-shaped or vase-like.

Pitcher leaves have nectar-secreting glands around the rim. The distinctive odor produced by these glands attracts insects, which often fall into the watery fluid at the bottom. If the insects try to climb out, they find the walls highly polished and slippery. In fact, the walls of some pitcher plant leaves are coated with wax, and as the insects struggle up the surface, their feet become coated with the wax, which builds up until the victims seem to have acquired heavy, clod-like boots. Eventually they drown, and their soft parts are digested by bacteria and by enzymes secreted by the plant's digestive glands near the bottom of the leaves (fig. 67).

Fig.67. Pitcher plants

Sundews

The tiny plants called *sundews* often do not measure more than 2.5 to 5.0 centimeters in diameter. The roundish to oval leaves are covered with up to 200 upright glandular hairs that look like miniature clubs. There is a clear, glistening drop of sticky fluid containing digestive enzymes at the tip of each hair. As the droplets sparkle in the sun, they may attract insects, which find themselves stuck if they alight. The hairs are exceptionally sensitive to contact, responding to weights of less than one-thousandth of a milligram, and bend inward, surrounding any trapped insect within a few minutes. The digestive enzymes break down the soft parts of the insects, and after digestion has been completed (within a few days), the glandular hairs return to their original positions. If bits of nonliving debris happen to catch in the sticky fluid, the hairs barely respond, showing they can distinguish between protein and something "inedible" (fig. 68).

Fig.68. Sundews

Venus's Flytraps

The two halves of the blade have the appearance of being hinged along the midrib, with stiff, hair-like projections located along their margins. There are three tiny trigger hairs on the inner surface of each half. If two trigger hairs are touched simultaneously or if any one of them is touched twice within a few seconds, the blade halves suddenly snap together, trapping the insect or other small animal. As the creature struggles, the trap closes even more tightly. Digestive enzymes secreted by the leaf, break down the soft parts of the insect, which are then absorbed. After digestion has been completed, the trap reopens, ready to repeat the process (fig. 69).

Fig.69. Venus's flytraps

AUTUMNAL CHANGES IN LEAF COLOR

The chloroplasts of mature leaves contain several groups of pigments, such as green *chlorophylls* and *carotenoids*, which include yellow *carotenes* and pale yellow *xanthophylls*. Each of these groups plays a role in photosynthesis. Usually, considerably more chlorophyll than other pigments is present, and the intense green color of the chlorophylls masks or hides the presence of the carotenes and xanthophylls. In the fall, however, the chlorophylls break down, and other colors are revealed. The exact cause of the chlorophyll breakdown is not known.

Water-soluble *anthocyanin* and *betacyanin* pigments may also accumulate in the vacuoles of the leaf cells in the fall. Anthocyanins, the more common of the two groups, are red if the cell sap is slightly acidic, blue if it is slightly alkaline, and of intermediate shades, if it is neutral. Betacyanins are usually red (fig. 70).

Fig.70. Leaf colors

Chapter 6

FLOWERS, FRUITS AND SEEDS

Flowers may be of any color or combination of colors of the rainbow, as well as black or white; they may have virtually any texture, from firmly and transparent to thick and leathery, spongy to sticky, hairy, prickly, or even dewy wet to the touch.

Flowering plants can go from the germination of a seed to a mature plant producing new seeds in less than a month, or the process may take as long as 150 years. In **annuals**, the cycle is completed in a single season and ends with the death of the parent plant. **Biennials** take two growing seasons to complete the cycle; **perennials**, however, may take several to many growing seasons to go from a germinated seed to a plant producing new seeds, although many species that aren't annuals do produce seeds during their first growing season. Perennials may also produce flowers on new growth that dies back each winter, while other parts of the plant may persist indefinitely.

Flowering plants have been placed in two major classes, known as the *Dicotyledonae* and the *Monocotyledonae*, commonly **dicots** and **monocots**.

Structure of Flowers

Each flower, which begins as an embryonic primordium that develops into a bud, occurs as a specialized branch at the tip of a stalk called a peduncle, which may in some instances have branchlets of smaller stalks called pedicels. A peduncle or pedicel swells at its tip into a small pad known as a **receptacle.** The other parts of the flower, some of which are in whorls, are attached to the receptacle.

The outer-most whorl typically consists of three to five small, usually green, leaf-like sepals. The sepals of a flower, which are collectively referred to as the *calyx*, may, in some flowers, be fused together. In many species, the calyx protects the flower while it is in the bud (fig. 71).

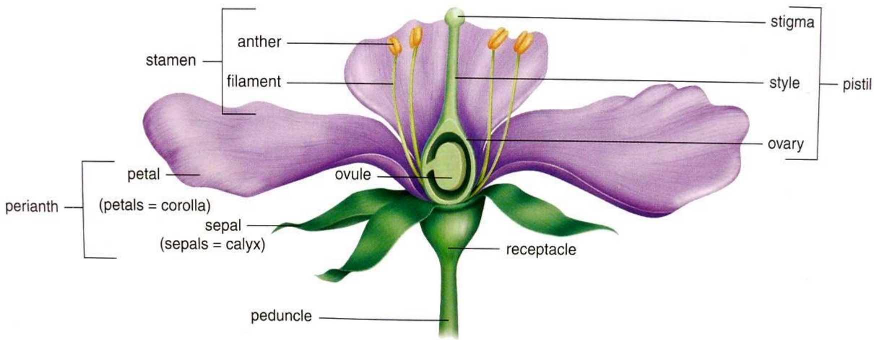


Fig.71. Structure of Flowers

The next whorl of flower parts consists of three to many petals; the petals collectively are known as the *corolla*. Corollas attract pollinators, such as bees, in some flowers (e.g. petunias), the petals are fused together into a single, flared, trumpet-like sheet of tissue. The corolla may not be showy and is often missing altogether or highly modified in wind-pollinated plants such as grasses. The calyx and the corolla together are called as the **perianth**. Bracts are specialized leaves that may be as colorful as petals and can attract pollinators the way petals do.

Several to many stamens are attached to the receptacle in the center of the flower. Each stamen consists of a semi-rigid but otherwise usually slender filament with a sac called an anther at the top.

The pistil, which often is shaped like a tiny vase that is closed at the top, consists of three regions that merge with one another. At the top is the stigma, which is usually connected by a slender, stalk-like style to the swollen base called the **ovary**. The ovary later develops into a fruit. Ovule bearing leaves are called **carpels**. In some instances, two or more carpels eventually fuse together, and many ovaries are now compound, consisting of two to several united carpels.

The ovary is said to be superior if the calyx and corolla are attached to the receptacle at the base of the ovary, as in pea and primrose flowers. In other instances, the ovary becomes inferior when the receptacle grows up around it so that the calyx and corolla appear to be attached at the top, as in cactus and carrot flowers. An ovule, the development of which takes place after fertilization has occurred, eventually becomes a seed (fig. 72).

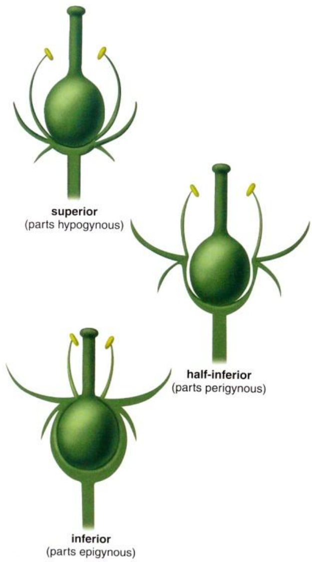


Fig.72. Ovary locations

Peach flowers are produced singly, each on its own peduncle, but many other flowers such as lilac, grape, and bridal wreath are produced in inflorescences, which are groups of several to hundreds of flowers that may all open at the same time, or they may follow an orderly progression to maturation.

FLORAL FORMULA is a system of representing the structure of a flower using specific letters, numbers, and symbols.

Ca (K) -calyx
Co (C) - corolla
P - perianth
A - androecium
G - gynoecium
$G_{\underline{2}}$ - superior ovary
$G_{\bar{2}}$ - inferior ovary
♂ - male

♀ - female

⚥ - bisexual

✱ - actinomorphic

↑ - zygomorphic

∞ - to represent many

x - number of floral parts

Enclosing figure within brackets () - fusion

Line drawn over symbols of floral parts - adhesion

Floral diagram

Floral diagram is a graphic representation of the flower structure. It shows the number of floral parts, their arrangement and fusion. Different parts of the flower are represented by their respective symbols. Floral diagrams are useful for flower identification.

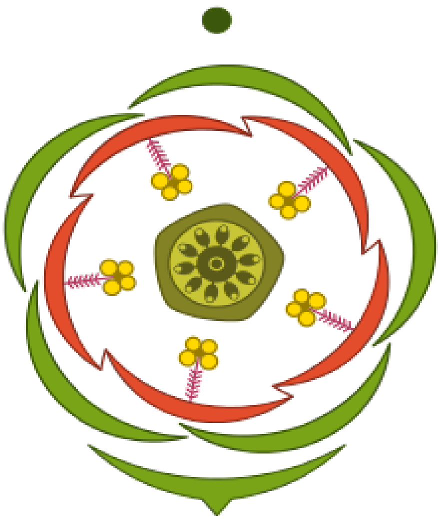


Fig.73. Floral diagram

The dot represents the main axis, green structure below is the subtending bract. Calyx (green arcs) consists of 5 free sepals: corolla (red arcs) consists of 5 fused petals; stamens are joined to petals by hairy filaments. Ovary is superior (fig. 73).

Microsporogenesis, Microgametogenesis, Megasporogenesis, Megagametogenesis

Microsporogenesis - is a process called microsporogenesis which takes place in flower anthers, four haploid microspores are produced from each diploid sporogenous cell (microsporocyte, pollen mother cell), after meiotic division. Pollen grains grow in size and form the outer wall called the **exine** and an inner wall called the **intine**.

Microgametogenesis - is the process in plant reproduction where a microgametophyte develops in a pollen grain to the three-celled stage of its development. In flowering plants it occurs with a microspore mother cell inside the anther of the plant. When the microgametophyte is first formed inside the pollen grain, four sets of fertile cells called *sporogenous cells* are apparent. These cells wall-**tapetum**, supplies food to the cell and then becomes the cell wall of pollen grain. The sporogenous cells develop into diploid microspore mother cells called **microsporocytes.** They undergo meiosis and become four microspore haploid cells. These new microspore cells then undergo mitosis and form a tube cell and a generative cell. The generative cell then undergoes mitosis one more time to form two male gametes, also called sperm.

Megasporogenesis - In gymnosperms and flowering plants the megaspore is produced inside the nucellus of the *ovule*. During megasporogenesis, a diploid cell, the *megasporocyte* mother cell, undergoes meiosis to produce four haploid cells called **megaspores.**

Megagametogenesis- After megasporogenesis the megaspore develops into the female gametophyte (the embryo sac) in a process called megagametogenesis. If the monosporic pattern occurs, the single nucleus undergoes mitosis three times producing an eight-nucleate cell. These eight nuclei are arranged into two groups of four. Both groups send a nucleus to the center of the cell; these become the polar nuclei, which fuse together the central cell. The three nuclei at the end of the cell near micropolar become the egg apparatus, with an egg cell in the center and two synergids. At the other end of the cell, a cell wall forms around the nuclei and forms the antipodal cells. Therefore, the resulting embryo sac is a seven-celled structure consisting of one central cell, one egg cell, two synergid cells, and three antipodal cells.

Pollination and Double Fertilization

Pollination is the process by which pollen is transferred to the female reproductive organs of a plant, thereby enabling fertilization to take place. Seed plants have a single major goal: to pass their genetic information onto the next generation. The reproductive unit is the seed, and pollination is an essential step in the production of seeds in all seed plants. For the pollination process a pollen grain produced by the *anther*, the male part of the flower, must be transferred to a *stigma*, the female part of the flower. It creates a *pollen tube* which grows down the *style* until it reaches the ovary. Sperm cells form the pollen grain then move along the pollen tube, one sperm enters the egg cell through the *micropyle* and fertilizes it, 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. This complex process is called **double fertilization**. 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.

INFLORESCENCE

Inflorescence is a collection of flowers sharing a common stalk, the peduncle usually subtended by a bract. Each flower usually arises in the axil of a small bract, and may or may not be born on its own individual stalk, called pedicel. The development of an inflorescence may represent the end of vegetative growth of that apex (definite growth), or allow it to continue (indefinite growth). There are many types of inflorescence, determined mainly by the method of branching. If the stem ends in a flower and growth is then from lateral buds below the apex, which themselves form flowers and more lateral shoots, the inflorescence is termed a **cymose** (cyme) inflorescence (*Tilia*). If one shoot develops behind each axis a monochasial cyme, or **monochasium**, is formed, as in *Avens* (*Geum*).

Variations in the inflorescence arrangement occur, according to the direction of the lateral branches, for example in *Forget-me-not* (*Myosotis*), all the branches arise on the same side of the parent stem while in *Buttercup* (*Ranunculus*), the branches arise on alternate sides of the parent stem. If 2 shoots develop below each axis this gives a dichasial cyme, or **dichasium** e.g. *Catchflies* (*Silene*). Cymose inflorescence typically opens from the apex downwards; in flat-topped forms the oldest flowers are in the center. In a **raceme** (racemose inflorescence) the apex continues growing, and subsequent flowers develop in sequence up the stem, e.g. *Foxglove* (*Digitalis*). In a **compound raceme** each branch of the inflorescence bears a smaller raceme of flowers, e.g. *Fescues* (*Festuca*). If the lateral branches of a raceme are branched themselves, as in many grasses, the inflorescence is called a **panicle**. This term is often applied to any sort of branched racemose inflorescence, e.g. *Horse chestnut*, in which each branch is actually a cyme (*Aesculus*). A **spike** is a type of racemose inflorescence having sessile flowers (they have no pedicels) borne on an elongated axis, as in *Wheat* (*Triticum*). The **catkin** and **spadix** are modifications of the spike. A catkin is a short, densely packed raceme bearing unisexual flowers with highly reduced or absent perianth, e.g. *Oak* (*Quercus*). A spadix is a type of inflorescence found in the family Araceae, e.g. *Cuckoopint* (*Arum*). It is a modified spike with a large fleshy axis on which are borne small unisexual flowers. The inflorescence is enclosed by a large bract, the spathe, which may be foliose or petalloid and has been shown to attract insects in certain species. In a **capitulum** as in many Asteraceae, e.g. *Daisy* (*Bellis*), the inflorescence comprises many unstalked florets inserted on the flattened disc-like end of the **peduncle** and surrounded by a ring of sterile bracts. Many species of f. Composite have 2 distinct types of floret in the capitulum: disc florets in the center are tubular florets ending in 5 short teeth, while ray florets have a strap-like extension to the tube and occur around the edge of the capitulum, rather like petals. Some species, such as *Thistles*, have only ray florets, others have only disk florets, e.g. *Chichory* (*Chichorium*), and many have both disk and ray florets, e.g. *Sunflower* (*Helianthus*). In **racemose** inflorescence the flowers typically open from below upwards. An **umbel** is a type of inflorescence in which the stem axis is not elongated and individually stalked flowers appear to arise from the same point on the stem. These flowers are massed on one plane, giving the appearance of an umbrella, with the oldest flowers on the outside and the youngest in the middle. The umbel is typical of the *Carrot family* (*Apiaceae*). Umbels may be grouped into a compound umbel, composed of smaller umbels as in *Onion* (*Allium*). A **corymb** is an inflorescence with flower stalks of different lengths, the lowest being the longest. This gives a flat-topped cluster of flowers at the same level that is characteristic of many brassicas, e.g. *Iberis*. Umbels, corymbs, and capitula can be grouped into **cymose** inflorescences, e.g. *Onion*, *Viburnum*, and *Scabiosa* respectively (fig. 74).

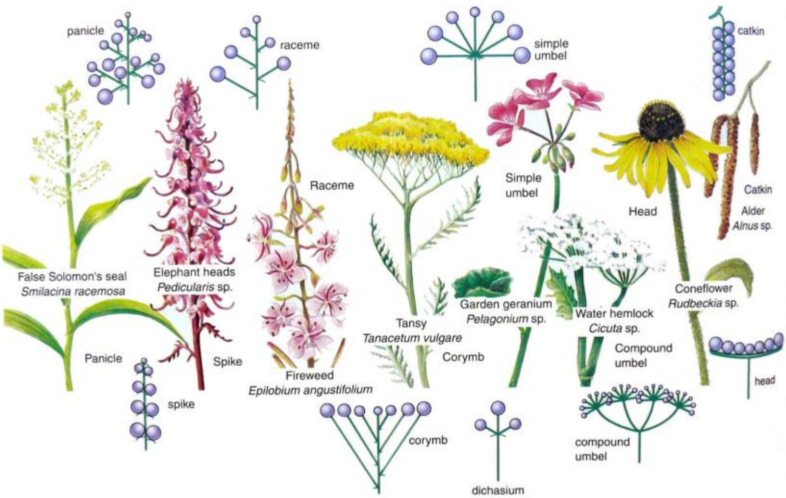


Fig.74. Types of inflorescence

FRUITS

A fruit, botanically speaking, is any ovary and its accessory parts that has developed and matured. It also usually contains seeds. By this definition, many so-called vegetables, including tomatoes, beans, cucumbers, and squashes, are really fruits. On the other hand, vegetables can consist of leaves (e.g. lettuce, cabbage), leaf petioles (e.g. celery), specialized leaves (e.g. onion), stems (e.g. white potato), roots (e.g. sweet potato), stems and roots (e.g. beets), flowers and their peducles (e.g. broccoli), flower buds (e.g. globe artichoke), or other parts of the plant.

All fruits develop from flower ovaries and accordingly are found exclusively in the flowering plants. Fertilization usually indirectly determines whether or not the ovary or ovaries (and sometimes the receptacle or other tissues) of a flower will develop into a fruit. If at least a few of the ovules are not fertilized, the flower normally withers and drops without developing further. Pollen grains contain specific stimulants called hormones, that may initiate fruit development.

Fruit Regions

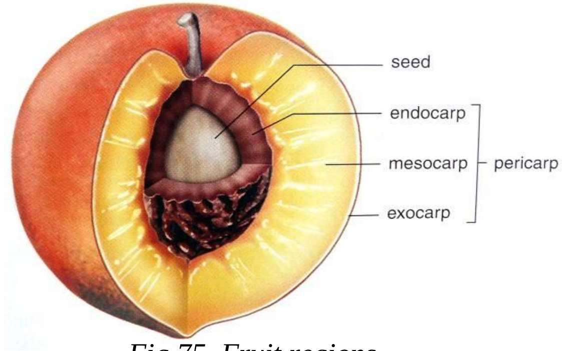


Fig.75. Fruit regions

Fruit has three regions, which sometimes can be difficult to distinguish from one another. The skin forms the **exocarp**, while the inner boundary around the seed(s) forms the **endocarp.** The endocarp may be hard and stony (as in a peach pit around the seed). It also may be papery (as in apples), or it may not be distinct from the **mesocarp**, which is often the fleshy tissue between the exocarp and the endocarp. The three regions collectively are called the **pericarp**. In dry fruits, the pericarp is usually quite thin. Fruits may be either fleshy or dry. They may be derived from a single ovary or from more than one (fig. 75).

KINDS OF FRUITS

Fleshy Fruits

Fruits whose mesocarp is at least partly fleshy at maturity are classified as fleshy fruits. Simple fleshy fruits develop from a flower with a single pistil.

A **drupe** is a simple fleshy fruit with a single seed enclosed by a hard, stony endocarp, or pit. In coconuts, for example, the husk, which is usually removed before the rest of the fruit is sold in markets, is very fibrous (the fibers are used in making mats and brushes). The seed of the coconut is hollow and contains a watery endosperm commonly but incorrectly referred to as “milk”. It is surrounded by the thick, hard endocarp typical for drupes. Other examples of drupes include the stone fruits (e.g. apricots, cherries, peaches, plums, olives, and almonds). In almonds, the husk, which dries somewhat and splits at maturity, is removed before marketing, and it is the endocarp that we crack to obtain the seed (fig. 76).

Fig.76. Drupe fleshy fruit

Berries usually develop from a compound ovary and commonly contain more than one seed. The entire pericap is fleshy, and it is difficult to distinguish between the mesocarp and the endocarp. Three types of berries may be recognized (fig. 77).

Fig.77. Berries

A true berry is a fruit with a thin skin and a pericarp that is relatively soft at maturity. However, most of them contain more than one seed. Dates and avocados have only one seed. Typical examples of true berries include tomatoes, grapes, peppers, and eggplants. Some fruits that popularly include the word berry in their common

Fig.78. True berry

name (e.g. strawberry, raspberry, blackberry) botanically are not berries at all.

Some berries are derived from flowers with inferior ovaries so that other parts of the flower also contribute to the flesh. They can usually be distinguished by the remnants of flower parts or their scars that persist at the tip. Examples of such berries include gooseberries, blueberries, cranberries (fig. 78).

Pepos are modified berries with hard and thick skin usually called a "rind". Fruits of members of the Pumpkin Family (Cucurbitaceae), including pumpkins, cucumbers, watermelons, squashes are pepos.

The **hesperidium** is also modified berry with a leathery skin containing oils. Numerous outgrowths from the inner lining of the ovary wall become saclike and swollen with juice as the fruit develops. All members of the Citrus Family (Rutaceae) produce this type of fruit. Examples include oranges, lemons, limes, grapefruits, tangerines.

Pomes are simple fleshy fruits, the fleshy bulk of whose comes from the enlarged floral tube or receptacle that grows up around the ovary. The endocarp around the seeds is papery or leathery. Examples include apples, pears (fig. 79).

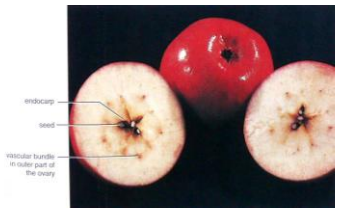


Fig.79. Pome fleshy fruit

Dry Fruits

Fruits whose mesocarp is definitely dry at maturity are classified as dry fruits.

Dry Fruits That Split at Maturity (Dehiscent Fruits).

The fruits in this group are distinguished from one another by the way they split. The **follicle** splits along one side or seam (suture) only, exposing the seeds within. Examples include larkspur, columbine (fig. 80).

Fig.80. Follicle

The **legume** splits along two sides or seams. Literally thousands of members of the Legume Family (Fabaceae) produce this type of fruit. Examples include peas, beans, lentils. Peanuts are also legumes, but they are atypical in that the fruits develop and mature underground (fig. 81).

Fig.81. Legume

Siliques also split along two sides or seams, but the seeds are borne on a central partition, which is exposed when the two halves of the fruit separate. Siliques are produced by members of the Mustard Family (Brassicaceae), which includes broccoli, cabbage, radish, shepherd's purse (fig. 82).

Fig.82. Siliques

Capsules are the most common of the dry fruits that split. They consist of at least two carpels and split in a variety of ways. Examples include irises, orchids, lilies, poppies, violets (fig. 83).

Fig.83. Capsules

Dry fruits that do not split at maturity (Indehiscent fruits).

In this type of dry fruit the single seed is united with the pericarp.

Only the base of the single seed of the **achene** is attached to its surrounding pericarp. Accordingly the pericarp is relatively easily separated from the seed. Examples include sunflower “seeds”, buttercup and buckwheat.

Nuts are one-seeded fruits similar to achenes, but they are generally larger, and the pericarp is much harder and thicker. They develop with a cup, or cluster of bracts at their base. Examples include acorns, hazelnuts. Botanically speaking, many nuts in the popular sense are not nuts. We have already seen that peanuts are typical legumes and that coconuts and almonds are **drupes**. Walnuts and pecans are also drupes, whose "flesh" part withers and dries after the seed matures and cashew nuts are the single seed of a unique drupe. Pistachio nuts are also the seeds of drupes.

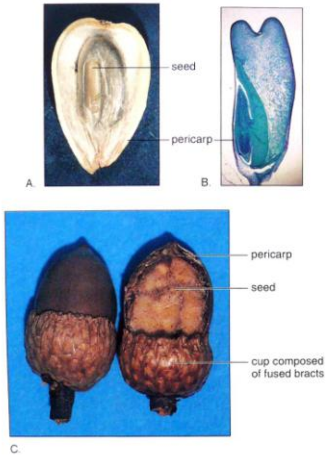


Fig.84. Acorn

The pericarp of the **grain** is tightly united with the seed and cannot be separated from it. All members of the Grass Family (Poaceae), including corn, wheat, rice produce grains (fig. 84).

In **samaras,** the pericarp surrounding the seed extends out in the form of a wing or membrane, which aids in dispersal. In maples, samaras are produced in pairs, but in ashes, elms, and the tree of heaven, they are produced singly. The **twin fruit** called a schizocarp is unique to the Parsley Family (Apiaceae). Members of this family include parsley, carrots, anise, caraway, and dill. Upon drying, the twin fruits break into two **one-seeded** segments (fig. 85).

Fig.85.Twin fruit

Aggregate Fruits

An aggregate fruit is one that is derived from a single flower with several to many pistils. The individual pistils develop into tiny drupes or other fruitlets, but they mature as a clustered unit on a single receptacle. Examples include raspberries, blackberries and strawberries. In a strawberry, the cone-shaped receptacle becomes fleshy and red, while each pistil becomes a little achene on its surface. In other words, the strawberry, while being an aggregate fruit, is also partly composed of accessory tissue (fig. 86).

Fig.86. Aggregate fruit

Accessory Fruits

Sometimes accessory fruits are called false fruits, because in this fruits some of the flesh is derived not from the ovary, but from some adjacent tissue exterior to the carpel. Examples of accessory tissue are the receptacle of the strawberry, calyx of Syzygium Jambos. Pomes, such as apples and pears are also accessory fruits, with fruit flesh derived from a hypanthium (fig. 87).

Fig.87. Accessory fruit

Multiple Fruits

Multiple fruits are derived from several to many individual flowers in a single inflorescence. Each flower has its own receptacle, but as the flowers mature separately into fruitlets, they develop together into a single larger fruit. Examples of multiple fruits include mulberries, pineapples and figs. Some figs varieties are pollinated by tiny wasps that crawl in and out through the opening (fig. 88).

Fig.88. Multiple fruits

Seeds

A seed is the part of a seed plant, which can grow into a new plant. It is a reproductive structure which disperses, and can survive for some time. A typical seed includes three basic parts: 1.an embryo, 2.a supply of nutrients for the embryo and 3. a seed coat.

The formation of the seed is a part of the process of reproduction in seed plants. Seeds are the product of the ripened ovule, after fertilization by pollen and some growth within the mother plant. The embryo is developed from zygote and the seed coat- from the integuments of the ovule. Ferns, mosses and liverworts do not have seeds and use water-dependent means to propagate themselves.

When a seed germinates, it begins to grow into a little plant called a **seedling**. It uses the soft fleshy material inside the seed for nutrients (food), until it is ready to make food on its own, using sunlight, water and air. The present-day seed plants are the

Gymnosperms, with naked seeds, and the Angiosperms with covered seeds, usually fruits.

Once the seed coat is removed, the two halves, called cotyledons, can be distinguished. The cotyledons, which have a tiny immature plantlet along one edge between them, are food-storage organs that also function as the firs "seed leaves" of the seedling plant. The cotyledons, and the tiny, rudimentary bean plant to which they are attached, constitute the embryo. Some seeds (e.g.; those of grasses and all other monocots) have only one cotyledon. The dicotyledons, also known as dicots, is a group of flowering plants, where the seed has two embryonic leaves or cotyledons. There are around 200,000 species within the group. The other group of flowering plants called monocotyledons or monocots, typically having one cotyledon. Historically, these two groups formed the two divisions of the flowering plants.

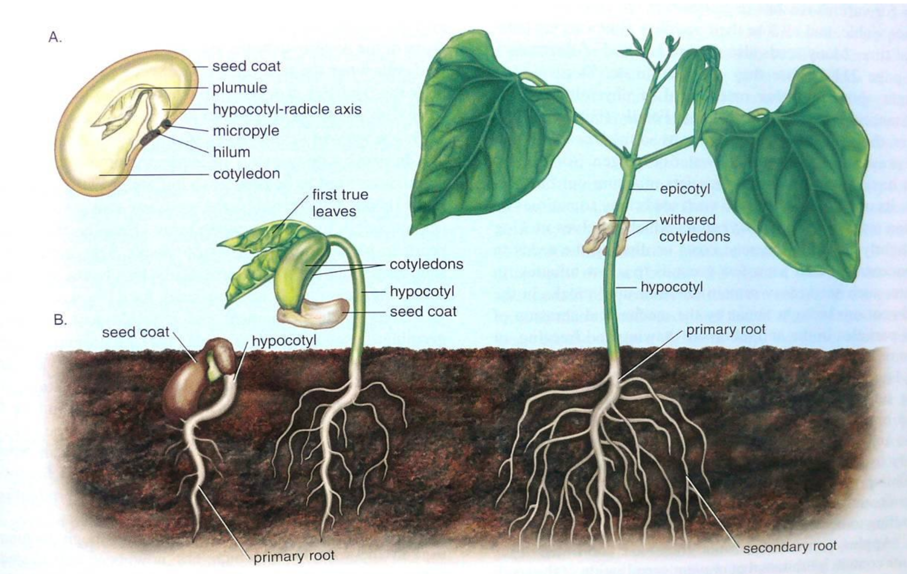


Fig.89. The structure of dicot seeds

The tiny embryo plantlet has undeveloped leaves and a meristem at the upper end of the embryo axis. This embryo shoot is called a *plumule*. The cotyledons are attached below the plumule. The very short part of the stem above the cotyledons is called the *epicotyl*, while the stem below the attachment point is the *hypocotyl*.

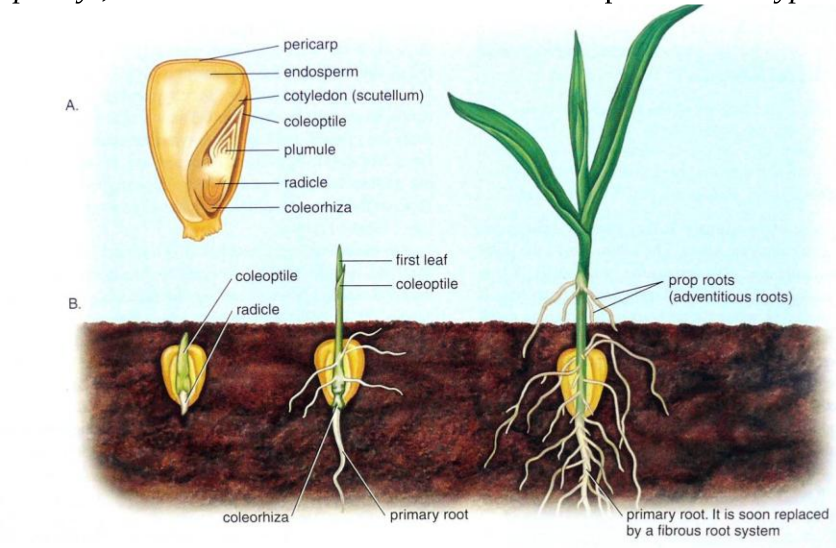


Fig.90. The structure of monocot seeds

The tip that will develop into a root is called a radicle. When a kidney bean germinates, the hypocotyls lengthen and bend, becoming hook-shaped. The top of the hook emerges from the ground, pulling the cotyledons above the ground.

In other seeds, the cotyledon(s) may not play a significant role in food storage. In corn, for example, the bulk of the food-storage tissue is endosperm (fig. 89,90).

Germination

Germination, which is the beginning or resumption of the growth of a seed, depends on the interplay of a number of factors, both internal and external. In order to germinate, a seed must first be viable (capable of germinating). Many seeds for various reasons (e.g. death of the embryo within) are not viable, and they all lose their viability after varying periods of time. Many seeds also require a period of dormancy before they germinate. Dormancy is brought about by either mechanical or physiological circumstances or both. In the Legume Family (Fabaceae) and others, the seeds may have such thick or tough seed coats that they prevent the absorption of water or oxygen. Some seeds even have a one-way valve that lets moisture out but prevents its uptake. Dormancy in such seeds may sometimes be broken artificially by scarification, which involves nicking or slightly cracking the seed coats or dipping the seeds in a concentrated acid for a few seconds up to a few minutes. In nature, such seeds may remain dormant until cracks in the seed coat are brought about by the mechanical of rock particles in the soil.

Apples, pears, citrus fruits, tomatoes, and other fleshy fruits contain inhibitors that prevent germination of the seeds within the fruits. Only the seeds are removed and washed, they germinate readily. The seeds will not germinate after fruit has dropped until the embryo has developed fully with the aid of food materials stored in its endosperm. Such process of development is called after-ripening. Water and oxygen are essential to the completion of germination, and light or its absence also plays a role. Many seeds imbibe 10 times or more their total weight in water before the radicle emerges.

After water has been imbibed, enzymes begin to function in the cytoplasm, which has now been rehydrated. Seeds of some varieties of lettuce will not germinate in the dark, while those of other seeds, such as the California poppy, germinate only in the dark.

Longevity

However, reports of seeds of the aquatic lotus plant germinating after about 1,200 years and another one documenting the germination of Arctic tundra lupine seeds that were frozen for an estimated 10,000 years have been confirmed.

A few species of both dicots and monocots produce seeds that have no period of dormancy at all. In some instances, the embryo, which develops from the zygote, continues to grow without any pause in a phenomenon known as vivipary.

Fruit and Seed Dispersal

Dispersal by Wind

Fruits and seeds have a variety of adaptation for wind dispersal. The samara of a maple has a curved wing that causes the fruit to spin as it is released from the tree. In a brisk wind, samaras may be carried up to 10 kilometers away from their source. In some members of the Families Ranunculaceae and Asteraceae, the fruits have plumes, and in Family Salicaceae, the fruits are surrounded by cotton or wooly hairs that aid in wind dispersal.

Fig.91. Dispersal by Wind

Seeds themselves may be so tiny and light that they can be blown great distances by the wind. Orchids and heaths, for example, produce seeds with no endosperm that can fly as fine as dust and equally are light in weight. Dandelion fruitlets have plumes that radiate out at the ends like tiny parachutes; these catch even a slight breeze (fig. 91).

Dispersal by Animals

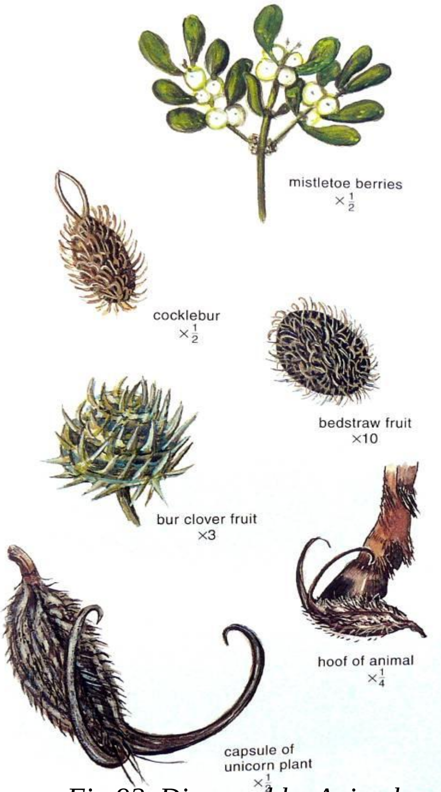


Fig.92. Dispersal by Animals

The adaptations of fruits and seeds for animal dispersal are legion. Birds, mammals, and ants all act as disseminating agents. Shore birds may carry seeds great distances. Other birds and mammals eat fruits whose seeds passed through their digestive tracts. Some seeds and fruits are gathered and stored by squirrels and mice, and then are abandoned. Blue jays and other birds carry away nuts and other fruits, which they may drop in flight. Many fruits and seeds catch in the fur of animals (fig. 92).

Dispersal by Water

Some fruits contain trapped air, adapting them to water dispersal. Many seeds have waxy material on the surface, which temporarily prevents them from absorbing water while they are floating. Large raindrops themselves may splash seeds out of their opened capsules.

Seeds and fruits of a few plants have thick, spongy pericarps that absorb water very slowly. Such fruits are adapted to dispersal by ocean currents, even though salt water eventually may penetrate enough to kill the delicate embryos.

Humans, both intentionally and unintentionally, are the most efficient transporters of fruits and seeds. Travelers and explorers have carried many noxious weeds and plant diseases, as well as valuable food and medicinal plants from one continent to another.

Chapter 7

PLANTS' GROWTH AND DEVELOPMENT

Plant development is the whole series of qualitative and quantitative changes such as growth, differentiation and maturation, which an organism undergoes throughout its life cycle. Plants constantly produce new tissues and structures throughout their life from **meristems** located at the tips of organs, or between mature tissues. Thus, a living plant always has embryonic tissues.

Plant growth occurs in three successive stages:

(I**)** **Cell division-** the number of cells increases due to mitosis;

(II) **Cell enlargement-** the size of individual cell increases after cell division due to increase in the volume of its protoplasm;

(III) **Cell differentiation-** structure of the cells changes to perform specific functions. And similar type of cells having the same functions form a group, which is known as tissue.

In lower organisms such as bacteria and algae the entire body grows. But in higher organisms like ferns, pine and flowering plants, growth is restricted to the cells present only in the growing regions, like shoot apex and root tip and close to the lateral sides of the stem and root. Growth at the tips leads to the elongation of body parts and lateral (sideways) growth leads to an increase in the thickness of stem and root.

Factors affecting plant growth

Generally plant growth is influenced by a number of factors both external and internal.

External growth factors are:

(I) **Light**- besides photosynthesis, light is also essential for seed germination, growth of seedling, differentiation of various tissues and organs, and reproduction.

(II) **Temperature**- some plants grow in cold and some in hot climate. The optimum temperature required for the growth of plants ranges between 28-30◦C, but it may occur at the temperature ranging 4-45 C. All metabolic activities of plants are directly affected by temperature variation.

(III) **Water**- for proper growth of plants a particular quantity of water is required.

(IV) **Mineral Nutrients**- all metabolic processes require inorganic nutrients.

Internal growth factors

In addition to the external factors, there are some substances produced in the plant body itself, which affects the growth of the plant. These are called **plant hormones** or **phytohormones**. A phytohormone is an organic substance produced in a small quantity in one part of plant body and capable of moving to other parts to influence the growth of that part.

The naturally produced growth hormones are grouped under five major classes. They are:

(i) **Auxin**- it is a growth promoter, generally produced by the growing apex of stem and root of the plants.

Functions of Auxin;

-it promotes cell elongation;

-it suppresses the growth of lateral bud. If the tip of a plant is removed the lateral branches begin to grow;

-it delays fall of leaves.

(ii) **Gibberellin**- in plants it is produced in embryos, roots, and young leaves and it enhances growth.

Functions of Gibberellins;

-it helps with elongation of stems in genetically dwarf plants. The height of the dwarf plants can be increased.

-it breaks dormancy of seeds and buds.

-it helps with the formation of seedless fruits without fertilization.

(iii) **Cytokinins-** are synthesized in root apex, endosperm of seeds, and young fruits, where cell division takes place continuously.

Functions of Cytokinins;

-they stimulate cell division, cell enlargement and differentiation,

-they prevent aging of plant parts,

-they inhibit apical dominance and help with the growth of lateral buds into branches.

(iv) **Ethylene-** it is a gaseous hormone. It is found in ripening fruits, young flowers and young leaves.

Functions of Ethylene;

-it induces ripening of fruits,

-it promotes senescence and abscission of leaves and flowers,

-in cells it only increases the width not the length.

(v) **Abscissic acid-** is also known as Dormin. It is synthesized in leaves.

Functions of Abscissic acid;

-it induces dormancy of buds and seeds,

-fall of leaves happens due to this acid,

-it inhibits seed germination and development,

-it causes closing of stomata.

Plant Reproduction

Plant Reproduction is the production of new individuals, which can be accomplished by sexual or asexual reproduction. Asexual reproduction produces new individuals without the fusion of gametes, genetically identical to the parent plants. Sexual reproduction produces offspring by the fusion of gametes, resulting in offspring genetically different from the parents.

Asexual reproduction: Plant has two main types of asexual reproduction in which new plants are produced, that are genetically identical clones of the parent individual. **Vegetative** reproduction involves a vegetative piece of the original plant (budding, tillering, etc.). A rhizome is a modified underground stem serving as an organ of vegetative reproduction; the growing tips of the rhizome can separate as new plants, e.g. Iris, Nettles. Plants like onion (Allium cepa), tulips (Tulipa) reproduce by dividing their underground bulbs into more bulbs. Other plants like potatoes (Solanum tuberosum) produce by a similar method involving underground tubers. Gladioli - similar way with corms. Runners or stolons are also important vegetative reproduction organs in some species, such as the strawberry, some ferns, etc. Some types of mould reproduce through **sporulation.** They produce reproductive cells- **spores**, that are stored in special spore cases. After they are released they develop into new, individual organisms (e.g. bread mould). **Budding**- during budding, a new organism starts growing from the parents' body. This bud later develops into a mature organism (yeast).

Sexual reproduction: During sexual reproduction, two gametes from both parents fuse, forming a zygote. All gametes are haploid cells, meaning they have only one set of chromosomes (1n). So, when gametes fuse, they form a diploid organism: 1n+1n=2n. The simplest sexual reproduction in algae is *conjugation*, in which two similar organisms fuse, exchange genetic material and then break apart. Flowers contain both male (stamens) and female (pistil) parts. The pistil consists of the ovary, ovule, style and stigma at the tip. Inside the ovary are the ovules. Each ovule contains an egg cell. The stamen consists of the filament and the pollen-producing anther. A new seed is formed when an egg cell joins with a pollen cell in the process of pollination. Pollination occurs when pollen grains are carried from the anther of the stamen to the stigma of the pistil.

Plant movements

Except for some unicellular plants, all other higher plants cannot move from place to place as their roots are fixed in the soil. Still they show movement by folding the buds, opening and closing the flowers, and bending towards sun light. These movements in plants are very slow. There are various types of movements shown by plants:

(a)Tropic Movements (directional response or growth movements) - Movement in plants or in any part of the plants towards or away from some environmental factors is known as tropic movement. We have observed the movement of plants in the direction of light, the downward movement of roots in the soil, drooping of leaves of some sensitive plants by touch, etc. These are examples of tropic movement.

(I) Phototropism: Induced by light e.g. bending of stems towards light.

(II) Geotropism: Induced by gravity e.g. growth of roots towards gravity.

(III) Thigmotropism: Movement caused by contact e.g. twinning stem and tendrils and the drooping of leaves of sensitive plant by touch.

(IV) Hydrotropism: Induced by water e.g. growth of roots towards the source of water.

(b) Nastic Movements (bending movements) are the growth movements resulting due to the difference in the rate of growth on opposite sides of an organ e.g., opening of petals, coiling of leaves, etc. When the upper side of an organ grows faster than the lower side, the movement is called **epinasty** (opening of sepals of goldmohur flower). When the lower side grows more rapidly than the upper side, it is called as **hyponasty** (upward curling of leaf blade).

(c) Turgor Movements. These movements are due to the change in the volume of water inside the cell. Some examples of turgor movements are:

(I) Leaves or leaflets of some plants close on the fall of darkness (sleep movement). E.g. Acacia.

(II) Closing of leaflets and drooping of leaves in response to a strong stimulus of blowing wind. E.g. sensitive plant (Mimosa pudica).

(III) Closing of leaves of Venus Flytrap to catch a landing insect.

(IV) Seed pods of some plants open on maturity, vigorously expelling their seeds. E.g. Balsam (Gulmehandi).

Chapter 8

PLANT NAMES AND CLASSIFICATION

In Europe, with its many languages, common names can become very numerous indeed. The widespread weed with the scientific name Plantago major, for example, is often called broad-leaved plantation in English, but it also has not less than 45 other English names, 11 French names, 75 Dutch names, 106 German names, and possibly as many as several hundred more names in other languages.

DEVELOPMENT OF THE BINOMIAL SYSTEM OF NOMENCLATURE

The use of Latin in schools and universities had become widespread, and it was then customary to use descriptive Latin phrase names for both plants and animals. All organisms were grouped into genera (singular; genus). For example, all known mints were given phrase names (polynomials) beginning with the word Mentha.

Linnaeus

At this point, the Swedish naturalist Carolus Linnaeus (1707-1778) began improving the way organisms were named and classified. The system he established worked so well that it has persisted to the present. In fact, Linnaeus's system is now used throughout the entire word.

Linnaeus, who was nicknamed the "Little Botanist" at school, inherited his passion for plants from his father, who was a minister and amateur gardener. After a brief tenure as a student at the

University of Loud, he spent most of his time making excursions to Lapland, Holland, France, and Germany. Eventually, he became a professor of botany and medicine at Uppsala, where he inspired large numbers of students, 23 of whom became professors themselves. When Linnaeus began his work, he set out to classify all the known plants and animals according to their genera. In 1753, he published a two-volume work entitled Species Plantarum, which was later to become the most important of all the works on plant names and classification. In this work, he not only included a referenced list of all the Latin phrase names previously given to the plants, but, when necessary, he also changed some of the phrases to reflect relationships, placing one to many specific kinds of organisms called species in each genus. He limited each Latin phrase to maximum of 12 words, and in the margin next to the phrase, he listed a single word, which, when combined with the generic name, formed a convenient abbreviated designation for the species. The word in the margin for spearmint was spicata, and the word for peppermint was piperita. Accordingly, the abbreviated name for spearmint was Mentha spicata and for peppermint, Mentha piperita.

Because of their two parts, these abbreviated names became known as binomials, and the method of naming became known as the Binomial System of Nomenclature. Today, all species of organisms are named according to this system, which also includes the authority for the name, either in abbreviated from or in full, after the Latin name. For example, the full scientific name for spearmint is written Mentha spicata L., the L. standing for Linnaeus; the full scientific name for the wild dandelion native to Scandinavia is written Taraxacum officinale Wiggers, after Fredericus Henricus Wiggers, who was the first to describe the species.

Linnaeus organized all known plants into 24 classes, which were based mainly on the number of stamens in flowers. All plants with five stamens per flower, for example, were placed in one class, while those with six stamens were placed in another class. Plants and other organisms that don’t produce flowers (e.g. mosses, fungi) were put in a class of their own. This classification was used in Species

Plantarum and other works by Linnaeus, and for a short period of time was adopted by some but not all botanists.

The International Code of Botanical Nomenclature

In 1867, more than 100 years after Species Plantarum had been published, about 150 European and American botanists met in Paris to try to standardize rules governing the naming and classifying of plants. They agreed to use the works of Linnaeus as the starting point for all the scientific names of plants and decided that his binomials, or the earliest ones published after him, would have priority over all the others.

Classification of Major Groups

Since Linnaeus’s time, a number of classification categories have been added between the levels of kingdom and genus. Genera are now grouped into families, families into orders, orders into classes, classes into phyla (divisions), and phyla (division) into kingdoms.

Chapter 9

IMPERIUM – CELLULAR ORGANISMS (CELLULATA)

SUPERKINGDOM – MONERA (PROCARYOTES) (PROCARYOTA)

Prokaryotes are the simplest living organisms. They generally have neither a cell nucleus nor cell organelles. They have only ribosomes. They have genetic material composed of a naked double-stranded DNA.

KINGDOM

ARCHAEBACTERIA, EUBACTERIA, BACTERIA

Eubacterias include:

Subkingdom – Oxyphotobacteria

Phylum a) Oxybacteria
b) Cyanobacteria, Cyanophyta

Phylum Cyanobacteria (Blue-green algae)

Cyanobacteria can live in both fresh and salty water, when conditions are optimal, they grow rapidly. All cyanobacteria have chlorophyll “a” and produce oxygen.

g. Nostoc

Some species (strains of Nostoc) are able to grow completely heterotrophycally, in the dark if supplied with sugars and inorganic salts. Cyanobacteria, such as Nostoc are unique among prokaryotes, some have truly multicellular bodies that may contain two types of cells. The large, round cells are called *heterocysts*, specialized for nitrogen (N_2) fixation, which can be absorbed by plants and converted into organic compounds. Once fixed, the nitrogen compounds are transported to surrounding vegetative cells.

The ability of many cyanobacteria to fix nitrogen is important ecologically.

g. Anabaena

Anabaena is a genus of filamentous cyanobacteria that exist as plankton. They are known for nitrogen-fixing abilities, and they form symbiotic relationships with certain plants, such as the mosquito fern.

g. Oscilatoria

It is a genus of filamentous cyanobacteria, which is named after the oscillation in its movement. It is found in watering-troughs' waters. It reproduces by fragmentation.

SUPERKINGDOM EUCKARYOTA

(EUKARYOTES OR NUCLEAR ORGANISMS)

These organisms contain cell nucleus, within which the genetic material and many other organelles are contained, such as mitochondria, chloroplasts, Golgi apparatus. Eukaryotes are either singular- or multiple-celled. There are two types of cell division processes (mitosis and meiosis) in Eukaryotes.

KINGDOMS:

1. Protoctista
2. Fungi
3. Animalia
4. Plantae

SUBKINGDOM MYXOBIONTA

Phylum OOMYCOTA

Oomycota or oomycotes are fungus - like eukaryotic microorganisms. They are filamentous, microscopic organisms that reproduce both sexually and asexually. They have saprophytic and pathogenic lifestyles. The oomycetes are often referred to as water molds. This group was originally classified among the fungi (the name "oomycota" means "egg fungus") and later treated as protists, based on general morphology and lifestyle.

g. Phytophtora

It is a genus of plant-damaging water molds, it remains the most destructive pathogen of solanaceous crops, including tomato and potato.

g. Plasmopara

Plasmopara species are known as plant pathogens, causing downy mildew on carrot, parsley, grape.

There are approximately 900 species of Myxomycetes. They are called slime molds. They can appear as gelatinous “slime”. Slime molds are usually found in soil, lawns and on the forest floor, they also grow in air conditioners, when the drain is blocked.

g. Trichia

The species has worldwide distribution. The slime molds live on the deadwood of conifers and broadleaf trees year-round.

g. Physarum

Approximately 80 species are known. Plasmodia is colorless or yellowish.

Phylum Chytridiomycota

Chytrids are zoosporic organisms, it means “little pot”, which have chitin cell walls, a posterior whiplash flagellum, absorptive nutrition, use of glycogen as an energy storage compound.

Chytrids are saprobic, degrading refractory materials such as chitin and keratin.

It has over 750 species distributed among 10 orders. Asexual reproduction occurs through the release of zoospores derived through mitosis. In some members, sexual reproduction is achieved through the fusion of isogametes (gametes of the same size and shape).

g. Synchitrium

The most well-known species is S. endobioticum, a parasite of Solanaceae, it is the causal agent of black wart in potatoes.

g. Olpidium

It is a brassica plant root-infecting fungal pathogen.

Chapter 10

KINGDOM ALGAE

Algae, singular alga, definition of numerous groups of chlorophyll – containing (photosynthetic), mainly aquatic organisms ranging from microscopic single-celled forms to multicellular forms 60 meter or more long, distinguished from plants by the absence of true roots, stems, leaves and flowers. In addition to their ecological roles as oxygen producers and as the food base for almost all aquatic life, algae are economically important as a source of **crude oil** and as sources of food and a number of pharmaceutical and industrial products for humans.

Algae have no true leaves or flowers. The algae are grouped into several major phyla based on the form of their reproductive cells and combinations of pigments and food reserves.

Phylum Chlorophyta – The Green Algae

Phylum Chlorophyta includes about 7.500 species of organisms commonly known as the **green algae.** They occur in a rich variety of forms in very diverse and widespread habitats; they possess some of the most beautiful chloroplasts of all photosynthetic organisms. Some are unicellular and microscopic; green algae form thread-like filaments, plate-like colonies, net-like tubes, or hollow spheres.

Some green algae are seaweeds, resembling lettuce leaves or long, green ropes. Several unicellular species grow on the bark of trees, or are found on the backs of turtles. The greatest variety, however, is found in freshwater ponds, lakes and streams. Ocean forms are also varied; there they are an important part of the **plankton** (free-floating, mostly microscopic organisms) and, therefore, of food chains.

The chlorophylls (a and b) and other pigments of green algae are similar to those of higher plants. The green algae, like the higher plants, store their food in the form of starch within the chloroplasts. Most green algae have a single nucleus in each cell. Green algae reproduce both asexually and sexually.

There are three classes in this phylum:

1. Isocontae
2. Conjugatae
3. Charae

CLASS ISOCONTAE

g. Chlamydomonas

A small, actively moving little alga, *Chlamydomonas*, is a common inhabitant of quiet freshwater pools. *Chlamydomonas* is unicellular, with a slightly oval cell surrounded by a complex multilayered wall. A pair of whip-like flagella at one end pull the cell very rapidly through the water. The flagella are, however, difficult to see with an ordinary light microscope. Near the base of the flagella there are two or more vacuoles. They apparently regulate the water content of the cell.

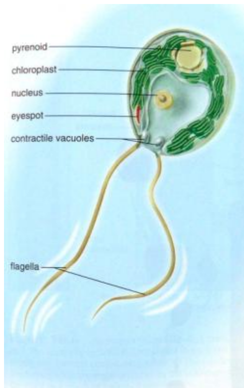


Fig.93. Chlamydomonas

A dominant feature of each *Chlamydomonas* is a single, usually cup-shaped chloroplast that at least partially hides the centrally located nucleus. One or two roundish **pyrenoids** are located in each chloroplast. Pyrenoids are proteinaceous structures which contain enzymes associated with the synthesis of starch. Most species also have a red *eyespot* on the chloroplast near the base of the flagella. The eyespot is sensitive to light (fig. 93).

Asexual Reproduction

Before a *Chlamydomonas* reproduces asexually, the cell's flagella degenerate and drop off, or are reabsorbed. Then the nucleus divides by mitosis, and the cell contents become two cells within the cellulose wall. The two daughter cells develop flagella, escape, and swim away as the parent cell wall breaks down. Once they have grown to their full size, they may repeat the process.

Sexual Reproduction

Under certain combinations of light, temperature, many cells in a population of *Chlamydomonas* may congregate together. A careful study of such events has revealed that pairs of cells appear to be attracted to each other by their flagella and function as gametes that are sometimes of two types. The cell walls break down as the protoplasts slowly emerge, fusing together and forming *zygotes.* The cell contents, now *diploid*, undergo meiosis, producing four haploid **zoospores** (motile cells that do not unite with other cells). When the zygote's wall breaks down, the zoospores swim away and grow to full-size *Chlamydomonas* cells.

g. Chlorella

Chlorella is a genus of single-cell green algae. It is spherical in shape and is without flagella. It contains green photosynthetic pigments chlorophyll-a and -b in its chloroplast. Through photosynthesis, it multiplies rapidly. Chlorella is a potential food source because it is rich in protein and other essential nutrients (fig. 94).

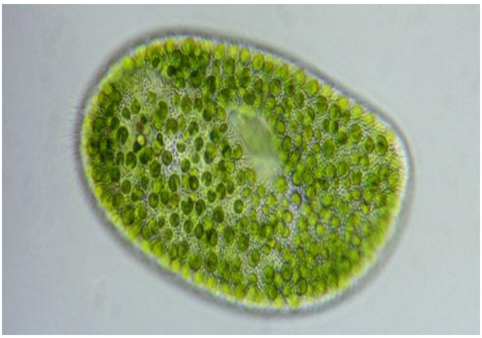


Fig.94. Chlorella

g. Volvox

Volvox forms spherical colonies of up to 50,000 flagellate cells. They live in a variety of freshwater habitats. An **asexual** colony includes both somatic (vegetative) cells, which do not reproduce, and large, non-motile gonidia in the interior, which produce new colonies through repeated division. In **sexual reproduction** two types of gametes are produced (fig. 95).

Fig.95. Volvox

g. Ulothrix

It is a genus of filamentous green algae, generally found in fresh and marine water. Reproduction is normally vegetative (fig. 96).

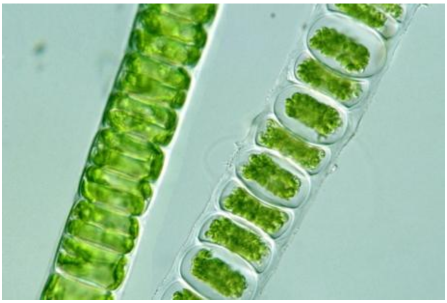


Fig.96. Ulothrix

g. Ulva

Ulva is also known by the common name **sea lettuce**, it is edible thin flat green algae growing from a discoid holdfast (fig. 97).

Fig.97. Ulva

g. Caulerpa

Caulerpas are unusual because they consist of only one cell with many nuclei, making them among the biggest single cells in the world. Some Mediterranean species can have a stolon more than 3 meters long. Some species are eaten under the names "green caviar", or "sea grape" (fig. 98).

Fig.98. Caulerpa

CLASS COJUGATAE

g. Spirogyra

Watersilk, as *Spirogyra* is called, has watery sheaths surrounding the filaments. These common freshwater algae, consisting of unbranched filaments of cylindrical cells, frequently float on the surface of quiet water. Each cell contains ribbon-shaped chloroplasts that look as though they had been spirally wrapped around an invisible pole. Every elegant green ribbon has pyrenoids at regular intervals throughout its length (fig. 99).

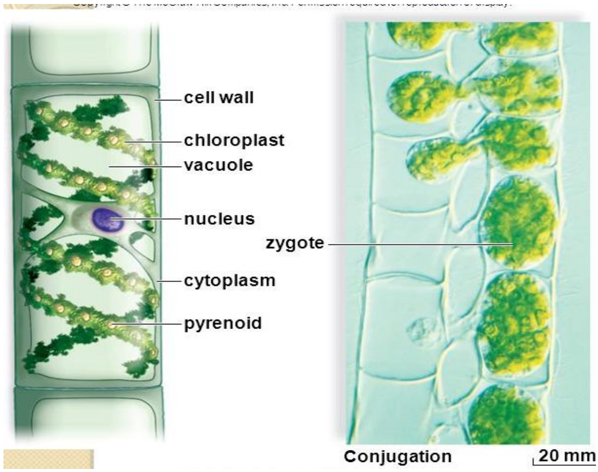


Fig. 99. Spirogyra

Asexual Reproduction

Any cell is capable of dividing, but the only asexual reproduction resulting in new filaments is brought about through the breakup, or *fragmentation* of existing filaments. Fragmentation often occurs as a result of a storm.

Sexual Reproduction

In colonies of *Spirogyra*, the filaments usually are produced so close to each other that they may actually be touching. When sexual reproduction begins, the individual cells of adjacent filaments form little dome-shaped bumps, or **papillae**, opposite each other. The papillae fuse at their tips, forming small, cylindrical **conjugation tubes** between each pair of cells. The condensed protoplasts then function as gametes. Usually, those of one filament will seem to flow or crawl like amoebae through the conjugation tubes to the adjacent cells, where each fuses with the stationary gamete, forming a zygote. Each moving protoplast is considered a male gamete, while the stationary ones function as female gametes.

CLASS CHARAE

g. Chara

Chara is a genus of green algae. They are multicellular and superficially resemble land plants because of the stem-like and leaf-like structures. They are found in fresh water attached to the muddy bottom. The branching system of Chara is complex with branches derived from apical cells which cut off segments at the base to form nodal and internodal cells alternately. They are typically anchored to the substrate by means of branching underground **rhizoids**. Chara reproduces vegetatively and sexually. Antheridia (male organs) and archegonia (female organs) may occur on the same or separate plants. After fertilization, the zygote develops into an **oospore** (fig. 100).

Fig.100. Chara

Phylum Phaeophyta

Brown Algae

Many brown algae are relatively large, and can be unicellular or colonial. Only 6 of the 265 known genera occur in fresh water, the vast majority growing in colder ocean waters.

Many of the brown algae have a **thallus** (the term for multicellular bodies that are usually flattened and not organized into leaves, stems, and roots) that is differentiated into a **holdfast**, a **stipe**, and flattened, leaf-like **blades**. The holdfast is a tough structure resembling roots. It holds the seaweed to rocks.

The color of brown algae can vary from light yellow-brown to almost black, reflecting the presence of varying amounts of the brown pigment fucoxanthin (fig. 98).

Fig.101. Brown algae

g.Laminaria

Commonly Laminaria is called "kelp". It is a type of seaweed. The sporophyte is the dominant phase. Sporophyte is differentiated into holdfast, stipe and lamina. Sexual reproduction is **oogamous**. Laminaria species are found on rocky shores of the north Atlantic and the north Pacific oceans. They are rich in iodine, vitamins and minerals which improve health, including weight loss, lowering cholesterol levels and healthy for digestive system (fig. 102).

Fig.102.Laminaria

g. Fucus

Fucus species are found on the rocky seashores almost throughout the world. The thallus is perennial with disc-shaped holdfast. The erect portion of thallus is dichotomous branched. The base of the thallus is stipe-like and is attached to the rock by a holdfast (fig. 103).

Fig.103. Fucus

g. Macrocystis

Macrocystis has pneumatocysts at the base of its blades. Sporophytes are perennial, and they are the major component of kelp forests. One species, *Macrocystis pyrifera* has the fastest linear growth of any organism on earth (fig. 104).

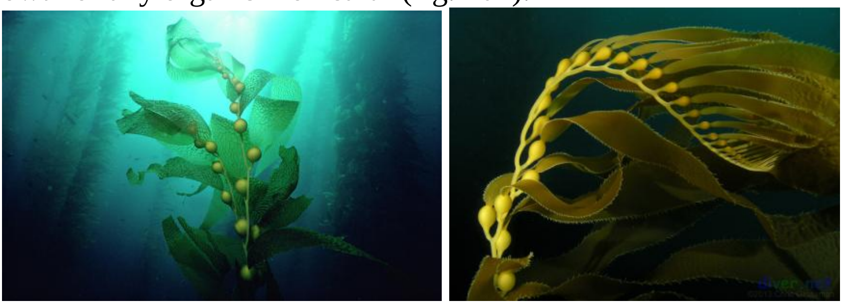


Fig.104. Macrocistis

g. Durvillea

It is found on exposed shores, especially in the northern parts. It attaches itself with a strong holdfast. The blades are golden brown with a leathery texture (fig. 105).

Fig.105. Durvillea

Phylum Rhodophyta

The Red Algae

Like many brown algae, most of the more than 5,000 species of *red algae* are seaweeds. Some grow attached to rocks, others grow at depths of up to 200 meters where light barely reaches them. In 1984, a new species of red algae was discovered at a depth of 269 meters, where the light is only 0.0005 % of peak surface sunlight. A few are unicellular, but most are filamentous. The plant appears to have branching segments. Some develop as beautiful feathery structures that have the appearance of delicate works of art (fig. 106).

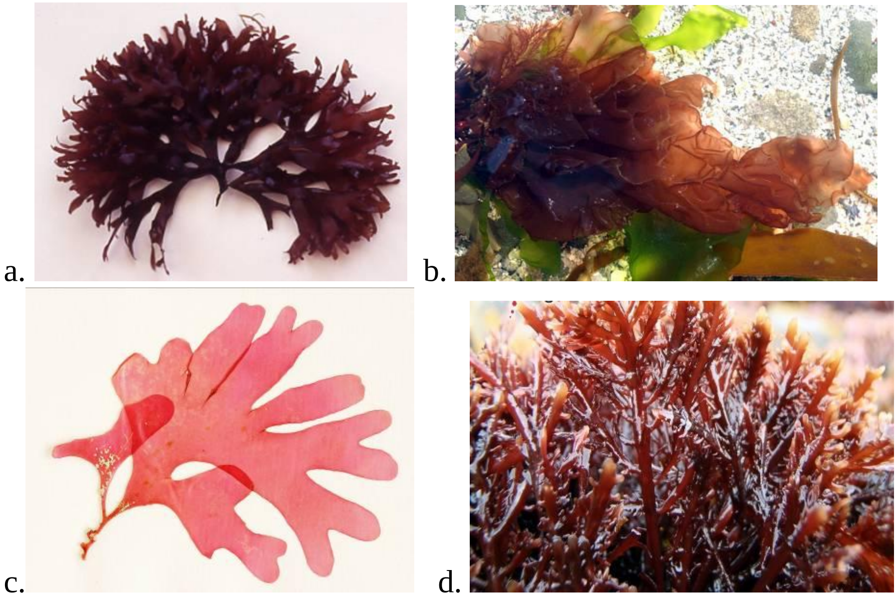


Fig.106. Representative of red algae.
a) Chondrus. b) Porphyra. c) Rhodimenia. d) Gelidium.

Gametes are produced on separate male and female thalli. All of the reproductive cells are nonmotile and are carried passively by water currents. Zygotes may migrate from one cell to another through special tubes.

g. Gelidium

One of the most important of all algal substances is **agar**, produced most by the red alga ***Gelidium***. This substance, which has the consistency of gelatin, is used around the world in laboratories and medical institutions as a solidifier of nutrient culture media for the growth of bacteria.

g. Porphyra

Porphyra is a cold-water seaweed. The thallus can reproduce asexually by forming spores which grow to replicate the original thallus. It can also reproduce sexually. Both male and female gametes are formed on the one thallus.

g. Chondrus

It is commonly called ***Irish moss***, which grows along the rocky parts of the Atlantic coast of Europe and North America. It is soft and cartilaginous, varying in color from red to dark purple or purplish-brown. Chondrus is small red algae (20 cm in length). It grows from a discoid holdfast and branches 4 or 5 times in a dichotomous, fan-like manner.

g. Rhodimenia

It is flattened, fan-shaped, rose-red fronds (100mm high), with long or short stipes arising from the discoidal base. Fronds are dichotomously lobed axils wide, margin smooth.

Economic importance of Algae

Beneficial aspects of Algae are:

1. Role as primary producers: Because of their photosynthetic abilities the algae are the primary producers of the aquatic environments. They produce oxygen and take up carbon dioxide.

2. Source of food: More than 100 species belonging to green, brown and red algae are used as food for humans because of the presence of proteins, carbohydrates, minerals and vitamins. These include Monostroma, Ulva, Codium and Chlorella. The most

important of these are the Chlorella which has all essential amino acid contents in it, therefore used as substitute food especially in space flights. The algae also afford as food for animals in coastal countries. Laminaria, Sargassum, Fucus are used as fodder for animals.

3. Industrial use: Many algae yield certain chemical products which are used in various industries for various purposes. Some of the uses of these products are:

a. Agar-agar: It is dried, jelly-like, non-nitrgenous, extracted from some genera of Rhodophyta like Gelidium, Chondrus, Gigartina, Furcellaria, etc. The algae are collected, mucilaginous matter is extracted with water under pressure. The important use of agar is in microbiology and tissue culture (in the preparation of culture media for growing fungi and bacteria in the laboratories).

b. Alginates: The alginic acids are extracted from the brown and red algae. The alginates are used in rubber–tyre industry, paints and ice-creams and in preparation of flame proof fabrics and plastic articles.

c. Carrageenin: It is carbohydrate mucilage extracted from red algae used as clearing agent in beer preparation, in tooth pastes, cosmetics and in pharmaceutical industries.

4. Antibiotics and medicines: Some species produce antibacterial substances which are effective against gram-negative and gram-positive bacteria.

Because of high iodine contents, brown algae are used in manufacture of various medicines.

5. Nitrogen fixation: The conversion of atmosphere nitrogen compounds is one of the major roles being played by the algae plants (Cyanophyta).

6. Fertilizers: Due to presence of potassium chloride in sea weeds, they are used as fertilizers in many countries.

Chapter 11

KINGDOM FUNGI

DISTINCTION BETWEEN KINGDOM PROTISTA AND FUNGI

In the past, the true fungi, slime molds, and bacteria were all placed in a single division of the Plant Kingdom. Once the fundamental differences between prokaryotic and eukaryotic cells became known, however, the bacteria were placed in the prokaryotic Kingdom Monera. Then it became increasingly apparent that the metabolism, reproduction, and general lines of diversity of fungi were different from those of members of the Plant Kingdom. Accordingly, fungi were placed in their own kingdom.

All true fungi are filamentous or unicellular heterotrophs, most of which absorb their food in solution through their cell walls. Some are saprobes (organisms that live on dead organic matter); others are parasitic decomposers; still others (mycorrhizal fungi) have a mutualistic relationship with plants.

The members of Kingdom Fungi are placed in five phyla. Filamentous fungi produce hyphae that grow at their tips. The cell walls of true fungi consist primarily of *chitin*, a material also found in the shells of arthropods (e.g., insects, crabs).

KINGDOM FUNGI – THE TRUE FUNGI

1.Phylum Chytridiomycota (The Chytrids)
2.Phylum Zygomycota (The Zygomycotes)
3.Phylum Ascomycota (Sac Fungi)
4.Phylum Basidiomycota (The Club Fungi)
5.Phylum Deuteromycota (The Imperfect Fungi)

Phylum Chytridiomycota – (The Chytrids)

The chytrids are the simplest and most primitive fungi, they have chitin in cell walls, most are single-celled. Chytrids usually live in aquatic environments, but some species live on land. Some are parasites on plants, insects, while others are saprobes. The sp. ***Allomyces*** reproductive cycle includes both asexual and sexual phases. It produces zoospores in sporangium.

Phylum Zygomycota – (The Zygomycotes)

Black bread molds are probably the best-known members of Phylum Zygomycota.

Rhizopus, a well-known representative of black bread mold, has spores that are everywhere. They are found in the air above the North Pole, over jungles, inside of buildings, in soils, clothing.

Asexual reproduction

When a spore lands in a suitable growing area, it germinates and soon produces hyphae that may become an extensive mycelium.

Sexual reproduction

Black bread molds reproduce sexually by conjugation.

Phylum Ascomycota – The Ascomycetes (Sac Fungi)

Ascomycota is the largest phylum of the Kingdom Fungi, with 64.000 species. Ascomycetes are fungi, which produce microscopic spores inside special elongated cells or sacs, known as "asci", which give the group its name. Fungi with spores produced inside a sac is called an <u>ascus</u>. Each ascus usually contains 8 spores (sometimes 4).

Truffles are gourmet "mushrooms," which grow mostly between 2.5 and 15 centimeters beneath the surface of the ground, usually near oak trees. They give off a tantalizing aroma that has been shown to contain pig sex *pheromones* (chemicals that produce specific responses). Pigs can detect truffles a meter below the surface and more than 15 meters away. The owners dig up the truffles, which are sold for about $400 a pound.

Truffles are of true fungi called **ascomycetes (sac fungi)**. Most produce mycelia.

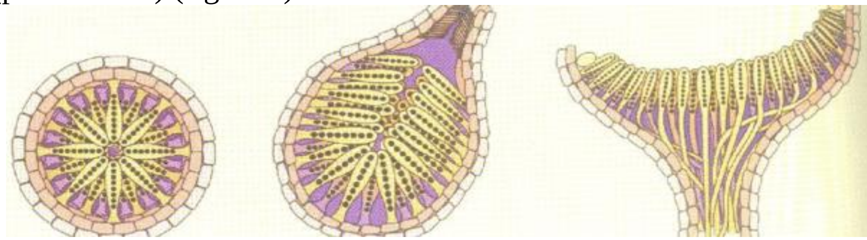
Asexual Reproduction

Asexual reproduction is by means of **conidia**. Conidia are spores that are produced externally- outside of sporangium-either singly or in chains at the tips of hyphae called *conidiophores*. Asexual reproduction in yeasts is by **budding**. As a yeast cell buds, the nucleus divides, and a small protuberance appears to balloon out slowly from the cell. One daughter nucleus moves into the bud, which becomes pinched off as it grows to full size.

Sexual Reproduction

Sexual reproduction involves the formation of tiny fingerlike sacs called **asci** (singular: **ascus**). When hyphae of two different "sexes" become closely associated in a more complex sac fungi, male *antheridia* may be formed on one and female *ascogonia* on the other, although in many species, antheridia and ascogonia may be produced on the same mycelium. Hyphae grow and connect an antheridium and an ascogonium to each other; male nuclei then migrate into the ascogonium. There, the male nuclei pair with the female nuclei present but do not unite. New hyphae (*ascogenous hypha*) whose cells each contain one male and one female nucleus, grow from the ascogonium, the cells dividing in a unique way so that each cell has one of each kind of nucleus.

Thousands of asci may be packed together in an ascoma, which often is cup shaped (apothecium), but also may be completely enclosed (cleistothecium) or flask shaped with a little opening at the top (perithecium) (fig. 107).



a b c

Fig.107. Types of ascomas: a) cleistothecium, b) perithecium, c) apothecium

g. Saccharomyces

xxxxxxx,

Saccharomyces is a genus of fungi that includes many species of yeasts. It means sugar fungus. Many members of this genus are considered very important in food production. It is known as *baker's yeast*. They are unicellular and saprophytic fungi. Some species are used in making wine, bread and beer. Some are used in medicine. Colonies of Saccharomyces grow rapidly and mature in 3 days. They are flat, smooth, moist, and creamy in color. They are very small, unicellular, globose and ellipsoid in shape***. Blastoconidia*** (cell buds) are observed. Hyphae are absent. Saccharomyces produce acospores, which are globose and located in asci. Growth in yeast is synchronised with the growth of the bud, which reaches the size of the mature cell by the time it separates from the parent cell (fig. 108).

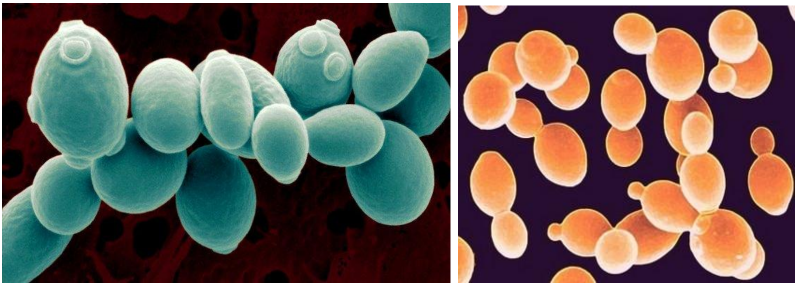


Fig.108. Saccharomyces

g. Claviceps

Clavicep is an ergot fungus that grows on the ears of ***rye*** and related cereal and forage plants. The ergot sclerotium can cause ergotism in humans and other mammals. Alkaloids and lipids accumulate in the sclerotium. C. purpurea most commonly affects rye, wheat, barley.

This fungus causes serious damage to the crop, when develops in the maturing grain. If the infected grain is harvested and milled, a disease called **ergotism** may occur in those who eat the contaminated bread. The disease can affect the central nervous system, often causing hysteria, convulsion, and sometimes death (fig. 109).

Fig.109. Claviceps

Ergotism was common in Europe in the Middle Ages. Known then as *St. Anthony's Fire*, it killed 40.000 people.

In small, controlled doses, ergot drugs are medically useful. They stimulate contraction of the uterus to initiate childbirth and have been used in abortions and in the treatment of migraine headaches.

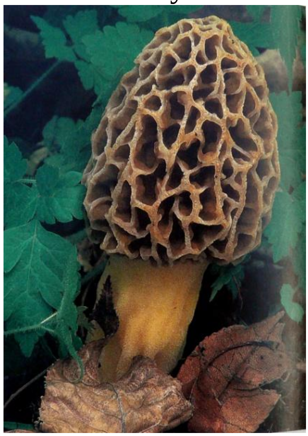


Fig.110. Morel

Morels, which some people have called the world's most delicious mushrooms, and *truffles* have been prized as food for centuries.

Morels are tan in color, and have a sponge-like, somewhat cone-shaped top on a stalk that resembles a miniature tree trunk (fig. 110).

Phylum Basidiomycota – The Basidiomycetes (Club Fungi)

Members of this phylum include mushrooms, or toadstools (the only distinction between mushrooms and toadstools is based on folklore or tradition, with edible species being called mushrooms and poisonous species being called toadstools - mycologically, there is no difference). They are called club fungi because in sexual reproduction, they produce their spores at the tips of swollen hyphae that often resemble small clubs. These swollen hyphae tips are called **basidia** (singular: **basidium**). The hyphae, like those of sac fungi, are divided into individual cells (fig. 111).

Fig.111. Club fungi

Asexual Reproduction

Asexual reproduction is much less frequent in club fungi than in the other phyla of fungi. When it does occur, it is mainly by means of conidia (spore formation). When a spore lands in a suitable place often an area with good organic material and humus in the soil, it germinates and produces mycelium.

Most mushrooms have an expanded umbrella-like cap and a stalk. Thin, fleshy-looking plates called **gills** radiate out of the stalk on the underside of the cap. Microscopic examination of a gill reveals that it is composed of compacted hyphae, with large numbers of **basidia**.

Sexual Reproduction

Sexual reproduction in many club fungi mushrooms begins in the same way as it does for the members of the two fungal phyla previously discussed. Meiotic development of haploid nuclei, their fusion, and the emerging diploid nuclei or zygote are the key-steps of sexual reproduction. Both Ascomycota and Basidiomycota have a special phase in their life cycle, the dikaryotic phase, when two haploid nuclei are in one hyphal segment. The gametes fusion is called **gametogamy**. The gametes can develop in special structures called a **gametangium**.

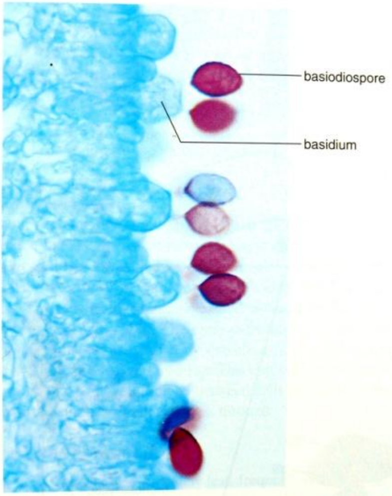


Fig.112. Basidium with basidiospors

Fig.113. Gills

Tiny pegs at the tip of the basidium cells are **basidiospores**. The tiny pegs, called *sterigmata*, serve as stalks for the basidiospores. One large mushroom may produce several billion basidiospores within a few days (fig. 112).

Shelf or *bracket fungi* grow out horizontally from the bark or dead wood from which they have grown, some adding a new layer of growth each year. Perennial species can become large enough and so securely attached that they can support the weight of a human adult.

Only one species of mushroom (*Agaricus bisporus*) is cultivated commercially (fig. 113).

g. Agaricus

Agaricus is a genus of mushroom containing both edible and poisonous species, with possibly over 300 members worldwide. Members of Agaricus are characterized by having a fleshy cap or ***pileus***, from the underside of which grow a number of radiating plates or ***gills*** on which are produced the naked spores, which are chocolate-brown. Members of Agaricus also have a stipe, which elevates it above the substrate on which the mushroom grows. One species reported from Africa, A. *aurantioviolaceus,* is deadly poisonous (fig. 114, 115).

Fig.114. A bolete (Suillus sp.) mushroom. The basidiospores are produced at the margins of pores instead of along gills.

Fig.115. A shelf, also called bracket, fungus growing out from the trunk of a tree.

g. Polyporus

The name of this fungi comes from "*poly*" meaning many and "*poros*" meaning passage. The vegetative body is mycelial and composed of slender, branched and septate hyphae. Mycelia are developed from the spore germination . Under the cap there is a tube layer, which consists of vertical column of tubes lined by basidia producing basidiospores.

Polyporus reproduces by both asexual and sexual means. Asexual reproduction is very rare but it is possible, conidia is reported in them. Sexual reproduction is of *somatogamous* type. (Somatogamy is the fusion of two somatic hyphae acting as gametes for two sexually compatible mycelia. This is the most reduced form of sexual reproduction.) (fig. 116)

Fig.116. Polyporus

Phylum Deuteromycota – The Deuteromycetes (Imperfect Fungi)

Any fungus for which a sexual stage has not been observed is classified as an **imperfect fungus**. Many fungi are grouped together in this artificial phylum.

Imperfect fungi most commonly reproduce by means of conidia (asexual spore).

Many higher plants have mycorrhizal fungi associated with their roots. These fungi greatly increase the absorptive surface area around the roots and may be far more important than root hairs in this regard, particularly in mature roots.

Among the best known of the medically important fungi are the *Penicillium* molds, which secrete *penicillin*, a well-known and widely used **antibiotic**. Species of Penicillium are recognized by their dense brush-like spore-bearing structures called **penicilli**. The spores (conidia) are produced in dry chains from the tip of the branches, with the youngest spore at the base of the chain, and are nearly always green.

Penicillium molds are also used in other ways. Some are introduced into the milk of cows, sheep, and goats at stages in the production of gourment cheeses, such as blue, Camembert, Roquefort, Gorgonzola, and Stilton. The molds produce enzymes that break down proteins and fats in the milk, giving the cheeses their characteristic flavors (fig. 117).

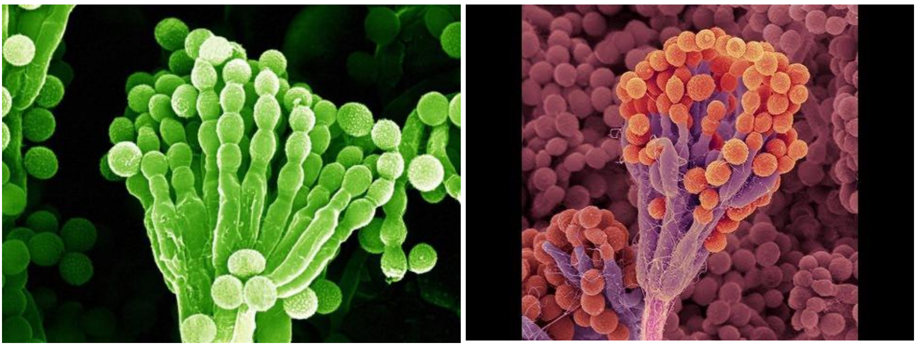


Fig.117. Penicillium

Chapter 12

LICHENS

Lichens traditionally have been referred to as prime examples of *symbiotic* relationships. Each consists of a fungus and an alga (or cyanobacterium) intimately associated in a spongy thallus. The thallus can range in diameter from less than 1 millimeter to more than 2 meters. The photosynthetic component supplies food for both organisms. The fungus protects the photosynthetic organisms from harmful light intensities, and absorbs water and minerals for both organisms. It would probably be correct to say that the fungus parasitizes the photosynthetic component.

There are about 14,500 known species of lichens. The photosynthetic component is either a green alga or a cyanobacterium. There are few lichens having two species of algae present. Lichens have members of the sac fungi for their fungal components. Lichens species, therefore, are identified according to the fungus present.

Lichens grow very slowly, at a maximum rate of 1 centimeter and a minimum of 0.1 millimeter per year. They are capable of living to an age of 4,500 or more years and are tolerant of environmental conditions that kill most other forms of life. They are found on bare rocks in the blazing sun or bitter cold in deserts, in both arctic and antarctic regions, on trees, and just below the permanent snow line of high mountains, where nothing else will grow (fig. 118).

a)  b) 

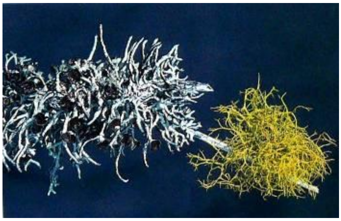
c) 

Fig.118. Three types of lichen thalli.
a) Crustose lichens on the surface of a rock. b) A fosilose lichen.
c) Fruticose lichens

One species grows completely submerged on ocean rocks. They even attach themselves to manufactured substances, such as glass, concrete, and asbestos.

External Structure of Lichens

Based on the external morphology, general growth and nature of attachment, three main types of lichens (crustose, foliose and fruticose) have been recognized (fig.118).

1. Crustose:

   Here the thallus is inconspicuous, flat and appears as a thin layer or crust on substrates like barks, stones, rocks. (e.g. Graphis, Lecanora, Lecidia) (fig. 118 a).

2. Filiose:

   They are leaf-like lichens, where thallus is flat, horizontally spreading and with lobes. They are attached with the substratum by means of hyphal outgrowth, the rhizomes (e.g. Parmelia, Xanthoria, Collema) (fig. 118 b).

3. Fruticose (Shruby):

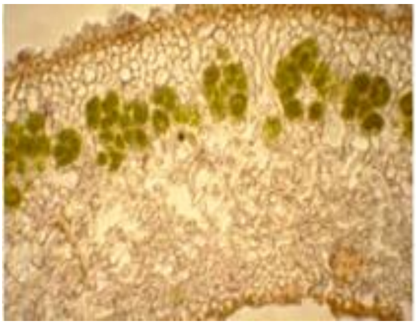
   These are shrubby lichens, where thallus is well developed, shrub-like, either grow erect (Cladonia) or hang from the substratum (Usnea) (fig. 118 c).

Anatomical structure of Lichens

Anatomically the lichens can be *homeomerous* and *heteromerous*.

In heteromerous lichen anatomical structure has both an upper and a lower cortex. The photobiontic layer is in the upper part of the medulla, where the algal cells receive enough light, yet are protected from the full strength of the sun's rays by the upper cortex. Below the algal cells there is the layer of fungal hyphae. Below this layer there is the lower cortex: this is composed of tightly woven hyphae. Small root-like structures called rhizines project down into the substrate (rocks, soil or trees) from the lower cortex. Photosynthesis occurs in the medulla (algal layer). So the four distinct layers in heteromerous structure are: upper cortex, algal zone, medulla and lower cortex. This type is found in foliose and fruticose lichens (e.g. Physcia) (fig. 119 a).

In homeomerous structure the fungal hyphae and the algal cells are more or less uniformly distributed throughout the thallus. The algal members belong to Cyanobacteria. This type is found in crustose lichens (e.g. Leptodium) (fig. b).

a)  

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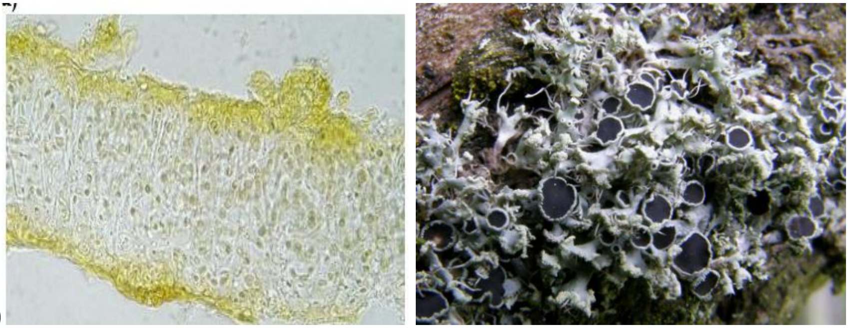


Fig.119. a) heteromerous. b homeomerous)

Reproduction of Lichens

Lichens reproduce by all the three means: vegetative, asexual and sexual.

1. Vegetative Reproduction.

a) fragmentation

It takes place by accidental injury where the thallus may be broken into fragments and each part is capable of growing normally into a thallus.

b) by death of older parts

The older region of the basal part of the thallus dies, causing separation of some lobes or branches and each one grows normally into new thallus.

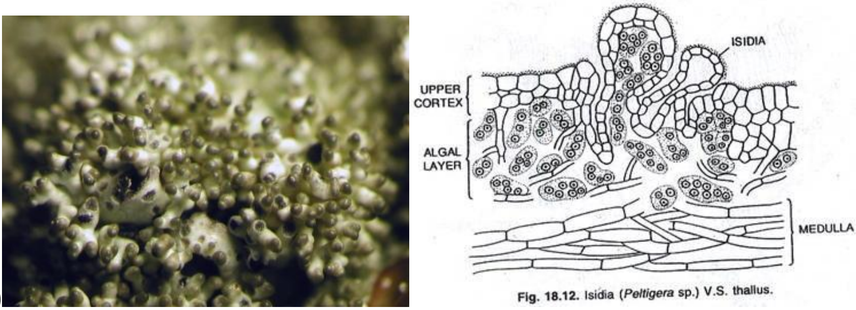
2. Asexual reproduction.

a) Soredium

These are small grayish white, bud-like outgrowths developed on the upper cortex of the thallus. They are composed of one or few algal cells enveloped by fungal hyphae. They are detached from the thallus by rain or wind and on germination they develop new thalli (fig. 120 a).

b) Isidium

These are small stalked simple or branched, grayish-black, coral-like outgrowths, developed on the upper surface of the thallus. The isidium has an outer cortical layer continuous with the upper cortex of the mother thallus which encloses the same algal and fungal elements as the mother. They are of various shapes (cigar-like, scale-like, rod-like). It is generally constructed at the base and detached very easily from the parent thallus. Under favorable condition the isidium germinates and gives rise to a new thallus (fig. 120 b).

a) 

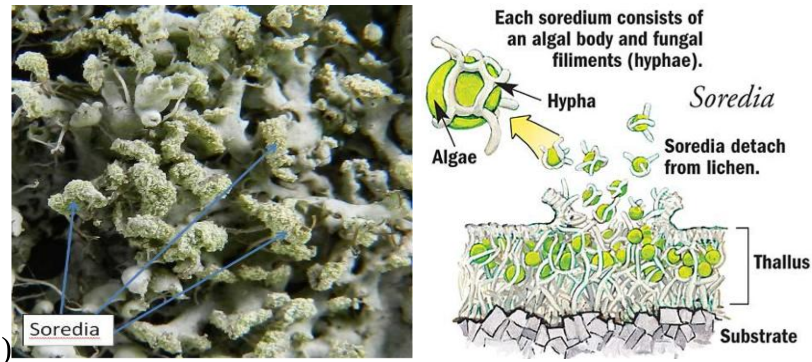
b) 

Fig.120. a) Soredium, b) Isidium

3.Sexual Reproduction.

Only fungal partner of the lichen reproduces sexually and forms fruit bodies on the thallus. The nature of sexual reproduction is like that of members of Ascomycetes or Basidiomycetes.

In Ascolichen, the female sex organ is carpogonium and the male sex organ is called spermogonium (mostly it develops close to carpogonium). The spermogonium develops spermatia as male gametes. The spermatium, after liberating from the spermogonium, gets attached with the trichogyne. The nucleus of spermatium migrates into the carpogonium and fuses with the egg.

In Basidiolichens the result of sexual reproduction is the formation of basidiospores that develop on basidium.

Importance of Lichens

Economic Importance

Lichens are useful to mankind in various ways as food and fodder, as medicine and industrial uses.

Lichens are used as food in many parts of the world and also by different animals. They contain polysaccharide lichenin, cellulose, vitamins and enzymes. Lichens are used in the treatment of epilepsy, diarrhea, skin diseases and for tuberculosis.

g. Cladonia and g. Cetraria islandica are used for the treatment of intermittent fever. Antibiotic obtained from sp. Cladonia is used against various bacterial diseases. Cetraria is used in tanning leather. Some are used in brewing of beer.

Dyes obtained from some lichens may be of different colors like brown, red, purple, blue (used for dyeing of wool and silk fabrics).

The aromatic compounds available in lichen thallus are extracted and used in the preparation of cosmetics and perfumes.

Ecological Importance of Lichens

Some ecological importance of Lichens are:

1. Pioneer of Rock Vegetation:

Lichens are pioneer colonizers on dry rocks, due to their ability to grow with minimum nutrients and water.

2. Accumulation of Radioactive Substances:

The fallout of radioactive strontium and caesium from the atomic research centers are absorbed by lichen. They purify the atmosphere.

3. Sensitivity to Air Pollutants:

The lichens are absent in cities and industrial areas. So they are used as “pollution indicators”.

g. Cladonia – Cup lichen

They are moss-like lichens. They are the primary food source for reindeer. Several Cladonia species grow on sand dunes (fig. 121).

Fig.121. Cladonia

g. Cetraria – Iceland moss

It is a genus of fruticose lichens that associate with green algae as photobionts. Most species are found at high latitude. Species have a “strap-like” form, with spiny lobe edges. Iceland moss is a culinary lichen (fig. 122).

Fig.122. Cetraria

KINGDOM PLANTS (PLANTAE, VEGETABILIA)

Plants are mainly multicellular, photosynthetic eukaryotes of the kingdom **Plantae.** This includes the flowering plants, conifers and other gymnosperms, ferns, clubmosses, hornworts, liverworts, mosses. Plants are characterized by sexual reproduction and alternation of generations, although asexual reproduction is also common. Multicellular land plants are called **embryophytes**, which include vascular plants, such as ferns, conifers and flowering plants. They also include bryophytes (mosses, liverworts).

Plants have two main types of asexual reproduction: **vegetative** and **apomixis**, in which new plants are produced that are genetically identical clones of the parent individual. **Vegetative** reproduction involves a vegetative piece of original plant (budding, tillering, by stolons, bulbs, tubers, etc.). Vegetative reproduction helps to perennialize the plants, allowing them to survive from one season to the next. Here the new individuals are formed without the production of seeds or spores.

Fragmentation is a form of asexual reproduction, where a new organism grows from a fragment of the parent. Some plants can produce seeds without fertilization. This method of reproduction is known as **apomixis**.

Spore, a reproductive cell capable of developing into a new individual without fusion with another reproductive cell. Spores thus differ from **gametes**, which are reproductive cells that must fuse in pairs in order to give rise to a new individual. Spores are agents of **asexual** reproduction, they are produced by bacteria, fungi, algae and plants.

In **sexual** reproduction the plant produces male and female gametes. After fertilization the ovules grow into seeds within the fruit.

The main 9 phylums of Kingdom Plantae are:

1. **Phylum Ryniophyta** – the first and oldest vascular land plants (Rhynia major, now Aglaophyton, 400 million years old) were found

in the Rhynie Chert (Scotland). This phylum includes also nonvascular plants that are intermediate between bryophytes and vascular plants (e.g. Aglaophyton).

2. Phylum Zosterophyllophyta – Zosterophylls lacked true leaves and roots, and photosynthesis is probably carried out all over the stems. They generally showed dichotomous branching (e.g. Asteroxylon).

3. Phylum Bryophita – Bryophyte is a traditional name used to refer to all embryophytes that are non-vascular plants: mosses, hornworts and liverworts. They have life cycles with alternation of generations.

4. Phylum Lycopodiophyta – The species reproduce by spores, some are homosporous, while others are heterosporous. They differ from all other vascular plants in having *microphylls*, leaves that have only a single vascular vein.

5. Phylum Psilotophyta – It is a sister-group to all other ferns (they are called primitive ferns). They have mycorrhizal rhizomes. The gametophytes of both genera Psilotum and Tmesipteris are non-photosynthetic and live in association with a fungus.

6. Phylum Equisetophyta – The plants are commonly called horsetails. The only living genus is Equisetum. The scale-like non-photosynthetic leaves are joined together to form the whorl that encircles the stem. The stem contains a ring of vascular bundles, consisting of xylem and phloem.

7. Phylum Polypodiophyta – They are commonly called ferns. The ferns are vascular plants with stems, roots and leaves. The small gametophyte and the large spore-producing sporophyte plants are quite independent of each other (e.g. Arolla).

8. Phylum Pinophyta or Gymnospermae – They are also known as conifers, a vascular land plant division. They are cone-bearing seed plants (e.g. cedars, junipers, pines). The great majority are trees, a few are shrubs. Most of conifers are evergreens, the leaves of many conifers are needle-like or scale-like. In conducting tissue they have elongated tracheids. Conifer seeds develop inside a protective cone called a *strobilus*.

9. Phylum Angiospermae or Magnoliophyta – Angiosperms or flowering plants, with 416 families, 13.164 known genera and approximately 295.000 known species.

They are seed-producing plants and are distinguished from gymnosperms by producing flowers, endosperm within the seeds, and fruits. In vascular bundles we can recognize xylem and phloem (e.g. oaks, lilies).

From 1 to 7 – they are spore-bearing plants, 8 and 9 – are seed-bearing plants.

Hundreds of millions of years ago, gymnosperms were the only kind of plant life on Earth. Between 250-200 million years ago, angiosperms started to evolve. Now angiosperms are considered the dominant plant life on the planet.

Chapter 13

SUBKINGDOM CORMOBIONTA

SPORE – BEARING PLANTS

Vascular plants, also known as higher plants, form a large group of plants that have lignified tissues (the xylem) for conducting water and minerals throughout the plant. Vascular plants include the clubmosses, horsetails, ferns, gymnosperms and flowering plants.

The scientific name for the group includes Tracheophyta.

Vascular plants are distinguished by two primary characteristics:

1. Vascular plants have vascular tissues.
2. In vascular plants, the principal generation phase is the sporophyte, by contrast, the principal generation phase in non-vascular plants is the gametophyte.

The xylem consists of vessels in flowering plants and tracheids in other vascular plants, which are dead, hard-walled, hollow cells that function in water transport.

Phylum Rhyniophyta

These were the earliest true vascular plants on earth. All members of this group have xylem cells with annular rings.

g. Rhynia

The plants have a branching horizontal rhizome from which dichotomizing upright photosynthetic axes arise. The upright axes grow in a wetland area. The xylem, composed of a few S-type tracheids.

g. Cooksonia

Cooksonia appeared in the middle Silurian and was one of the earliest land plants known. Individuals were small and had a simple structure. They had a simple stalk that branched dichotomously. Each branch ended in a sporangium, which is shaped like a kidney bean.

Phylum Zosterophyllophyta

The Zosterophylls are a group of extinct plants. The stems are covered with small spines, branched dichotomously.

g. Zosterophyllum

The sporangia are kidney-shaped and are borne laterally in a fertile zone towards the tips of the branches.

PHYLUM BRYOPHYTA -MOSSES

About 15,000 species of mosses are currently known. Botanically, mosses are non-vascular plants. These are divided into three different classes, commonly called *peat mosses*, *true mosses* and *rock mosses*. The gametophyte generation is the dominant phase of the life cycle. This contrasts with the pattern in all vascular plants, where the sporophyte generation is dominant. Mosses reproduce using spores, not seeds and have no flowers.

The “leaves” of moss gametophytes have no mesophyll tissue, stomata or veins as those of the leaves of more complex plants. The blades are nearly always only one cell thick, except at the midrib, which runs lengthwise down the middle, and they are never lobed or divided, nor do they have a petiole (leaf stalk). The “leaf” cells usually contain numerous chloroplasts. The “leaves” of peat mosses have large, transparent cells (without chloroplasts) that absorb and store water. Small, green photosynthetic cells are sandwiched between the large cells.

The axis is somewhat stem-like but has no xylem or phloem. At the base, there are root-like rhizoids consisting of several rows of colorless cells that anchor the plant. Some water absorbed by rhizoids rises up the central strand, but most water used by the plant apparently travels up the outside of the plant by means of capillarity. The closely packed habit of many mosses, and the fact that they rarely extend more than a few centimeters into the air, favor such outside movements of water. Water is absorbed directly through the plant surfaces.

Sexual Reproduction

Sexual reproduction in mosses begins with the formation of multicellular gametangia, usually at the apices of the “leafy” shoots of gametophytes. Both male and female gametangia are often produced on the same plant, but in some species, they occur on separate plants. The archegonia (female gametangia) are somewhat cylindrical. A single egg cell is produced in archegonium. The part of the archegonium is called the neck. The neck contains a narrow canal. The canal is at first plugged with cells, but these break down as the archegonium matures, leaving an opening to the outside at the top.

Male gametangia are sausage-shaped to roundish. These antheridia are borne on short stalks. A mass of tissue inside each antheridium develops into numerous sperm cells. This mass of sperms is forced out of the top of the antheridium when it absorbs water and swells. After release the sperm mass breaks up into individual cells, each with a pair of flagella. It is believed the breakup of the sperm mass is aided, in some cases, by fats produced by the moss, while in other instances, rain splash is responsible.

Archegonia release sugar, proteins, acids, or other substances that attract the sperm and, eventually, after swimming down the neck of an archegonium, the sperm unites with the egg, forming a diploid zygote. The zygote usually grows rapidly into a spindle-shaped embryo. The embryo is a developing sporophyte (fig. 123).

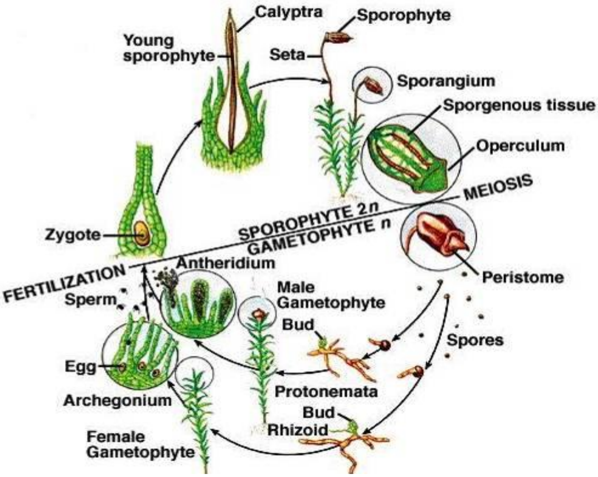


Fig.123. Sexual reproduction

The cells of the sporophyte become photosynthetic as it develops. The sporophyte, however, depends to varying degrees on the gametophyte for some of its carbohydrate needs as well as for at least a part of its water and minerals.

The mature sporophyte is first green and photosynthetic; it consists of a capsule and seta. As the capsule matures, sporocytes inside it undergo meiosis, producing haploid spores. These spores, often numbering in the millions, are released from the capsule. If light and other conditions are favorable, tiny "leafy" buds appear at intervals along the protonemal filaments after about 2 to 4 weeks of growth. These "leafy" buds develop rhizoids at the base and grow into new "leafy" gametophytes, completing the cycle.

CLASS HEPATICOPSIDA
g. Marchantia

The thallus shows differentiation into two layers: an upper *photosynthetic* and a *lower* storage. Purple colored scales and rhizoids are present on the ventral surface of the thallus, Marchantia can reproduce both sexually and asexually (fig. 124).

Fig. 124. Marchantia

CLASS ANTHOCEROTOPSIDA
g. Anthoceros

This genus is global in its distribution. Its name means "flower horn" and refers to the characteristic horn-shaped sporophytes that all hornworts produce. It grows in moist clay soils on hills and, in damp hollows among rocks (fig. 125).

Fig.125. Anthoceros

CLASS MUSCI
SUBCLASS SPHAGNIDAE

g. Sphagnum

Sphagnum is a genus of approximately 380 species of mosses, commonly known as **peat moss.** The plant can hold large quantities of water inside their cells. As sphagnum moss grows, it can slowly spread into drier conditions, forming larger mires, both raised bogs and blanket bogs (fig.126).

Fig.126. Sphagnum

SUBCLASS ANDREAEIDAE
g. Andreaea

They are small mosses, the capsules are formed at the tips of vertical branches, they grow on wet rocks in mountainous areas (fig. 127).

Fig.127. Andreaea

SUBCLASS BRYIDAE
g. Polytrichum

It is commonly called *haircap* moss or hair moss. Small leaves are arranged spirally around the stiff stem. It is generally dark green in color and doesn't grow very tall. Even dead the moss remains intact (fig. 128).

Fig.128. Polytrichum

Phylum Psilotophyta

Psilotopsida (whisk ferns) is a phylum represented by two living genera Psilotum and Tmesipteris. The green, photosynthetic stem is as well developed. The spore–producing structures are produced in clusters at the end of a short lateral branch. The life cycle is very much like that of ferns.

Chapter 14

THE SEEDLESS VASCULAR PLANTS

During the early stages of vascular plant evolution, conducting tissues (xylem and phloem) began to develop, true leaves appeared, and roots that function in absorption as well as anchorage developed. Gametophytes became progressively smaller and more dependent on sporophytes, that became larger.

Unlike conifers and flowering plants, the primitive vascular plants do not produce seeds. Four phyla of seedless vascular plants are recognized:

1. Phylum Psilotophyta
2. Phylum Lycopodiophyta – The stems of these plants are covered with microphylls (leaves with a single vein), which are photosynthetic.
3. Phylum Equisetophyta – The sporophytes of these plants have ribbed stems and whorled, scale-like microphylls that lack in chlorophyll.
4. Phylum Polypodiophyta – The sporophytes of ferns have megaphylls (leaves with more than one vein) that are often large and much divided.

Phylum Lycopodiophyta (Lycopods)

This is a tracheophyte subgroup of the Kingdom Plantae. It is one of the oldest (now living) vascular plants. Some species are *homosporous* while others are *heterosporous*. In most of members the sporophyte generation is dominant. They differ from all other vascular plants in having microphylls, leaves that have a single vascular vein rather than the much more complex megaphylls found in ferns.

This phylum includes two classes:

1.**Class Lycopodiopsida (Clubmosses**);
2.**Class Isoetopsida (Spikemosses).**

Class Lycopodiopsida
g. Lycopodium
sp.Lycopodium clavatum L. (Ground Pines)

Lycopodium clavatum often grows on forest floors. They are sometimes called ground pines, partly because they resemble little Christmas trees. The stems of ground pine sporophytes are branched. The plants are less than 30 cm tall. Stems develop from branching rhizomes (fig. 129).

Needle-like or scale-like leaves cover the stem and branches thickly. The kidney-shaped spore-cases (sporangia) contain spores of one kind only (homosporous) and are borne on the upper surface of the leaf blade of specialized leaves (sporophylls) arranged in a cone-like strobilus at the end of the stems.

Reproduction

Some species produce kidney bean-shaped sporangia in the axils of leaves. Such leaves are called sporophylls. In other species, the sporophylls have no chlorophyll, are smaller than the other leaves and are in terminal cone-like clusters, called *strobili*. Sporangias produce spores that are carried away by air currents. The spores germinate if they land in a suitable location. After germination, independent gametophytes develop from the spores. The gametophytes produce both antheridia and archegonia on the same gametophyte. Water is essential for fertilization to occur.

Zygotes first become embryos with a root, stem and leave and then develop into mature sporophytes.

Fig.129. Licopodium

Class Isoetopsida
g. Selaginella (Spikemosses)

Selaginella is the sole genus of vascular plants in this class. These plants are distinguished by having spores of two types. Leaves are simple, scale-like. The stems are aerial, horizontally creeping on the substratum sub erect or erect. The microphylls of Selaginella sp. Contain a branched vascular trace. In Selaginella, each microphyll and sporophyll has a small scale-like outgrowth called a *ligule* at the base of the upper surface. The plants are *heterosporous* with spores of two different sizes, known as *megaspores* and *microspores* (fig. 130).

Fig.130. Selaginella

Phylum Equisetophyta (The Horsetails)
g. Equisetum

About 25 species are scattered in all continents. They grow less than 1.3 meters tall. Species have tiny, scale-like leaves. They are green when they first appear, but they soon wither and bleach, and all photosynthesis occurs in the stems. The stems have obvious nodes and internodes. The aerial stems develop from horizontal rhizomes, which also have regular nodes, internodes and ribs (fig. 131).

Fig.131. Equisetum

Reproduction

In the spring some species produce special cream-to shiny-colored non-photosynthetic stems from rhizomes. Small, cone-like strobili develop at the tips of these special stems. The spores are released in sporangias. Spores are carried by an air current.

Germination of spores occurs within a week of their release. Lobed, green gametophytes (prothalli) develop and seldom grow to 8 mm in diameter. Rhizoids anchor them to the surface. Male gametophytes produce antheridia with sperm cells, with several flagellas. Eggs in archegonia, on a female gametophyte, may be fertilized when water contacts antheridia and sperms swim to the archegonia with the help of flagella. The development of more than one sporophyte is common (fig. 132).

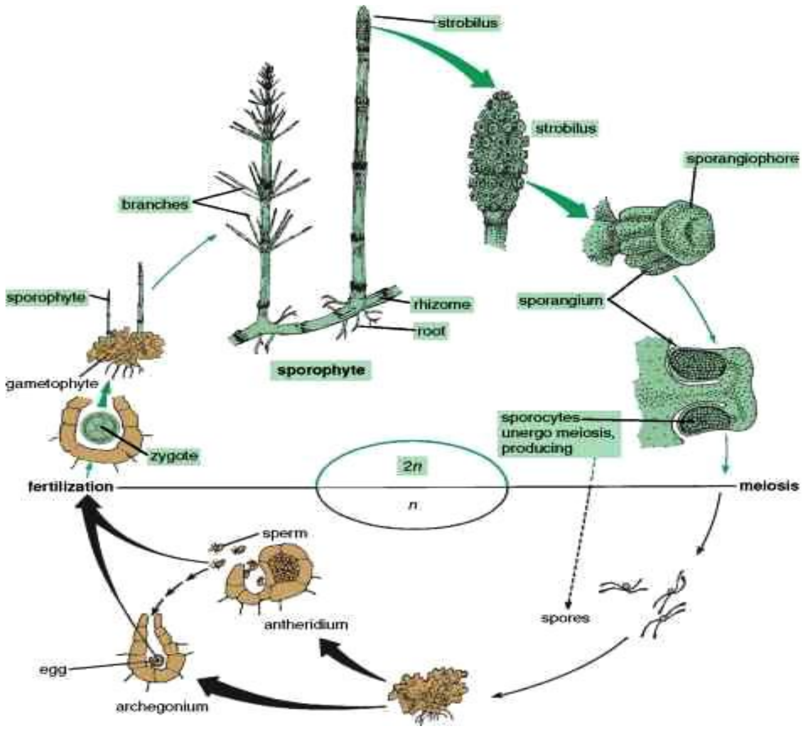


Fig.132. The Horsetail life cycle

Phylum Polypodiophyta (The Ferns)

The ferns are vascular plants which have neither seeds nor flowers. The small gametophyte and the large spore – producing fern plant are quite independent of each other. The sporophyte plant (recognized as a fern) may have an erect or prostrate stem. The leaves are large and much divided, they unroll as they develop from a coiled early bud stage called <u>fiddlehead</u>.

About 10.560 species are known. Ferns first appear in the fossil record 360 million years ago in the late Devonian period.

sp. Dryopteris Filix Mas (Male Fern)

This is a common fern of the temperate Northern Hemisphere. It favours damp shaded areas. The name means “male fern”. The green leaves reach a maximum length of 150cm. Leaves are bipinnate. This is large, deciduous male fern with erect, stout rhizomes (fig. 133).

Fig.133 Male fern

Structure and Form

Fern leaves are megaphylls (leaves have branching veins), and are feathery.

Reproduction

A fern sporophyte consists of the fronds, a stem in the form of a rhizome and adventitious roots. When the fronds have expanded, small, circular, rust-colored patches of powdery-looking material may appear on the lower surface of some or all of the blades. The patches are actually clusters of sporangia. The sporangia are called sori (singular: sorus). Spores are dispersed by wind. Those that germinate in favorable locations produce little prothalli (sing: prothallus), a green, heart-shaped gametophytes (5 to 6mm in diameter) (fig. 134).

Prothalli are only one cell thick, except toward the middle, where they are slightly thicker. Antheridia are produced on the lower surface of the central area of most prothalli, archegonia – closer to the notch of the heart-shaped gametophyte. Antheridium produces sperms. Fertilization of an egg takes place within an archegonium. Only one zygote develops into a young sporophyte to complete and continue the cycle. So here we can see the **alternating generations** of separate spore producing plants (sporophytes) and gamete producing plants (gametophytes). Sporophyte is the asexual part of the life cycle, and gametophyte is the sexual part of the life cycle.(fig. 135).

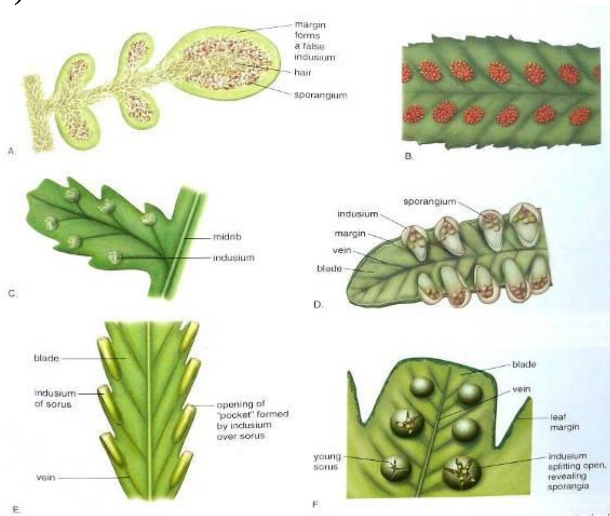


Fig.134. Ferns

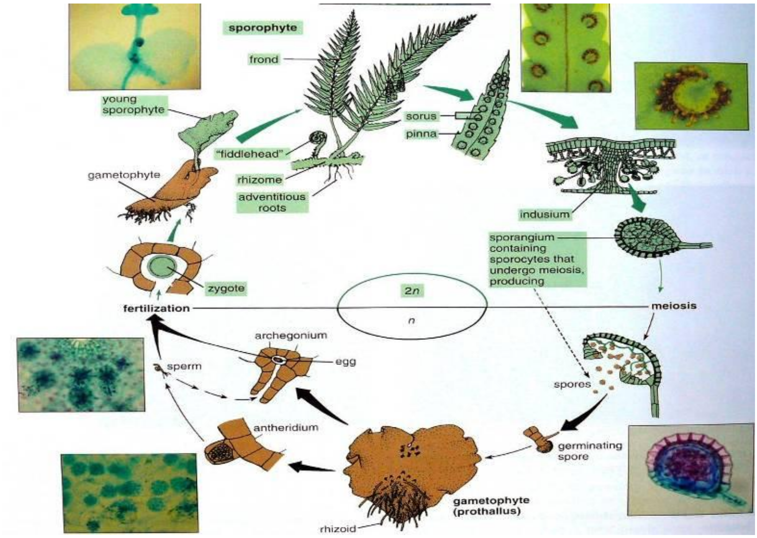


Fig.135. Ferns life cycle

g. Brackens - Pteridium L.

Pteridium also known as eagle fern, occurring in temperate and subtropical regions in both hemispheres.

This is herbacous perennial plant. The large triangular fronds arising upwards from an underground rhizome, grow 1-3m tall. The main stem is up to 1cm in diameter at the base.

The plant contains carcinogenic compound ptaquiloside (fig. 136).

Fig.136. Brackens

g. Watermoss – Salvinia L.

This is water fern, heterosporous (producing spores of different sizes) plant. When the growth is robust, the plants pose a particular hindrance on certain lakes, having choked off much of the water in lakes (fig. 137).

Fig.137. Watermoss

g. Duckweed fern - Azolla L.

Azolla is an aquatic fern, it is highly productive plant. It doubles its biomass in 3-10 days, depending on conditions.

They form a symbiotic relationship with the cyanobacterium, which fixes atmospheric nitrogen (fig. 138).

Fig.138. Duckweed fern

g. Water clover - Marsilea L.

These small aquatic plants have long-stalked leaves, which have four clover-like lobes and are either held above water or submerged (fig. 139).

Fig.139. Water clover

Sporogenesis

Sporogenesis (spore formation) is the production of spores. Reproductive spores are found to be formed in eukaryotic organisms, such as plants, algae and fungi, during their normal reproductive life cycle. Most eukaryotic spores are haploid and are formed through cell division, though some types are diploid and are formed through cell fusion. Algae and some fungi often use motile zoospores that can swim to a new location before developing into sessile organisms. Plant spores are most obvious in the reproduction of ferns and mosses. However, they also exist in flowering plants, where they develop hidden inside the flower. For example, the *pollen grains* of flowering plants develop out of microspores produced in the *anthers* and megaspores produced in *ovules*.

Reproductive spores grow into multicellular haploid individuals. In *heterosporous* organisms, two types of spores exist: microspores are produced in microsporangia, give rise to males, and megaspores produced in *megasporangia*, to females. In *homosporous* organisms, all spores look alike and grow into individuals carrying reproductive parts of both genders.

Sporogenesis occurs in reproductive structures termed sporangia. The process involves *sporocytes* (sporogenous cells) undergoing cell division to give rise to spores.

In gymnosperms (conifers) microspores are produced from *microsporocytes* in male cones (microstrobili). In flowering plants, microspores are produced in the anthers of flowers. *Megasporogenesis* occurs in *megastrobili* in conifers, and inside the *ovule* in the flowering plants.

Gametogenesis

Gametogenesis is a process by which diploid or haploid precursor cells undergo cell division and differentiation to form mature haploid *gametes*. Plants produce gametes through mitosis in gametophytes.

Fungi, algae and primitive plants form specialized structures called *gametangia*, where gametes are produced. In some fungi, such as the Zigomicota, the gametangia are single cells, situated at the ends of hyphae. More typically, gametangia are multicellular structures that differentiate into male organs (antheridium) and female organs (archegonium).

In flowering plants (angiosperms) the male gametes are produced inside the pollen tube or pollen grains. This can occur while the pollen forms in the anther. The female gamete is produced inside the *embryo sac* of the *ovule*.

Chapter 15

SEED PLANTS

Seeds, when compared to spores, have distinct advantages due to their hard outer shells and internal structure called endosperms, which provide essential nutrients for enclosed seedlings. Seeds are found only in flowering plants and gymnosperms. They contain embryos deep within their centers.

Seed-bearing plants produce microspores, macrospores. Gymnosperms include four groups: conifers, cycads, ginkgos and gnetophytes. These species take the shape of trees and shrubs, while angiosperms are mostly small flowering plants.

Seed plants are divided into two groups:

1. **Gymnosperms**
2. **Angiosperms**

SEED PLANTS: GYMNOSPERMS

The name gymnosperm is derived from two Greek words gymnos, meaning "naked", and sperma, a "seed". The name refers to the exposed nature of the seeds, which are produced on the surface of sporophylls or similar structures instead of being enclosed within a fruit as they generally are in the flowering plants. The seed-bearing sporophylls of the sporophyte are often spirally arranged in strobili (seed cones) that develop at the same time as smaller pollen-bearing strobili (pollen cones). The pollen cones produce pollen grains.

The female gametophyte is produced inside an ovule that contains a fleshy, nutritive diploid tissue called the **nucellus**. The nucellus is itself enclosed within one or more outer layers of diploid tissue. These outer layers of tissue constitute an **integument** that becomes a seed coat after the fertilization and development of an embryo take place.

The sporophytes of gymnosperms are mostly trees and shrubs.

Four phyla of living gymnosperms are recognized. **Phylum Pinophyta** includes about 575 species of coniferous woody plants. Fossils of some conifers extend back 290 million years. **Phylum Ginkgophyta** has a single living representative, Ginkgo, which has fan-shaped leaves, and seeds enclosed in a fleshy covering. The palm-like cycads are assigned to **Phylum Cycadophyta. Phylum Gnetophyta** includes three genera of gnetophytes that have wood with vessels- a structural element unknown in other gymnosperms.

Class Pteropsida – Pteropsids

A subdivision of vascular plants. It includes all flowering plants and seed ferns. They have well-developed large leaves with branched venation.

Class Cycadopsida Cycades

Cycads have a woody trunk with large, evergreen leaves. They are sometimes mistaken for palms and ferns. The living cycads are found in subtropical and tropical parts of the world.

Class Benettitopsida

They are considered to be close relatives of the flowering plants on account of their flower-like structure. But they are more closely related to cycads, ginkgo and conifers, that to angiosperms. According to experts, the representatives of this class were ancestry of seed plants, because the seeds had two cotyledones.

Class Ginkgoopsida

The only extant species is Ginkgo biloba.

Sp. Ginkgo - Ginkgo Biloba L.

The only living species native to China. The Chinese name means “silver fruit”. Ginkgos are large trees (20-35 m), with an angular crown. The leaves are unique among seed plants, being fan-shaped, never anastomosing to form a network. Cones are globoid, seeds are edible. Plant is poisonous (fig. 140).

Fig.140. Ginkgo

Class Gnetopsida

g. Jointfir - Ephedra L.

Ephedra is the only genus of family Ephedraceae. They grow on shores or in sandy soil. The plant has similarity with horsetails in the form of the stems (Equisetum). Leaves are scale-like. Ephedra produce small, cone-like reproductive structures followed by berry-like fruits, which are bright red or orange in color (fig. 141).

Fig.141. Jointfir

g. Tumbo - Welwitschia L.

Sp. Welwitschia mirabilis is endemic to the Namib desert within Namibia and Angola. Two foliage leaves are produced at the edge of a woody crown. The leaves grow from basal meristem reaching lengths up to 4-6 m. The plant has an elongated, shallow root system, consisting of a taproot. The species is dioecious, with separate male and female plants (fig. 142).

Fig.142.Tumbo

Class Pinopsides - Pinopsida

They are gymnosperms, cone-bearing seed plants with a secondary growth. They are perennial woody trees or few shrubs. The world's tallest, thickest and oldest trees are all conifers. Leaves of many are long, thin and needle-like or scale-like, dark green. In some generas the leaves are evergreen, usually remaining on the plant for several (2-40) years before falling. Tree rings are records of the influence of environmental changing conditions. Tracheids make up more than 90% of timber volume.

g. Firs - Abies L.

Firs are a genus of evergreen coniferous trees (10-80m). The leaves are significantly flattened, even looking like they are pressed. In most species they are gray-green, bluish to silvery. Firs have erect, cylindrical cones (5-25cm), green when young and then silver or brown (fig. 143).

Fig.143. Firs

g. Yew - Taxus L.

They have a reddish bark, lanceolate, flat, dark-green leaves, arranged spirally on the stem. The seed cones are modified, each cone containing a single seed, partly surrounded by a modified scale which develops into a soft, bright red berry-like structure called *aril* (open at the end) (fig. 144).

Fig.144. Yew

g. Spruce - Picea Dietr

Spruce is a coniferous evergreen tree, found in the northern temperature and boreal (taiga) regions of the world. Leaves are needles, attached singly in a spiral fashion (fig. 145).

Fig.145. Spruce

g. Cedar - Cedrus Mill

They are native to the mountains of Himalayas and the Mediterranean region (fig. 146).

Fig.146. Cedar

Cypress family - Cupressaceae

The family includes junipers and redwoods. The bark of the trees are commonly orange- to red-brown, smooth.

g. Juniper - Juniperus L.

Junipers vary in size and shape from tall trees to low spreading shrubs. They are evergreen with needle-like or scale-like leaves. The female seed cones are with fleshy, fruit-like coalescing scales, which fuse together to form a “berry”-like structure. In some species these berries are brown or orange, but in most they are blue (often aromatic) (fig. 147).

Fig.147. Juniper

g. Cypress - Cupressus L.

They are evergreen trees or large shrubs (5-40 m). The leaves are scale-like, arranged in opposite pairs. The cones are globose or ovoid. Seeds are small, with 2 narrow wings (fig. 148).

Fig.148. Cypress

g. California redwood - Sequoia L.

It is an evergreen, long-lived tree (1200-1800 years or more). This species includes the tallest living trees on Earth, reaching 115.5 m in height (without the roots), and up to 9m in diameter (fig. 149).

Fig.149. California redwood

g. Northern White-Cedar - Thuja L.

It is a small or medium-sized tree. The bark is red-brown, branches are fan-like. The foliage forms flat sprays with scale-like leaves. The seed cones are slender, yellow-green, ripening to brown. The branches may take root if the tree falls. It is native to Canada and North America (fig. 150).

Fig.150. Northern White-Cedar

Pine family - Pinaceae

The family includes many of the well-known conifers of commercial importance such as cedars, firs, pines, hemlocks. Trees, rarely shrubs are evergreen, resinous and aromatic, monoecious. Leaves are linear to needle-like. Resin canals are present. Cones are generally lateral.

g. Pine tree - Pinus
sp. Scots Pine - Pinus sylvestris L.

The largest genus of conifers, Pinus (pines) has over 100 living species. They are the dominant trees in the vast coniferous forests. They include the world's oldest known living organisms. Some trees still standing are about 4,600 years old (fig. 151).

Fig.151. Pines

Reproduction

Pines produce two kinds of spores. Pollen cones (male strobili) consist of papery or membranous scales arranged in a spiral or in whorls around an axis; they are usually produced in the spring. The pollen cones usually develop toward the tips of the lower branches in clusters of up to 50 or more and are mostly less than 4cm long. Microsporangia develop in pairs toward the bases of the scales.

Each of the microsporocytes in the microsporangia undergoes meiosis, producing 4 *microspores*. These then develop into pollen grains; each grain consists of four cells and a pair of external air sacs. The air sacs look something like tiny wings, which helps with wind dispersal. Pines produce pollen grains in astronomical numbers. Within a few weeks after the pollen has been released, the now shriveled pollen cones fall off the trees (fig. 152, 153).

Fig.152. Reproduction

Fig.153. Sugar Pine cone

Megaspores are produced in megasporangia located within ovules at the bases of the seed cone scales. The seed cones (female strobili) are larger than the pollen cones. They are mostly produced on the upper branches of the same tree on which the pollen cones appear. Each ovule has within it a megasporangium containing the **nucellus** and a single *megasporocyte*. This, in turn, is surrounded and enclosed by a thick, layered **integument**. The integument has a somewhat tubular channel or pore called a **micropyle**. One of the integument layers later becomes the seed coat of the seed.

A single megasporocyte within the megaspoangium of each ovule undergoes meiosis, producing four relatively large megaspores. Three of the megaspores soon degenerate. Over a period of months, the remaining one slowly develops into a *female gametophyte*. The nucellus is used as a food source for the growing gametophyte. Each archegonium contains a single large egg. During the first spring pollen grains carried by the wind sift down between the scales. There they catch in sticky drops of fluid (pollen drops) oozing out of the *micropyles.* As the fluid evaporates, the pollen is drawn down through the micropyle to the top of the nucellus.

After pollination, the scales grow together and close, protecting the developing ovule. Meanwhile, the **pollen grain** (male gametophyte) produces a pollen tube that slowly grows and digests its way through the nucellus to the area where the archegonia develop. While the pollen tube is growing, two of the original four cells in the pollen grain enter it. One of these, called the *generative cell*, divides and forms two more cells, called the *sterile cell* and the *spermatogenous cell*. The spermatogenous cell divides again, producing two male gametes, or *sperms*. The germinated pollen grain, with its pollen tube and two sperms, constitutes the mature *male gametophyte*. Notice that no antheridium has been formed.

About 15 months after pollination, pollen tube arrives at an archegonium, unites with it, and discharges the contents. One sperm unites with the egg, forming a zygote. The other sperm and remaining cells of the pollen grain degenerate. Zygote begins to develop into an embryo. While this development is occurring, one of the layers of the integument hardens, becoming a seed coat (fig. 154).

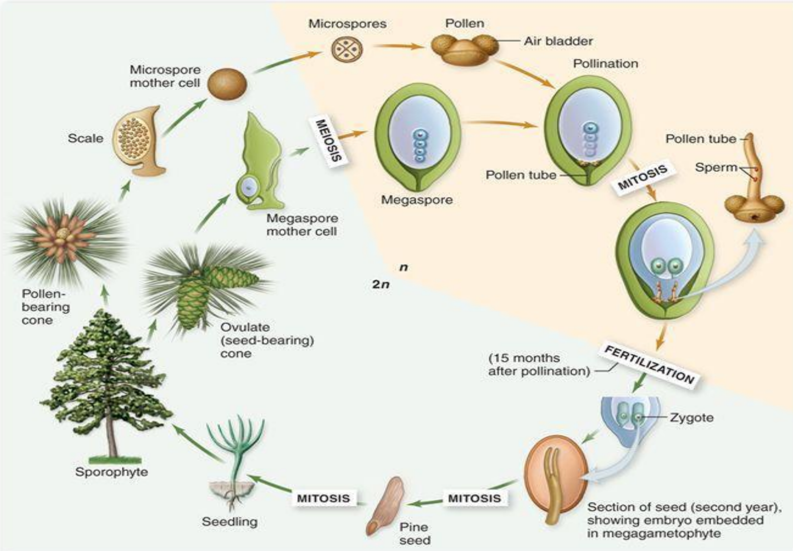


Fig.154. Pine reproduction

Chapter 16

SEED PLANTS: ANGIOSPERMS

The flowering plants are called **angiosperms**.

The term angiosperm is derived from two Greek words: *angeion*, meaning “vessel”, and *sperma,* meaning “seed”. The “vessel” is the carpel. Many flowers have pistils composed of either a single carpel or two more united carpels. A seed develops from an ovule within a carpel and is part of an ovary that becomes a fruit. Although the angiosperms generally have organs and tissues to those of the gymnosperms, the enclosed ovules and seeds of the angiosperms distinguish them from gymnosperms, which have exposed ovules and seeds.

All angiosperms are presently considered to be in the **Phylum Magnoliophyta**. Phylum Magnoliophyta has been divided into two large classes: the **Magnoliopsida** *(dicots*) and the **Liliopsida** *(monocots).*

Since Darwin’s Origin of Species appeared in 1859, there have been two major theories concerning the origin of angiosperms. The older and now more or less disregarded theory was held by the German botanist Adolph Engler and his followers. It suggested that flowering plants evolved from conifers and that primitive flowers are similar in structure to the strobili of conifers.

The most primitive flower is thought to be one with a long receptacle and many spirally arranged flower parts that are separate and not differentiated into sepals and petals. In addition, the stamens and carpels are flattened and numerous. Such flowers are found among relatives of magnolias and buttercups.

Phylum Magnoliophyta - the Flowering Plants

The plants of this phylum vary greatly in size, shape, texture and form. The phylum includes, for example, tiny duckweeds that may be less than 1 millimeter long, all the grasses and palms, many aquatic and epiphytic plants, and most shrubs and trees, including the huge Eucalyptus trees.

A few flowering plants are parasitic. Dodders, for example, occasionally cause serious crop losses as they twine about their hosts and, by means of haustoria, intercept food and water in the host xylem and phloem.

Still others, such as the beautiful snowplant and some of the orchids, are saprophytes (i.e., their nutrition comes mostly from the absorption in solution of dead organic matter). The vast majority of flowering plants, however, produce their food independently through photosynthesis.

Like the gymnosperms, the angiosperms are *heterosporous* (produce two kinds of spores), and the sporophytes are even more dominant than in the gymnosperms. The female gametophytes are wholly enclosed within sporophyte tissue and reduced to only a few cells. At maturity, the male gametophytes consist of a germinated pollen grain with three nuclei.

Development of Gametophytes

While the flower is developing in the bud, a diploid megasporocyte cell differentiates from all the other cells in the ovule. The *megasporocyte* undergoes meiosis, producing four haploid megaspores. Soon after they are produced in most flowering plants, three of these megaspores degenerate and disappear, but the nucleus of the fourth undergoes mitosis, and the cell enlarges. While the cell is growing larger, its two haploid nuclei divide once more. The resulting four nuclei then divide yet another time. Eight haploid nuclei in all are produced. By the time these three successive mitotic divisions have been completed, the cell has grown to many times its original volume. At the same time, two outer layers of cells of the ovule differentiate. These layers, called *integuments*, later become the seed coat of the seed. As they develop, they leave a pore, or gap, called the *microphyle*, at one end (fig. 155).

Fig.155. Gametophytes

At this stage, there are eight haploid nuclei in two groups, four nuclei toward each end of the large cell. One nucleus from each group then migrates toward the middle of the cell. These two central cell nuclei may become a binucleate cell, or they may fuse together, forming a single diploid nucleus. In the group closest to the micropyle, one of the cells functions as the female gamete, or *egg*. The other two cells, called *synergids*, either are destroyed or degenerate. At the other end, the remaining three cells, called *antipodals*, have no apparent function, and later they also degenerate. The large sac constitutes the female gametophyte (megagametophyte), formerly known as the **embryo sac.**

Usually while the megagametophyte is developing, a parallel process that leads to the formation of male gametophytes takes place in the anthers. As the anther develops, four patches of tissue differentiate from the main mass of cells. These patches of tissue contain many diploid microsporocyte cells, each of which undergoes meiosis, producing a quartet of *microspores*. As the anther matures, the walls between adjacent pairs of chambers break down so that only two larger sacs remain.

After meiosis, the haploid microspores in the pollen sacs undergo several changes. The following three changes are the most important:

1. the nucleus in each microspore divides once by mitosis;
2. the members of each quartet of microspores separate from one another;
3. a two layered wall, the outer layer of which is often finely sculptured, develops around each microspore.

When these events are complete, the microspores become **pollen grains**. The outer layer of the pollen grain wall is called the *exine*. The cytoplasm of pollen grain is often rich in vitamins, and pollen is often collected and sold in health-food stores. One of the pollen grain's two nuclei, the generative nucleus, later divides, producing two nuclei that become surrounded by a plasma membrane and function as sperm cells. The remaining vegetative nucleus (often referred to as the tube nucleus) is involved in events that take place after the pollen grain has left the anther.

Classification of Flowering Plants

When the ovary is embedded in the receptacle and other parts, it is said to be an **inferior ovary.** A more primitive **superior ovary** is produced on top of the receptacle with the other flower parts attached around its base.

If a flower has a *calyx*, *corolla*, *stamens*, and a *pistil*, it is complete. If, however, the corolla or other parts are missing, the flower is incomplete. If, as the case with most flowers, both stamens and a pistil are present, it is said to be *perfect*. In some families, however, the flowers are not only incomplete but also have become *imperfect* (unisexual). Each imperfect flower has either stamens or a pistil but not both. The Pumpkin Family (Cucurbitaceae) includes pumpkins, watermelons, cucumbers, and other species with imperfect flowers. When both male and female imperfect flowers occur on the same plant, the species is *monoecious*. If a plant bears only male flowers and other plants of the same species bear only female flowers, the species is said to be *dioecious* (fig. 156).

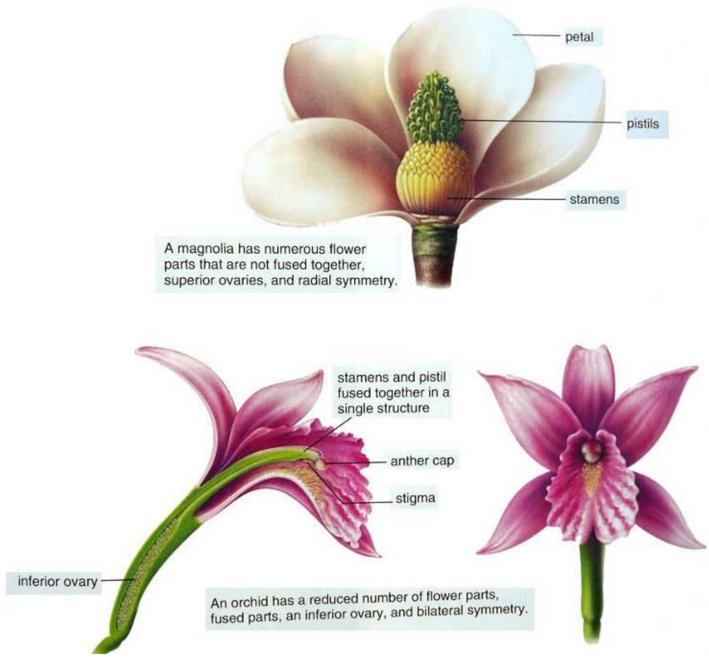


Fig.156. Flowering plants

Pollination ecology

Many insects and animals become dusted with *pollen*, and as they feed or collect nectar, they unknowingly but effectively bring about pollination of the plants they visit. Pollinators are honey bees. Their chief source of food is nectar.

Many bee-pollinated flowers are delicately sweet and fragrant. In contrast, flowers pollinated by beetles tend to have stronger, yeasty, spicy or fruity odors. Beetles don’t have keen visual senses, and flowers pollinated by them are usually white or dull in color. Flies with longer tongues may also pollinate bee-pollinated flowers.

Moth-and butterfly-pollinated flowers often have sweet frangrances. Night-flying moths visit flowers that tend to be white or yellow-colors that stand out against dark backgrounds in starlight or noonlight.

Red flowers are sometimes pollinated by butterflies, some of which can detect red colors, but these insects are more often found visiting bright blue, yellow or orange flowers. The birds do not have a keen sense of smell, but they have excellent vision. The flowers they visit are often bright red or yellow and typically large.

Bat-pollinated flowers, found primarily in the tropics, tend to open only at night when the bats are foraging. These flowers are dull in color, and like flowers pollinated by birds, they either are large enough for the animal to insert part of its head or consist of ball-like inflorescences containing large numbers of small flowers that gust the visitor with pollen.

Chapter 17

KINGDOM – PLANTS (PLANTAE)

DIVISION – ANGIOSPERMAE (MAGNOLIOPHYTA) – ANGIOSPERMS

CLASS – DYCOTYLEDONES (MAGNOLIOPSIDA) – DICOTYLEDONS

Characteristics of dicots:

1. The dicot embryo has two cotyledons;
2. Leaf veins are reticulated;
3. Flower petals are in multiples of 4 or 5;
4. They have taproot system;
5. Secondary growth is often present;
6. Vascular bundles are in a ring;
7. Presence of herbaceous and woody plants;
8. Two seed leaves.

MAGNOLIA FAMILY – MAGNOLIACEAE

The Magnoliaceae consist of species of trees or shrubs. The leaves are simple, spiral, pinnate-netted, and stipulate. The inflorescence is a terminal solitary flower. Flowers are large, bisexual, actinomorphic. The perianth is multiwhorled or spiral. Stamens are numerous, spiral. The gynoecium is superior, spirally arranged ovaries. The fruit is an aggregate of follicles, berries, or samaras; seeds are endospermous, rich in oils and protein.

The members of this family are distributed in tropical to warm temperate regions.

g. Magnolia – Magnolia L.

Height is up to 90ft (27 m), type-evergreen.

The bark is brown to gray, thin, smooth, later developing scales. The leaves are alternate, pinnately veined, leathery, dark glossy above, with a velvety underside. The flower is fragrant, with white petals, 20-30 cm wide. It has bright red fruits. The seeds are kidney-shaped that hang from a red-brown cone-like structure, that is 5-10cm long (fig. 157).

Fig.157. Magnolia

Fig.158.Magnolia vine

g. Magnolia vine – Schisandra Baill.

Schisandra is native to China. Given a structure to climb, the vines can reach up to 8m during one growing season. The plants are deciduous, losing their leaves in the fall and winter to expose the woody stems. The vine produces small white flowers in the spring and fruits as red berries (fig. 158).

LAUREL FAMILY - LAURACEAE

The Lauraceae consist of mostly trees or shrubs with aromatic oil glands. The leaves are evergreen, simple, spiral, whorled or opposite, undivided or lobed pinnate-netted. The inflorescence is cyme or raceme, rarely a solitary flower. The flowers are small, bisexual or unisexual, actinomorphic.

The Lauraceae are distributed in tropical to warm temperate regions. Economic importance includes several timber trees, spice and other flavoring plants (including the bark of *Cinnamomum cassia* and the leaves of *Laurus nobilis*, laurel or bay), and food plants, especially avocado.

g. Bay – Laurus L.

It is a large shrub or small tree bearing simple, leathery leaves with wavy margins. Male and female flowers are usually borne on separate trees. Yellowish-white flowers occur in small clusters and develop, in the case of female trees, into black fruits resembling small olives (fig. 159).

Fig.159. Bay

g. Cinnamon - Cinnamomum L.

G. Cinnamomum is a large evergreen tree of up to 10m in height with simple, alternate leaves that are three-nerved from the base. The flowers are yellowish-white and are followed by round drupes of about 8mm in diameter. The fruit is small and round (fig. 160).

Fig.160. Cinnamon

Camphor tree – Cinnamomum Camphora L. Nees Eberm.

Camphor tree is a large evergreen tree that grows up 20-30m tall. The leaves have a glossy, waxy appearance and smell of camphor when crushed. Flowers are small, white. It produces clusters of black berry-like fruits around 1cm in diameter. The bark is pale and very rough.

g. Avocado – Persea Mill.

An evergreen tree up to 10m with large, simple, bright green leaves that are paler green below. Small, yellowish flowers are borne near the branch tips and they are followed by large, usually pear-shaped, green or purple fruits. The fruit has a thin leathery skin with a thick layer of greenish yellow, butter-textured flesh around a very large seed. Avocado's fruit is berry (fig. 161).

Fig.161. Avocado

WATER –LILY FAMILY - NYMPHAEACEAE

The Nymphaeaceae consist of aquatic, annual or perennial herbs, with a milky latex often present. The underground stems are rhizomatous or tuberous. The leaves are simple, floating. The inflorescence consists of floating or emergent flowers. Flowers are bisexual, actinomorphic, arising from the underground stem. The fruit is a berry or capsule.

Fig.162. Water Lily

g. Water Lily - Nymphaea L.

These are tropical, aquatic perennials. Water Lilies produce handsome, floating foliage. Rhizomes are thin, horizontal growth with rapidly growing eyes along their length. Leaves and flowers are produced along the rhizomes rather than from a specific growing tip or eye.

Water Lilies usually hold their flowers above the surface of the water. There are day-blooming and night-blooming varieties. The flowers are dark raspberry pink with greenish based sepals veined with purple. The green leaves have wavy borders and pointed projections. Fruit is dehiscent fleshy capsule (fig. 162).

SUBDIVISION RANUNCULIDAE

Fig.163. Common barberry

BARBERRY FAMILY - BERBERIDACEAE

The Berberidaceae consist of perennial trees, shrubs or herbs. The leaves are whorled or spiral (rarely opposite), petiolate. The inflorescence is a raceme, spike, panicle, cyme. The flowers are bisexual, actinomorphic. The gynoecium is with a superior ovary. The fruit is a berry.

g. Common barberry - Berberis L.

Barberry is a thorny shrub up to 3m high with small leathery leaves in clusters along the stem, small yellow flowers and with edible, bright red berries (fig. 163).

BUTTERCUP FAMILY (meaning 'little frog') - RANUNCULACEAE

The Ranunculaceae consist of terrestrial or aquatic, perennial or annual shrubs, herbs, or lianas. The leaves are spiral, simple to compound, stipulate. The inflorescence is raceme or solitary flower. The flowers are bisexual, rarely unisexual, actinomorphic or zygomorphic. The ovaries are superior.

g. Spring Adonis - Adonis L.

A small perennial herb with divided, feathery leaves and large, bright yellow or red actinomorphic flowers produced in early spring. They have thick dark grey rhizomes. These plants are toxic. Fruit is achene (fig. 164).

Fig.164. Spring Adonis

Fig. 165. Larkspur

g. Larkspur - Delphinium L.

Delphinium is a genus of about 300 species of perennial flowering plants in the Ranunculaceae family.

The leaves are deeply lobed with 3-7 toothed, in palmate shape. The main flowering stem is erect, it is topped with a raceme of many flowers, varying in color from purple and blue to red, yellow or white. The flower has 5 petal-like sepals, which grow together to form a hollow pocket with a spur at the end, which gives the plant its name. There is only one true petal. The seeds are small and shiny black. Most species are toxic. Fruit is follicle (fig. 165).

g. Aconite, Monkshood - Aconitum L.

Aconite is a perennial herb with erect flowering stems that grow from a tuberous root. The stems bear deeply dissected, toothed leaves and clusters of purple to blue flowers. Enlarged sepals (calyx lobes) from the conspicuous part of the flower – the upper one is characteristically hood-shaped and gives the flowers their distinctive appearance. The fruit is an aggregate of follicles with many-seeded structure. The roots of A. ferox contain large quantities of deadly poison (alcaloids) (fig. 166).

Fig.166. Aconite, Monkshood

POPPY FAMILY – PAPAVERACEAE

The Papaveraceae consist of annual or perennial herbs, shrubs or small trees, with milky latex. The leaves are spiral to subopposite, usually lobed or divided. The inflorescence is a solitary flower or cyme. The flowers are bisexual, actinomorphic, zygomorphic. The gynoecium is with a superior ovary. The fruit is a dehiscent or capsule. The seeds are oily endospermous.

Papaver somniferum, opium poppy, is an addictive narcotic plant, the source of heroin and very important medicinally, e.g., as the source of the analgesic morphine and other alkaloids.

Fig.167. Celandine

g. Celandine - Chelidonium L.

A perennial herb with yellow-green, deeply lobed or feathery leaves, which are alternate. The flowers are orange-yellow, inflorescence is an umbel. All parts of the plant contain yellow to orange colored latex (fig. 167).

g. Yellow hornpoppy – Glaucium Grantz

Glaucium is a summer flowering plant in the Papaveraceae family. All parts of the plant, including the seeds, are toxic and can produce a range of symptoms including respiratory failure resulting in death.

The thick, leathery deeply segmented, wavy, bluish-grey leaves are coated in a layer of wax. The sepals, petals and stamens have a similar structure as a *Red Poppy*, except that the sepals are not hairy. Large quantities of seeds are held in siliqua-like capsules (fig. 168).

g. Poppy - Papaver L.

An erect annual herb (up to 1.5m), bearing hairy, grey-green feathery or lobed leaves, with attractive white, red or purple, dark in the base flowers and characteristic spherical or oval fruit capsules, containing numerous greyish to black seeds (fig. 169).


Fig.168. Yellow hornpoppy


Fig. 169. Poppy

SUBDIVISION CARYOPHYLLIDAE

PINK FAMILY - CARYOPHYLLACEAE

Family Caryophyllaceae, commonly called the pink family, is a family of flowering plants. This cosmopolitan family of mostly herbaceous plants consists of annuals and perennials, a few species are shrubs or small trees. The leaves are almost opposite, rarely whorled. The flowers are terminal, single or branched in cymes. The inflorescence is dichasial. Petals are 4 or 5, sepals 5. The fruit is a capsule containing a single seed.

g. Soapwort - Saponaria L.

Soapwort is a perennial herb with leafy stems arising from thin, underground rhizomes. The bright green leaves are borne in opposite pairs and the attractive, tubular pink flowers occur in clusters at the tips of the stems (fig. 170).

Fig.170. Soapwort

BUCKWHEAT FAMILY – POLYGONACEAE

The Polygonaceae consist of annual or perennial herbs, shrubs, lianas, vines, or trees. The stems often have nodes. The leaves are usually spiral, simple. The flowers are small, bisexual or unisexual, actinomorphic. The gynoecium is with a superior ovary. Nectaries are often present. The fruit is usually a 3-sided achene. The seeds are endospermous, oily and starchy.

g. Knotweed – Polygonum L.
sp. Water pepper - Polygonum hydropiper L.

It grows in damp places and shallow water. It has some use as a spice because of its punget flavour. This is an annual plant, with a simple or branched, erect stem, of reddish or greenish color. The leaves are lanceolate. The flowers are borne in a panicled raceme. The green calyx is usually 4-parted, stamens 4. Fruit is a triangular achene (fig. 171).

sp. Knotweed, Knotgrass - Polygonum aviculare L.

A spreading, wiry annual weed with sparse, slender stems and small, narrow, almost stalkless elipsoid alternate leaves. Minute white or reddish flowers are borne in the leaf axils. Fruit is a triangular achene (fig. 172).

Fig.171. Water pepper

Fig. 172. Knotgrass

sp. European bistort, Snakeweed – Polygonum bistorta L.

It is a herbaceous flowering plant. The Latin name "bistorta" refers to the twisted appearance of the root (snake root). They produce tall stems ending in single terminal racemes with pink-rose coloured flowers. The foliage is normally basal with a few smaller leaves produced near the lower end of the flowering stems. The leaves are oblong ovate or triangular ovate in shape and narrow at the base. The petioles are winged. The flowers consist of 5 coloured sepals. The fruit is 3-seeded (triangular achene) (fig. 173).

Fig.173. Snakeweed

Fig. 174. Yellow dock

g. Yellow dock - Rumex L.

Yellow dock is a robust, leafy herb of up to 1.5m in height, bearing large leaves with distinctive sheathing leaf bases. Numerous small greenish flowers are produced on an extensive panicle, followed by small, reddish brown, winged achene fruit (fig. 175).

g. Rhubarb - Rheum L.

It is a genus of about 60 perennial plants. The species have large triangular shaped leaves with long fleshy petioles. The flowers are small, greenish-white to rose-red. While the leaves are toxic, the stalks are used as food. The fruits are three-sided achene with winged sides.

Fig. 175. Rhubarb

SUBDIVISION HAMAMELIDIDAE

OAK FAMILY – FAGACEAE

The Fagaceae consist of trees or shrubs. The leaves are simple, undivided to divided, usually spiral, rarely opposite or whorled. The inflorescence is usually unisexual, the male inflorescence is a catkin or head. The flowers are small, unisexual, actinomorphic. Fruit is acorn.

Economically important are *Quercus* (oak), *Fagus* (beech), and *Castanea* (chestnut).

g. Oak – Quercus L.

A large tree (up to 50m), easily recognized by leaves, lobed wavy leaf margins, long flowering stalks and the characteristic fruits - acorns. In Europe the oak bark is used as a source of tannins for wine taste improvement (fig. 176).

Fig.176. Oak

Fig. 177. Birch

BIRCH FAMILY - BETULACEAE

The Betulaceae consist of trees or shrubs. The leaves are simple, usually spiral, with toothed margin. The inflorescences are unisexual, the male inflorescence is a catkin, the female - a short, erect catkin.

The gynoecium is with superior ovary. The fruit is a nut or 2-winged samara. The seeds are with or without endosperm.

g. Birch - Betula Roth.

Birch is an erect tree (up to 30m in height), with a characteristic white papery bark. Flowers appear in catkins. *Betula pubescens* (white birch) and *Betula pendula* are commonly hybridised. Birch has toothed leaves with short, soft hairs on both surfaces (fig. 177).

g. Alder – Alnus (L.) Gaertn

Alnus grows to a height of 20-30m. It has short-stalked rounded leaves, with toothed margin. When young they are glutinous, later become glossy dark green.

Flowers are catkins: cylindrical male catkins are reddish in color; the female flowers are smaller and dark brown in color, hard, woody, and similar to some conifer cones. When the small winged seeds appear, woody, blackish cones remain (fig. 178).

WALNUT FAMILY - JUGLANDACEAE

The Juglandaceae, also known as the Walnut Family, is a family of trees, or sometimes shrubs. Members of the walnut family have large aromatic leaves, which are usually alternate, or opposite. The leaves are pinnately compound.

The trees are wind-pollinated, and the flowers are usually arranged in catkins.

The Persian walnut, *Juglans regia*, is one of the major nut crops in the world.

g. Walnut – Juglans L.

Walnut is a tree of up to 25m in height, with large compound leaves bearing five to nine leaflets. The fruit is a drupe with a fleshy outer pericarp and a bony endocarp that encloses the two edible cotyledons (known as walnuts). Another source of nuts is the black walnut or American walnut (*J. nigra*) (fig. 179).

Fig.178. Alder

Fig. 179. Walnut

SUBDIVISION DILLENIIDAE

CAMELLIA FAMILY - THEACEAE

The Theaceae is a family of flowering plants, composed of shrubs and trees. Plants in this family are characterized by simple leaves that are alternate and usually glossy. Most of the genera have evergreen foliage. The flowers are usually pink or white and large, often with a strong scent.

The fruits are capsules. The seeds are few, sometimes winged.

g. Tea plant – Camellia L.

Tea plant is a large shrub with glossy and attractive white flowers. The leaves are evergreen, short stalked leathery, ellipsoid, the upper surface is dark green. The flowers are white, borne in the leaf's axils. Fruit is a capsule (fig. 180).

VIOLET FAMILY - VIOLACEAE

The Violaceae consist of herbs, shrubs, trees or lianas. The leaves are simple, undivided to divided, usually spiral and stipulate. The inflorescence is in heads, panicles, or racemes. The flowers are usually bisexual, zygomorphic. The fruit is a berry or a capsule, rarely a nut. The seeds are endospermous.

g. Violet – Viola L.

Violet is an annual or short-lived perennial herb with rounded to heart-shaped leaves which can be in rosette, and characteristic three-colored flowers. Fruit is a capsule (fig. 181).

Fig.180.Tea plant

Fig. 181. Violet

PASSION FLOWER FAMILY - PASSIFLORACEAE

The Passifloraceae consist of lianas, shrubs, or trees. The stems have tendrils in lianous species. The leaves are simple, rarely compound. The inflorescence is a cyme or a solitary flower. The flowers are bisexual or unisexual, actinomorphic. The gynoecium is with a superior ovary. The fruit is a berry or a capsule. The seeds are endospermous.

g. Passion flower – Passiflora L.

A woody perennial vine climbs with tendrils. It has hairless, lobed leaves, large solitary, very characteristic, white and violet flowers. The origin is said to be a “Calvary Lesson” by Catholic missionaries in South America. The numerous petaloid corona threads are seen as a symbol for the Crown of Thorns, the five stamens for the Wounds, the three stigmas for the Nails on the Cross and the five sepals and five petals as the ten Apostles (excluding Judas and Peter). The fruit is a characteristic many-seeded berry (fig. 182).

Fig.182. Passion flower *Fig. 183. Saint-John's wort*

ST. JOHN'S WORT FAMILY - HYPERICACEAE

These are perennial herbs with simple, opposite leaves. The leaves are often covered with dark glands or clean dots. The petals are usually yellow. The flowers are regular and bisexual with 4 to 5 sepals, and 10 or more stamens. The ovary is superior and consists of 3 or 5 united carpels. The fruit is a capsule.

g. Saint-John's wort – Hypericum L.

The most famous sp. is *Hypericum perforatum* (St. John's-wort). They vary from annual or perennial herbaceous herbs 5-10 cm tall to shrubs and small trees. The leaves are opposite, simple, oval, 1-8cm long. The flowers vary from pale to dark yellow with 5 (or 4) petals. The fruit is usually a dry capsule (fig. 183).

CUCUMBER FAMILY - CUCURBITACEAE

The Cucurbitaceae consist of vines. The leaves are simple, palmately lobed, spiral. The flowers are usually unisexual, actinomorphic.

The Cucurbitaceae have largely worldwide distributions. The economic importance includes important food crops such as *Citrullus lanatus* (watermelon), *Cucumis melo* (melons), *Cucumis sativa* (cucumber, squashes, pumpkins), those of *Luffa* (luffa) are used as a sponge.

g. Bryony - Bryonia L.

Bryony is a perennial plant with creeping branches growing from a large, tuberous rootstock. Leaves are palmately lobed and flowers are in axillary clusters. The fruit is a smooth, globular berry (fig. 184).

CABBAGE FAMILY - BRASSICACEAE (CRUCIFERAE)

The Brassicaceae consist of usually herbs, rarely shrubs. The leaves are simple, often lobed to divided, spiral. The inflorescence is a raceme. The flowers are bisexual, usually actinomorphic. The fruit is a silique. The Brassicaceae as vegetable plants have a worldwide distribution. The economic importance includes broccoli, brussels sprouts, cauliflower, cabbage.

g. Wallflower - Erysimum L.

Wallflowers are small, annual, short-lived perennial herbs or sub-shrubs. Most species have erect stems with T-shaped trichomes. The leaves are narrow and sessile. The lower leaves are linear. The inflorescence is in raceme, with bright yellow to red or pink flowers. The fruit is multiseeded silique (fig. 185).

Fig.184. Bryony

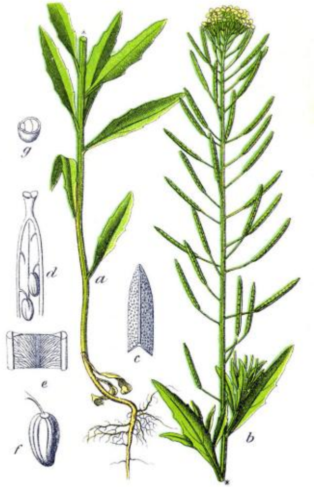


Fig. 185. Wallflower

g. Capsella (Shepherd's - purse) – Capsella L. Medic.

This well-known weed is a small annual or biennial herb with a rosette of deeply lobed leaves directly on the ground. Small, white flowers are borne on a single central stalk. The characteristic heart-shaped fruit resembles a traditional shepherd's purse (fig. 186).

Fig.186. Capsella *Fig. 187. Cabbage*

g. Cabbage - Brassica L.

An erect leafy annual herb with lobed leaves, yellow flowers and oblong, smooth seeds capsules. White mustard (*Sinapis alba*) is quite similar but has distinctive hairy fruit capsules (fig.187).

g. Mustard - Sinapis L.

The stems are erect, branched, with spreading hairs especially near the base. The leaves are petiolate, the basal leaves are oval, lanceolate. The inflorescence is a raceme made up of yellow flowers having 4 petals. The fruit is a silique that is flattened-quadrangular (fig. 188).

Fig.188. Mustard

Fig.189. Bearberry

HEATH FAMILY - ERICACEAE

The Ericaceae consist of shrubs and small trees, rarely lianas. Some taxa are mycotrophic (‘fungus feeding’, obtaining nutrition from mycchorizal fungi in the soil). The leaves are simple, spiral, opposite, evergreen. The inflorescence is a raceme, head-like cluster, or of solitary flowers. The flowers are bisexual, actinomorphic. The fruit is a capsule, berry, or drupe. The seeds are endospermous.

g. Bearberry - Arctostaphylos L. Spreng.

Bearberry is a variable evergreen shrub with small bright green leaves. The branches grow flat along the ground and are smooth, with reddish brown, flaking bark. Delicate, white or pinkish un-shaped flowers are followed by bright red berries (fig. 189).

g. Bilberry - Vaccinum L.

Vaccinum is a genus of shrubs. The fruit of many species are eaten by humans and some have commercial importance, including the cranberry, bilberry, cowberry, and huckleberry. The fruit develops from an inferior ovary, and is a berry; it is usually brightly colored, often being red or bluish with purple juice (fig.190).

PRIMROSE FAMILY – PRIMULACEAE

The Primulaceae are herbaceous plants, usually perennial but some are annual. The family has leaves that are basal, opposite, or alternate, but usually entirely covered with glandular hairs. The flowers grow in clusters of different shapes. They are symmetric, bisexual and usually consist of 5 parts. The fruit is a capsule with many seeds.

Some members of the family are poisonous, and a few have useful medicinal properties.

g. Cowslip – Primula Jaeq.

It is an attractive perennial herb with a basal rosette of wrinkled leaves arising each spring from a fleshy rhizome. Golden yellow, strongly scented flowers are borne in multi-flowered clusters on slender stalks. The fruit is a capsule (fig. 191).

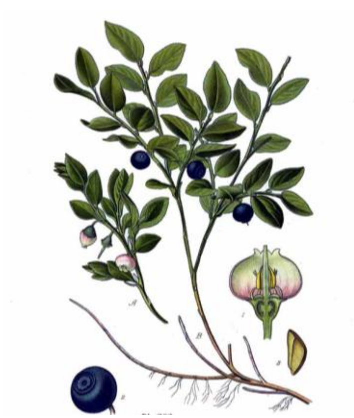


Fig.190. Bilberry

Fig.191. Cowslip

LINDEN FAMILY - TILIACEAE

They are trees, shrubs, or herbs. The leaves are simple, alternate or rarely opposite, basally veined, entire or serrate, sometimes lobed. The inflorescence is a cymose. The flowers are bisexual or unisexual, actinomorphic. The fruit usually is a capsule, sometimes samara.

g. Lime, Linden – Tilia L.

Lime or linden is a deciduous tree of up to 30m in height bearing large, heart-shaped leaves with serrate margins and brown hairs along the veins on the lower sides. Groups of five to ten greenish yellow flowers with numerous stamens are characteristically borne on a slender stalk hanging down from a large, oblong, leaf-like bract. The fruit is samara (fig. 192).

MALLOW FAMILY - MALVACEAE

The Malvaceae consist of shrubs, or herbs, often with either stellate trichomes or peltate scales. The leaves are simple or palmately compound, sometimes lobed to divided, usually spiral. The inflorescence is of solitary or paired flowers. The flowers are bisexual, actinomorphic. The fruit is a capsule or samara.

Economical importance includes medicinal plants, several fiber plants, especially *Gossypium spp*. (cotton, the world's most important fiber plant); food and flavoring plants, such as *Theobroma cacao* (cacao, the source of chocolate).

Fig.192. Linden

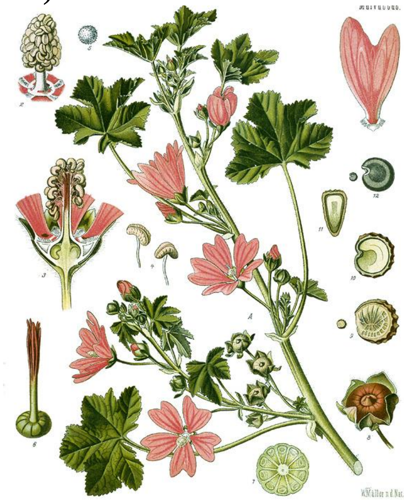


Fig. 193 Mallow

g. Mallow - Malva L.

Mallow is a biennial herb or shrub (up to 1m) with rounded, lobed and dentate leaves. The attractive pink flowers have five petals with characteristic dark veins at their bases. The fruit is a samara (fig. 193).

g. Marshmallow – Althaea L.

It is an erect perennial plant reaching 1.5m in height. The leaves are shallowly 3-5 lobed, the petals are pale pink, or rarely white in color. The fruit is a samara (fig. 194).

Fig. 194. .Marshmallow

Fig. 195. Stinging nettle

THE NETTLE FAMILY - URTICACEAE

The Urticaceae are monoecious or dioecious herbs, shrubs or small trees, often with specialized stinging hairs. The leaves are alternate or opposite, simple, and almost always stipulate. The minute, unisexual flowers are in cymose clusters.

The fruit is an achene.

g. Stinging nettle – Urtica L.

The perennial stinging nettle (*U. dioica*) is an erect herb (up to 1.5 m) with drooping, somewhat grey leaves. The slender flower clusters are longer than the leaf stalks in both male and female plants (fig. 195).

SUBDIVISION ROSIDAE

SAXIFRAGE FAMILY (LATIN FOR ‘ROCK BREAKING’) - SAXIFRAGACEAE

The Saxifragaceae consist of perennial herbs or subshrubs. The leaves are usually spiral, simple, pinnate, or palmate. The inflorescence is a cyme, raceme, or of solitary flowers. The flowers are bisexual, actinomorphic. The gynoecium is with a superior ovary. The fruit is a berry or a capsule.

g. Elephant’s ears - Bergenia L.

They are rhizomatous, evergreen perennials with a spirally arranged rosette of leaves and pink flowers produced in a cyme. The leaves are large, leathery, ovate or cordate with wavy edges. They have cone-shaped pink flowers. The fruit is a capsule (fig. 196).

g. Blackcurrant - Ribes L.

Blackcurrant is a shrub of about 2m in height, with deeply lobed, doubly dentate leaves. The white flowers are borne in short clusters, and develop into brownish black, shiny fruits. The fruit is berry, used to make jam and jelly (fig. 197).

Fig.196. Elephant's ears

Fig.197. Blackcurrant

ROSE FAMILY - ROSACEAE

The Rosaceae consist of trees, shrubs, or herbs. The leaves are spiral (rarely opposite), simple or compound, undivided to divided. The inflorescence is variable. The flowers are bisexual, actinomorphic. The gynoecium is with a superior or inferior ovary. The fruit is a drupe, pome, achene, or capsule.

The family is economically very important as the source of many cultivated fruits, including apple, plum, almond, apricot, cherry, peach, pear, as well as essential oils (e.g., *Rosa*).

g. Raspberry (Blackberry) - Rubus L.

Blackberry is a prickly shrub bearing compound leaves with prickles along the midrib, and hairs on the lower surface. The flowers are white to pale pink and are followed by clusters of black berries. Raspberry (*R. idaeus*) is less prickly but has a dense layer of white hairs on the lower surface of the leaves and the fruit is pinkish red when ripe. Raspberries are aggregate fruits (fig. 198).

Fig.198. Ruspberry

Fig. 199. Strawberry

g. Strawberry - Fragaria L.

Wild strawberry is a perennial herb that spreads along the ground by numerous runners (stolons), a root at the nodes to produce new plants. The leaves are divided into three broad leaflet faces. The small white flowers are borne on slender stalks, followed by small, red edible fruits (technically a fleshy receptacle with numerous achenes on the surface) (fig. 199).

g. Tormentil - Potentilla L.

Tormentil is a small, much-branched herb. The sparsely hairy leaves are dissected into four or five dentate leaflets which are borne directly on the stems (leaf stalks are absent). The flowers are solitary, relatively small and yellow (fig. 200).

g. Burnet – Sanguisorba L.

Burnet is an erect perennial herb of up to 1m in height, with feathery compound leaves and slender, branched flowering stalks bearing dense, oblong heads of purple flowers. The plant was previously known as *Poterium officinalis* (fig. 201).

Fig.200. Tormentil

Fig. 201. Burnet

g. Hawthorn - Crataegus C. Koch.

Crataegus species are shrubs or small trees (up to 10m), with lobed leaves, thorny branches and white flowers, followed by red fruits. Two species (that readily hybridise) are mostly used for medicine, namely *C. monogyna* and *C. laevigata.* The fruit, known as a "haw", is berry-like but structurally is a pome containing from 1 to 5 pyrenes (fig. 202*)*.

g. Rose - Rosa L.

The dog rose is a woody creeper (up to 5m), with curved thorns on the stem, leaves with about three pairs of toothed leaflets, attractive pink flowers and fleshy red fruits known as rose hips. Various species are acceptable sources of rose hips and seeds (fig. 203).

Fig.202. Hawthorn

Fig. 203. Rose

BEAN/PEA FAMILY - FABACEAE (LEGUMINOSAE, PAPILIONACEAE)

The Fabaceae consist of herbs, shrubs, trees, or vines, with spines sometimes present. The roots of many members have a symbiotic association with nitrogen-fixing bacteria, which induce the formation of root nodules. The leaves are usually compound (pinnate, bipinnate, trifoliate, or palmate), sometimes simple, usually spiral. The flowers are usually bisexual, sometimes unisexual, zygomorphic. The upper-most petal is the largest (*the banner*). The petals on two sides of the banner are called *wings*. The lower-most two petals are fused, forming the boat, called *the keel*. Stamens are 10, fused, or not (or only 9 are fused). The fruit is generally a legume.

Economically, the legumes are one of the important plant groups, being the source of numerous pulses such as peanut, soybeans, lentils, peas.

g. Thermopsis - Thermopsis R. BR.

This is a genus of the family Leguminosae. The plants are perennial herbs with long, spreading rhizomes. The leaves are alternate, stipulate; the flowers are usually yellow and gathered in apical racemose inflorescences. The fruit is a two-seeded or many-seeded legume (fig. 204).

g. Sweet clover - Melilotus L.

It is an erect herb with trifoliolate dentate leaves, small yellow flowers in dense oblong clusters and small, almost spherical, indehiscent pods (fig. 205).

Fig.204. Thermopsis

Fig. 205. Sweet clover

g. Goat's rue - Galega L.

Goat's rue is a perennial herb of up to 1 m in height, with pinnately compound leaves and attractive white or pink legume flowers arranged in dense, many-flowered clusters (fig. 206).

Fig.206. Goat's rue

Fig. 207. Milkvetch

g. Milkvetch- Astragalus L.

Astragalus is a perennial herb. It has pinnately compound leaves and 10 to 15 yellowish flowers arranged in short, oblong clusters. The roots are fibrous and yellowish brown (fig. 207).

g. Trefoil - Trifolium L.

The clover or trefoil has a cosmopolitan distribution. They are small annual, biennial, or short-lived perennial herbaceous plants. The leaves are trifoliate (rarely 5 or 7-foliate), and heads of small red, purple, white or yellow flowers, the small, few-seeded pods are enclosed in a calyx (fig. 208).

Fig.208. Trefoil

Fig. 209.Lequorice

g. Liquorice - Glycyrrhiza L.

Liquorice is a perennial herb of up to 1m high, with branched rhizomes and woody stems bearing compound leaves and pale purple or white flowers. The fruits are pods, each pod contains 2-5 brown to blackish seeds (fig. 209).

g. Cassia - Cassia L. (Senna)

This perennial subshrub has thin, paired, pale green leaflets, yellow flowers, and distinctive, oblong, fruit pods in early summer. The bark is used in tropical Asia for leather tanning. The fruit is a long legume with pungent odor (fig. 210).

Fig. 210.Cassia

MYRTLE FAMILY - MYRTACEAE

The Myrtaceae consist of trees and shrubs. The roots possess mycorrhizae. The leaves are opposite or spiral, simple. The flowers are bisexual, actinomorphic. The fruit is a berry or a capsule.

The members of this family have distributions in warm tropics. The economic importance includes important timber trees, especially

Eucalyptus, edible fruits (*Psidium guajava*, guava), spices (*Syzygium aromaticum*, cloves), oils (*Eucalyptus*).

Sp. Clove tree –Syzygium aromaticum L. (Eugenia caryophylata L.)

The clove tree (fig. 211) is an evergreen tropical plant that may reach 12m, bearing simple, glossy green leaves and small white flowers with numerous stamens. The dried flower buds are used as a spice. Another species of *Syzygium* that is well known for its medicinal properties is the jambolan (*S. cumini*). The fruit is a berry.

g. Eucalyptus - Eucalyptus Her.

The eucalyptus is a very large tree (up to 60m) with a characteristic shedding bark, grey foliage and white flowers. The leaves are rounded and opposite when young and narrow, lanceolate on the elder branches. Also distinctive are the woody capsules (fig. 212).

Fig.211. Clove tree

Fig. 212. Eucalyptus

CITRUS FAMILY - RUTACEAE

The Rutaceae consist of trees, shrubs, lianas or rarely herbs. The stems of some taxa have thorns. The leaves are simple, trifoliate, to pinnate. The inflorescence is a cyme or raceme, rarely of solitary flowers. The flowers are usually bisexual and actinomorphic. The fruit is a drupe, or hesperidium. The economic importance includes many important fruits, among them *Citrus* (oranges, grapefruits, lemons, limes, etc.).

g. Lemon tree - Citrus Burm.

Lemon is a small, evergreen tree (up to 6m), easily recognized by the scarcely winged leaf stalks and the flowers, which are not pure white but tinged purple. The fruits are hesperidiums (fig. 213).

THE FLAX FAMILY - LINACEAE

The Linaceae is a family of flowering plants. The family is cosmopolitan. The leaves are always simple; the arrangement varies from alternate to opposite or whorled. The flowers are pentameric or tetrameric. The fruits are capsules or drupe-like.

g. Flax, Linseed – Linum L.

An erect annual herb of up to 1m in height with slender stems bearing small, hairless leaves and attractive blue flowers. The fruit capsules contain reddish-brown, smooth seeds. Some cultivars are grown for stem fibers (flax); others for the seeds or seed oil (fig. 214).

Fig.213. Lemon tree

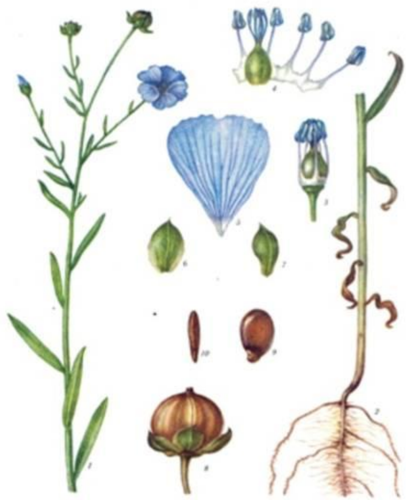


Fig. 214. Flax, Linseed

BUCKTHORN FAMILY - RHAMNACEAE

The Rhamnaceae consist of trees, shrubs, lianas, or rarely herbs. The roots of some taxa are associated with nitrogen-fixing bacteria. The stems are sometimes modified as thorns, tendrils. The leaves are simple, pinnately or palmately veined, spiral or opposite, with spines. The inflorescence is racyme. The flowers are unisexual or bisexual, actinomorphic. The fruit is a drupe.

g. Buckthorn – Rhamnus L.

Buckthorn is a woody shrub of 3m in height, with opposite, finely toothed leaves borne on spiny branches. The yellowish green flowers are borne in clusters in the leaf axils. These are followed by spherical, shiny fruits (drupes) that are initially red but black when they ripen (fig. 215).

Fig.215. Buckthorn

Fig. 216. Glossy buckthorn

g. Glossy buckthorn - Frangula L.

Frangula is a genus of shrubs or small trees of the family Rhamnaceae. The branches are not spiny, and the buds are without scales. The leaves are alternate and simple. The flowers are small and bisexual. The fruit is drupe, juicy and globular (fig. 216).

OLEASTER FAMILY - ELAEAGNACEAE

The Elaeagnaceae is a plant family with small trees and shrubs. They are commonly thorny, with simple leaves often coated with tiny scales or hairs. Most of the species are *xerophytes* (found in dry habitats). The fruit is an achene or a flashy drupe containing a single seed.

The Elaeagnaceae often harbor nitrogen-fixing actinomycetes of the genus *Frankia* in their roots, making them useful for soil reclamation.

Fig. 217. Sea buckthorn

g. Sea buckthorn – Hippophae L.

They are commonly thorny, with simple leaves often coated with tiny scales or hairs. Most of the species are *xerophytes* (found in dry habitats). The flowers are in racemes, they are odorless. The fruit is an achene, enclosed in a fleshy *hypanthium* (often drupe-like- fleshy outside, bony within) (fig. 217).

GINSENG FAMILY - ARALIACEAE

The Araliaceae consist of trees, shrubs, lianas, or herbs. The leaves are palmate, pinnate, or simple, usually spiral, rarely opposite or whorled. The inflorescence is usually terminal umbel, head. The flowers are usually bisexual, actinomorphic. The fruit is a drupe or berry. The plant tissues usually have secretary canals.

g. Ginseng - Panax C. A. Mey

A small perennial geophyte with a single stem emerging every year from a short rhizome attached to a fleshy root. One to four palmately compound leaves are formed at a single node which also bears a single cluster of small white flowers, that each develops into a fleshy, bright red fruit. The plant root's characteristic shape resembles a person's legs (fig. 218).

g. Siberian Ginseng - Eleutherococcus

Siberian ginseng is a woody shrub with erect stems, compound leaves and flowers produced in multi-flowered umbels. The roots and rhizomes of spikenard (*Aralia racemosa*) are traditional *panacea* (cure all) (fig. 219).

Fig.218. Ginseng

Fig. 219.Siberian Ginseng

g. Spikenard - Aralia Rup. Et Max.

Aralia is a genus of evergreen trees, shrubs, and rhizomatous herbaceous perennials. Aralia plants vary in size, with some herbaceous species only reaching 50cm in height, while some are trees growing up to 20m tall.

Aralia plants have large bipinnate (doubly compound) leaves clustered at the ends of the stems. The flowers are whitish or greenish, occur in terminal panicles, and the spherical purple berry-like fruits (fig. 220).

Fig. 220. Spikenard

CARROT FAMILY - APIACEAE (UMBELLIFERAE)

The Apiaceae consist of herbs, less often shrubs or trees. The leaves are usually pinnate, spiral, with a broad sheathing base. The inflorescence is a compound umbel. The flowers are small, bisexual, actinomorphic. The fruit is a *schizocarp*, composed of two *mericarps*. The seeds are oily.

Economically important members include food, herb and spice plants, such as *Anethum* (dill); *Apium* (celery); *Carum* (caraway); *Coriandrum* (coriander); *Cuminum* (cumin); *Daucus* (carrot); *Foeniculum* (fennel); and *Petroselinum* (parsley). Some species are poisonous, such as *Conium maculatum*, poison hemlock (an extract of which Socrates drank in execution).

g. Coriander - Coriandrum L.

An annual herb with aromatic leaves and pale pink flowers arranged in umbels. The upper leaves are much dissected and feathery in appearance; the lower ones are undivided and quite different in shape. The small, dry, spherical fruits (schizocarp) split into two mericarps (fig. 221).

Fig.221. Coriander

Fig. 222. Poison hemlock

g. Poison hemlock – Conium L.

This is a genus of highly poisonous perennial herbaceous flowering plants. The stems are smooth green, usually spotted with red or purple on the lower half of the stem. The leaves are divided. The flowers are small, white, in umbels. When crushed, the leaves and root have unpleasant odor (fig. 222).

g. Fennel - Foeniculum L.

It is an erect, perennial herb of up to 1.5 m in height. The leaf stalks form sheaths around the thick stems and the leaves are finely divided, giving them a feathery appearance. The small yellow flowers are borne in umbels (fig. 223).

Fig.223. Fennel

Fig. 224. Dill

g. Dill - Anethum L.

Dill is an annual herb with bright green leaves that are pinnately divided into numerous thin segments, giving them a feathery appearance. The typical flower heads are borne at the tips of hollow stems and the small, dry fruits are flattened, with pale brown, narrow marginal wings (fig. 224).

g. Caraway - Carum L.

Caraway is a biennial herb with compound, feathery leaves and small white flowers arranged in umbels. The small dry fruits are dark brown (fig. 225).

g. Anise - Pimpinella L., Anisum L.

An erect annual, bearing variable leaves on slender stalks. The basal leaves are more or less round and undivided, while the upper ones become more divided. Numerous small white flowers are borne in a typical umbel, and are followed by small grey green fruits (fig. 226).

Fig.225. Caraway

Fig. 226. Anise

g. Celery - Apium L.

Apium is a genus of flowering plants. They are medium to tall biennial or perennial plants growing on the wet ground. They grow up to 1m high and have pinnate to bipinnate leaves and small white flowers in compound umbels (fig. 227).

Fig.227. Celery

g. Wild carrot - Daucus L.

Wild carrot is a biennial herb with a single, erect stem, feathery leaves, small white flowers and small dry fruits in characteristic umbels, surrounded by finely branched bracts. Wild carrot - *D. carota subsp.* – has a thin, white inedible root, while the common cultivated carrot is edible (fig. 228).

g. Parsley - Petroselinum Hoffm.

Parsley is a biennial herb with a fleshy root and finely divided, compound and curly leaves in basal rosette. The greenish yellow flowers and small dry fruits are formed on erect double umbels in the second growing season (fig. 229).

Fig.228. Wild carrot *Fig. 229. Parsley*

HONEYSUCKLE FAMILY – CAPRIFOLIACEAE (VIBURNACEAE)

The Caprifoliaceae consist of shrubs, trees, lianas or herbs. The leaves are simple, opposite. The inflorescence is usually a cyme. The flowers are bisexual. Nectaries are often present on the inner corolla tube. The fruit is a capsule, berry, or drupe. The seeds are oily, with endosperm.

g. Black haw – Viburnum L.

Black haw is a woody, deciduous shrub of up to 4m in height, with lobed leaves, clusters of small, white flowers. The fruit is a spherical, oval, flattened drupe, red to purple, blue or black, containing a single seed (fig. 230).

VALERIAN FAMILY - VALERIANACEAE

The Valerianaceae consist of herbs, rarely shrubs. The leaves are simple or pinnate, opposite. The inflorescence is compound of cyme units. The flowers are usually bisexual. The fruit is an achene, sometimes winged. The seeds have an oily endosperm.

g. Valerian – Valeriana L.

Valerian represents a species complex; it is an erect perennial herb with creeping, aromatically smelly rhizomes, somewhat fleshy roots, hollow stems, compound leaves and small white or pinkish flowers, arranged in flat- topped terminal clusters (fig. 231).

Fig.230. Black haw

Fig. 231. Valerian

SUBDIVISION LAMIIDAE

COFFEE FAMILY - RUBIACEAE

The Rubiaceae consist of trees, shrubs, lianas or herbs. The leaves are simple, undivided and entire, whorled or spiral. The inflorescence is a cyme, rarely of solitary flowers. The flowers are usually bisexual. The fruit is a berry, capsule, drupe. The seeds are usually with endosperm.

The economic importance includes *Cinchona*, the source of quinine used to treat malaria, *Coffea arabica* and other species, the source of coffee.

g. Madder - Rubia L.

This climbing or rambling herb has whorls of leathery, pointed leaves, and clusters of yellowish-green flowers from summer to autumn, followed by small, fleshy, purple-brown berries (fig. 232).

g. Cinchona tree – Cinchona L.

They are large shrubs or small trees with evergreen foliage. The leaves are opposite, rounded to lanceolate. The flowers are white, pink or red, produced in terminal panicles. The fruit is a small capsule containing numerous seeds.

The bark of the tree is medicinally active, containing a variety of alkaloids, including the anti-malarial compound quinine (fig. 233).

Fig.232. Madder

Fig. 233. Cinchona tree

g. Coffee tree - Coffea L.

Coffee is a shrub or small tree with dark green leaves, clusters of small, white, fragrant flowers and small, rounded berries that turn yellow, red or purple when they ripen (fig. 234).

MILKWEED FAMILY - APOCYNACEAE

The Apocynaceae consist of lianas, trees, shrubs or herbs, with latex present in tissues. The stems are succulent in some taxa. The leaves are simple, undivided, sometimes opposite, whorled or rarely spiral. The inflorescence is a cyme (often umbelliform), raceme, or of solitary flowers. The flowers are usually bisexual, actinomorphic. The fruit can be a berry, drupe, or follicle. The plants typically contain various glycosides and alkaloids.

g. Strophanthus – Strophanthus Kombe.

Strophanthus is a woody climber that can grow up to 10m in height. It has robust stems, simple glossy leaves and large, attractive, bright pink or purple flowers. The name (“strophos- anthos”, “twisted cord flower”) derives from the long, twisted, threadlike segments of the corolla, which attain a length of 30-35cm (S. preussii). The seeds are borne in long narrow pods (fig. 235).

Fig.234. Coffee tree

Fig. 235. Strophanthus

NIGHTSHADE FAMILY - SOLANACEAE

The Solanaceae consist of herbs, shrubs, trees or lianas, with trichomes. The leaves are simple, pinnate, usually spiral. The inflorescence is of solitary flowers or cyme units. The flowers are bisexual, actinomorphic, rarely zygomorphic. The fruit is a berry, drupe, or capsule. Alkaloids are present in many family members.

The economic importance includes many edible plants, such as *Capsicum* (peppers), *Lycopersicon esculentum* (tomato), *Solanum tuberosum* (potato), and *Nicotiana tabacum* (tobacco). Alkaloids from various taxa have medicinal properties (e.g. atropine from *Atropa Belladona*), hallucinogenic properties (e.g. *Datura*, Jimson weed), or deadly poisons (e.g. *Datura, Solanum* spp.) or known carcinogens (e.g. *Nicotiana tabacum*).

g. Bittersweet - Solanum L.

A deciduous woody climber (up to 5m), bearing simple or lobed leaves, dark purple flowers and attractive berries that are bright red when mature (fig. 236).

g. Henbane - Hyoscyamus L.

Henbane is an annual or biennial herb of up to 0.5m in height, with soft hairy stems bearing pale green, lobed and hairy leaves. The calyx is bell-like and toothed, and the petals are grey- yellow, with dark purple veins towards their bases. The fruits are capsules (fig. 237).

Fig.236. Bittersweet *Fig. 237. Henbane*

g. Deadly nightshade - Atropa L.

A perennial herb with a soft stem, large simple leaves and brown tubular flowers. Typical are the attractive, shiny black berries (fig. 238).

g. Thorn apple, Jimson weed - Datura L.

A robust annual of up to 1.5m in height, with unpleasantly scented leaves, large, white or purplish tubular flowers and characteristic fruit capsules containing blackish, kidney-shaped seeds (fig. 239).

Fig.238. Deadly nightshade

Fig. 239. Thorn apple, Jimson weed

FIGWORT FAMILY - SCROPHULARIACEAE S.L.

The Scrophulariaceae is characterized as shrubs or herbs with opposite leaves, zygomorphic flowers. The plants are annual or perennial. The leaves have entire or toothed margins. In the flowers there are 4-5 sepals that are usually fused together at the base, and 4-5 petals are also fused to form a bell or a tube. The stamens are 4-5. The fruit is a capsule or berry.

g. Mullein – Verbascum Schrad.

Mullein is a leafy biennial herb with a rosette of woolly leaves. The flowers have 5 symmetrical petals. In different species the petals can be yellow, orange, red-brown, purple, blue or white. The fruit is a capsule containing numerous minute seeds. Mostly used are orange mullein (*V. phlomoides)* and large-flowered mullein (*V. densiflorum)*. They are distinguished mainly by the size of the flowers and the hairiness of the stamens. The fruit is a capsule (fig. 240).

g. Foxglove – Digitalis L.

A perennial plant, with smooth, pointed leaves and long flowering stalks bearing numerous pale yellow or cream-colored flowers. *D. purpurea* (common or purple foxglove) forms a dense rosette of leaves in the first year, and slender flowering stem of up to 2m in height in the second year. The fruit is a capsule (fig. 241).

Fig.240. Mullein

Fig. 241. Foxglove

PLANTAIN FAMILY - PLANTAGINACEAE

A family of flowering plants consisting of 3 genera. It is a cosmopolitan family. It consists of herbs, shrubs and also a few aquatic plants. The leaves are spiral to opposite, simple to compound.

The flowers are symmetric, corolla is often 2-lipped. The fruit is a capsule.

g. Plantain – Plantago L.

A rosette-forming perennial herb bearing narrowly oblong, hairy and parallel-veined leaves, distinctly ridged flowering stalks and numerous white or pale pink flowers in a dense solitary cluster (fig. 242).

Fig.242. Plantain

MINT FAMILY - LAMIACEAE (LABIATAE)

The Lamiaceae consist of herbs, shrubs or rarely trees, often with short glandular trichomes producing aromatic ethereal oils. The stems are usually 4-sided (square in cross-section), at least when young. The leaves are simple, opposite, sometimes whorled. The inflorescence is a lateral cyme, or solitary flowers. The flowers are bisexual, mostly zygomorphic. The original family name Labiatae refers to the fact that the flowers have petals fused into the upper lip and the lower lip. The fruit is a schizocarp of usually four nutlets, a drupe, or a berry. The plants often have ethereal oils.

g. Motherwort – Leonurus Gilib.

Motherwort is an erect perennial herb of up to 1.5m in height, with distinctive toothed leaves and small pink flowers arranged in axillary clusters on the elongated flowering branches (fig. 243).

g. Dead nettle - Lamium L.

White dead nettle is a perennial herb with branched rhizomes and erect branches bearing heart-shaped, toothed leaves in opposite pairs. The white, tubular and two-lipped flowers form small clusters in the axils of the upper leaves. When not in flower, it resembles a nettle (*Urtica dioica*) (fig. 244).

Fig.243. Motherwort

Fig. 244. Dead nettle

g. Germander – Teucrium L.

Germander is a small perennial herb with small opposite leaves and clusters of pink or purple flowers borne on the branch tips. Several other species are used in folk medicine (fig. 245).

Fig.245.Germander

g. Mint - Mentha L.

Mints are aromatic, exclusively perennial, rarely annual herbs. They have erect, square, branched stems. The leaves are arranged in opposite pairs, from oblong to lanceolate, with serrated margins. The flowers are white to purple. The corolla is two-lipped. The fruit is a nutlet, containing one to four seeds (fig. 246).

g. Sage - Salvia L.

Sage is a perennial shrub with square stems bearing opposite pairs of grey leaves and attractive purplish blue flowers (fig. 247).

Fig.246.Mint

Fig. 247.Sage

g. Oregano – Origanum L.

Oregano is an aromatic perennial herb with hairy, opposite leaves and white or pink flowers. It is very similar to marjoram (*O. majorana*) and the two species (both popular culinary herbs) are often confused (fig. 248).

g. Thyme - Thymus L.

A small perennial herb or shrub with thin stems bearing small, grey green leaves in opposite pairs and minute violet flowers (fig. 249).

Fig.248.Oregano

Fig. 249.Thyme

g. Basil - Ocimum L.

Sweet basil is a robust, aromatic annual, with soft, hairless leaves and broad spikes of white flowers (fig. 250).

g. Orthosiphon – Orthosiphon Benth.

Orthosiphon is a medicinal plant. It is an herbaceous shrub. Orthosiphon is a popular garden plant because of its unique flower, which is white and bluish with filaments resembling a cat's whiskers (fig. 251).

Fig.250.Basil

Fig. 251.Orthosiphon

SUNFLOWER FAMILY - ASTERACEAE (COMPOSITAE)

The Asteraceae consist of herbs, shrubs, trees or vines, with laticifers or resin ducts. The leaves are simple or compound, spiral or opposite. The inflorescence consist of one or more heads arranged in various secondary inflorescences, each head consisting of a flat to conical compound receptacle that bears one to many flowers. The heads can be of five general types:

1. **discoid,** with only disk flowers, all bisexual;
2. **disciform,** with only disk flowers, a mixture of pistillate and sterile flowers, with bisexual and staminate, in the same or different heads;
3. **radiate**, with central (bisexual or male) disk flowers and peripheral (female) ray flowers;

4. **ligulate,** with all ray flowers (typically with 5-toothed corolla apices);

5. **bilabiate** (two lipped flowers). The flowers are bisexual or unisexual.

The fruit is an achene.

g. Sandy everlasting - Helichrysum (L.) Moench.

A small perennial herb with narrow, silver-hairy leaves and small, yellow flower heads arranged in cymes. Also well known is the curry plant, *H. italicum*- a shrubby species with narrow leaves and small, yellow flower heads used mainly as a culinary herb (fig. 252).

g. Cudweed - Gnaphalium L.

Gnaphalium is a genus of flowering plants in the daisy family, Asteraceae. It contains about 120 species, which are commonly called **cudweeds** (fig. 253). It is a small annual herb up to 25cm tall. The stems and leaves are covered with a dense coat of wooly hairs, giving the plant a whitish appearance. The leaves are narrowly linear (4.5 cm long). The flower heads contain numerous florets, mostly yellowish, but sometimes with purple tips.

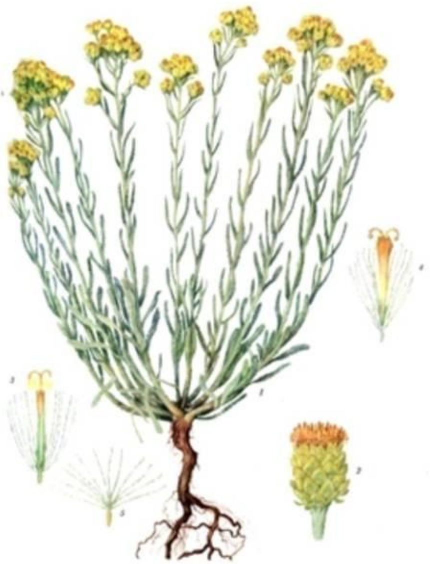


Fig.252.Sandy everlasting

Fig. 253.Cudweed

g. Elfdock - Inula L.

A large, leafy perennial herb with erect stems, which are very stout and near the top, branched. The whole plant is downy. It produces a radical rosette of enormous, ovate, pointed leaves with toothed margins and borne on long foot-stalks. The flowers are bright yellow, in large, terminal heads. The broad bracts under the head are velvety. The fruit is quadrangular and crowned by a ring of pale-reddish hairs, bearing toothed leaves and large, yellow flower heads (fig. 254).

g. Chamomile - Matricaria L.

It is an annual plant with branched, erect and smooth stem, which grow to a height of 15cm. The long and narrow leaves are bipinnate or tripinnate. The flowers are borne in *paniculate* flower heads *(capitula*). The white ray florets are furnished with a ligula, while the disc florets are yellow. The receptacle is characteristically hollow. The flowers have a strong, aromatic smell (fig. 255).

Fig.254.Elfdock

Fig. 255.Chamomile

g. Bur-marigold – Bidens L.

The name means “two-tooth” from Latin bis “two”+ dens “tooth”. The plants are “**zoochorous**”- their seeds can stick to clothing, fur or feathers, and be carried to a new habitat. Annuals or perennials, the stems are erect, the leaves are opposite, rarely whorled or alternate. The heads are discoid, yellow, white or pink. The fruits have 2 or 4 barbed bristles (fig. 256).

g. Tansy – Tanacetum L.

These herbs are annual, perennial subshrubs. Their leaves are aromatic. The button-shaped flowers are showy in shades including pinks, whites and yellows. The flower heads consist of both ray and disk flowers, disk flowers only, or ray flowers only (fig. 257).

Fig.256.Bur-marigold

Fig. 257.Tansy

g. Yarrow - Achillea L.

A perennial herb with several erect stems, arising from multiple rhizomes below the ground. The compound leaves are bright green and feathery. The inflorescence contains ray and disc flowers which are white and pink. The ray flowers are ovate to round. The flowers are produced in a flat-topped capitulum and are visited by many insects. The fruits are small, achene-like (fig. 258).

g. Coltsfoot – Tussilago L.

Coltsfoot is a small perennial herb with distinctive heart-shaped leaves, that are bright green above and silvery below, due to a felt-like layer of white hairs. The bright yellow flower heads are produced on stalks in early spring, before the leaves emerge (fig. 259).

Fig.258. Yarrow

Fig. 259. Coltsfoot

g. Wormwood – Artemisia L.

It is a perennial herb. The leaves are pinnately compound and silvery in color. Numerous small pale yellow flower heads are borne along the branch ends (fig. 260).

g. Ragworth – Senecio L.

It is an erect perennial herb with narrow, toothed leaves and a large number of flower heads borne in loose clusters. Each flower head is tubular in shape. The flower heads are usually completely yellow, but green, purple, white and blue flowers are known as well. Several Senecio species have been traditionally used as medicinal plants (fig. 261).

Fig.260. Wormwood

Fig. 261. Ragworth

g. Burdock – Arctium L.

Burdock is a robust biennial weed with large leaves and rounded purple flower heads surrounded by bristly, hooked bracts (fig. 262).

g. Globe-thistle - Echinops L.

This is a glandular, woolly perennial herbaceous plant. The erect, gray and hairy stems bear sharply toothed green leaves. They are sticky, hairy above and white, woolly below.

At the top of each stem there is a spherical inflorescence, packed with white or blue-gray disc florets.

The fruits are hairy, cylindrical achenes (fig. 263).

Fig.262. Burdock

Fig. 263. Globe-thistle

g. Blue cornflower - Centaurea L.

It is an annual, widely branched herb. The lower leaves are lobed and stalked; the upper ones simple, oblong to linear and sessile. The attractive flower heads are usually bright blue, but white, purple or pink forms also occur (fig. 264).

g. Dandelion – Taraxacum Weber

Dandelion is a leafy perennial herb with a fleshy taproot and a rosette of toothed leaves. The solitary yellow flower heads are borne on hollow, unbranched stalks. The small brown fruits (achenes) have a hairy “parachute” for wind dispersal. All parts of the plant exude a bitter, milky juice when cut or broken (fig. 265).

Fig.264. Blue cornflower

Fig. 265. Dandelion

g. Chicory – Cichorium L.

It is an erect perennial herb with a thick root, large dentate leaves and attractive, pale blue, sessile flower heads (fig. 266).

g. Marigold - Calendula L.

Marigold is an annual or biennial aromatic herb, with soft glandular leaves and attractive yellow or orange flower heads (fig. 267).

Fig.266. Chicory

Fig. 267.Marigold

g. Sunflower - Helianthus L.

Sunflower is an annual plant. The sunflower has a rough, hairy stem, coarsely toothed, rough leaves and circular heads of flowers. The heads consist of 1,000- 2,000 individual flowers joined together by a receptacle base.

The sunflower seeds were brought to Europe from America in the 16th century (fig. 268).

Fig.268. Sunflower

g. Arnica – Arnica L.

It is a perennial herb with hairy leaves and large, deep yellow flower heads. Mainly the flower heads are used, rarely- the roots or the whole plant (fig. 269).

Fig.269. Arnica *Fig. 270.Milk thistle*

g. Milk thistle - Silybum L.

They contain a milky sap. The seeds of the milk thistle have been used for 2000 years to treat chronic liver disease. The members of this genus grow as annual or biannial plants. The erect stem is tall, branched. The large, alternate leaves are toothed and thorny. They have large, disc-shaped pink-to-purple, rarely white, solitary flower heads at the end of the stem. The fruit is a black achene (fig. 270).

CLASS MONOCOT PLANTS – MONOCOTILEDONES (LILIOPSIDA)

Characteristics of monocot plants:

1. They have one cotyledon in the embryo;
2. Leaf veins are parallel;
3. Petals are in multiples of 3;
4. They have fibrous root systems;
5. Secondary growth is absent;
6. Vascular bundles scattered throughout the stem;
7. Usually herbaceous plants;
8. One seed leaf.

BUNCHFLOWER FAMILY - MELANTHIACEAE

It is a family of flowering perennial herbs, trees and shrubs. The plants usually arise from horizontal roots, some species may grow from bulbs or tubers. They are perennial herbs that usually have leaves clustered at the base of the plant, but sometimes have leaves that grow on the stem. The stem leaves are arranged alternately, or they may be whorled. The leaves have parallel or pinnately branched veins, and have untoothed edges. The flowers are actinomorphic. The fruit is a berry or capsule.

g. Hellebore - Veratrum L.

It is an extremely toxic plant. It is a herbaceous perennial plant with green stems. The leaves are spirally arranged, elliptic, lanceolate, hairy on the underside. The flowers are numerous, produced in a large branched inflorescence. The fruit is a capsule (fig. 271).

g. Meadow saffron - Colchicum L.

Colchicum is a perennial herb forming a fleshy corm in spring. In autumn, several long, tubular pink flowers are produced from the leafless plant. The fruit is a capsule, it contains numerous small, hard, black seeds (fig. 272).

Fig.271. Hellebore

Fig. 272.Meadow saffron

ALOE FAMILY - ASPHODELACEAE

They are stemless or very short-stemmed succulent plants. The leaves are thick and fleshy, green to grey-green, with some white flecks on the upper and lower stem surfaces. The margins of the leaves are serrated. The flowers are on a spike, with yellow tubular corolla. These plants like to have mycorrhiza. The fruit is a non-fleshy capsule.

g. Aloe – Aloe Mill.

This succulent plant grows as an evergreen perennial. The leaves are thick and fleshy. The gray-green or pale green upper surface sometimes have small white dots. Aloe leaves have soft teeth along the edges. The flowers appear on spikes. They are yellowish-orange and tubular. They are stemless or have a short stem. The fruit of the plant is a capsule with dark brown winged seeds (fig. 273).

ONION FAMILY - ALLIACEAE

The Alliaceae consist of biennial or perennial herbs, usually with onion-like odor. The stems are usually a bulb, rarely a short rhizome. The leaves are simple, basal, linear, or lanceolate, parallel veined. The inflorescence is a terminal umbel. The flowers are bisexual, actinomorphic. The fruit is a capsule. The seeds are black.

Economic importance includes important food and flavoring plants, including onion (*Allium cepa*), garlic (*Allium sativum*).

sp. Onion - Allium cepa L.

A bulbous perennial with hollow green leaves arising from a bulb. The hollow flowering stem bears a rounded cluster of white or purple flowers (fig. 274).

Fig.273. Aloe

Fig. 274.Onion

sp. Garlic - Allium sativum L.

Garlic is a perennial herb with fleshy grey leaves, rounded flower heads and numerous small bulbs (cloves) borne in a group and surrounded by a white papery sheets. The flowers are placed at the end of a stalk, rising directly from the bulb and are whitish, grouped together in a globular head or umbel (fig. 275).

LILY FAMILY - LILIACEAE

The Liliaceae consist of perennial herbs. The stems are usually bulbous, rhizomatous in some. The leaves are basal, spiral or whorled, usually sheathing and parallel veined. The inflorescence is a terminal raceme. The flowers are bisexual, actinomorphic or zygomorphic. The fruit may be a dry capsule or a fleshy berry.

g. Lily - Lilium L.

Lilium is a genus of herbaceous flowering plants growing from bulbs, all with large flowers. The bulbs are their overwintering organs. Some species develop stolons. A few species bear a basal rosette of leaves. The large flowers are often fragrant, they can be white, pink, red, purple, yellow and orange. The flowers are borne in racemes or umbels at the tip of the stem, they have nectaries at the base of each flower. The ovary is superior. The fruit is a capsule (fig. 276).

Fig.275. Garlik

Fig. 276.Lily

LILY OF THE VALLEY FAMILY - CONVALLARIACEAE

This family contains perennial or annual rhizomatous herbs. The roots are fibrous or tuber-like. The leaves are spiral, opposite or whorled on the stem or in basal rosettes. The inflorescence is racemes, or spikes, or borne in axillary clusters on a leafy stem. The flowers are bisexual, actinomorphic. The fruit is usually a berry or a capsule.

g. Lily-of-the-valley - Convallaria L.

An attractive perennial herb with a pair of broad leaves arising from the ground that grows in large clumps. It produces an elegant cluster of small, bell-shaped, white, fragrant flowers, all arranged on one side of the stalk. The fruits are small, red berries (fig. 277).

ASPARAGUS FAMILY - ASPARAGACEAE

This family contains shrubs, lianas or herbs. The leaves are reduced to small bracket-like structures. The herbs are perennial. The leaves are alternate; simple; parallel-veined. Floral nectaries are present. The flowers are aggregated in cymes, racemes, or in umbels. The flowers are small; regular; 3-merous. The fruit is a fleshy berry.

g. Asparagus – Asparagus L.

It is a perennial herb with green stems and minute white, or yellowish flowers. The small green berries turn bright red when they ripen. Young stems are white (when grown underground) or green (above the ground) and are a popular vegetable (fig. 278).

Fig.277. Lily-of-the-valley

Fig. 278.Asparagus

ORCHID FAMILY - ORCHIDACEAE

The Orchidaceae consist of perennial (rarely annual) herbs (rarely vines). The leaves are spiral or whorled, usually sheathing, simple, and parallel veined. The inflorescence is a raceme, panicle, spike, or a solitary flower. The flowers are bisexual, rarely unisexual, zygomorphic. The fruit is a capsule or a berry.

g. Orchids – Orchis L.

The Orchid has narrow leaves, often spotted purple-black, and a spike of purple flowers. It has glossy leaves, a dense spike of flowers that smell unpleasant). The stamens and carpels are fused and the seeds are extremely small (fig. 279).

Fig. 279.Orchis

GRASS FAMILY - POACEAE (GRAMINEAE)

The Poaceae consist of perennial or annual herbs. The roots are adventitious, often mycorrhizal. The erect stems are hollow, strawy woody-textured in some. The leaves are simple, the leaf blade is parallel-veined. The inflorescence consists of terminal spikelets. The flowers are bisexual or unisexual. The fruit is a caryopsis (grain).

The grasses are perhaps the most economically important group of plants, including barley (*Hordeum*), corn (*Zea mays*), oats (*Avena*), rice (*Oryza*), wheat (*Triticum*) and others.

g. Barley - Hordeum L.

This annual grass has straight stems, long, sheathed leaves, and grouped spikelets that produce husk-covered seeds with a characteristic upward "bristle" (fig. 280).

g. Wheat - Triticum L.

Wheat is the most important food grain of the temperate zones. It is an annual grass. The common wheat has a long, slender spike. The spikelets are 2 to 5 flowered. The stem centers are generally hollow. The leaves are narrower. The grains may be red or white, hard or soft (fig. 281).

Fig.280 . Barley

Fig.281 . Wheat

g. Corn – Zea mays L.

Corn is an annual grass with thick stems and broad, sheeting leaves. The male flowers are borne in clusters at the tips of the branches, while the female flowers are arranged in thick spikes in the leaf axils (fig. 282).

Fig. 282.Corn

Fig. 283. Oats

g. Oats - Avena L.

Oats is an annual grass with hollow stems and characteristically nodding spikelets, each protected by two large, leafy, persistent glumes (fig. 283).

g. Rice - Oryza L.

The genus includes both annual and perennial species. They have fibrous root systems, cylindrical stems, sheeting leaves with parallel veined blades and an inflorescence with spikelets (fig. 284).

g. Pheasant tail grass – Stipa

Stipa is a genus of perennial grasses known as feather grass. The leaves are linear, the flowers are feathery (fig. 285).

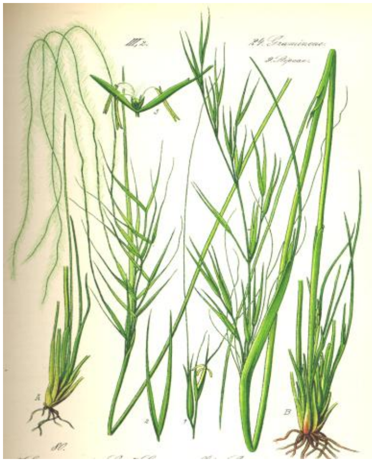


Fig. 284. Rice *Fig. 285. Pheasant tail grass*

SUBCLASS ARECIDAE

PALM FAMILY - ARECACEAE (PALMAE)

The Arecaceae family consist of perennial trees, large rhizomatous herbs or lianas. The roots are mycorrhizal, lacking root hairs. The stem is usually an unbranched trunk. The leaves are typically quite large, spiral, simple, pinnate, bipinnate or palmate. The inflorescence is panicle or spike. The flowers are unisexual or bisexual, actinomorphic. The fruit is a fleshy or fibrous drupe.

g. Coconut - Cocos L.

Cocos is a large palm with pinnate leaves of 4-6 meters long; the old leaves break away cleanly, leaving the trunk smooth. The coconut palm tree can yield up to 75 fruits per year. Botanically the coconut fruit is a drupe, not a true nut. Like other fruits it has three layers: exocarp, mesocarp, and endocarp. Within the shell is a single seed. The palm tree has a fibrous root system. On the same inflorescence, the palm produces both female and male flowers. The female flower is much larger than the male flower (fig. 286).

g. Date Palm - Phoenix L.

The generic name derives from "*phoinikos"*, the Greek word for the date palm. The leaves have short or absent petioles. The plants are dioecious, with male and female flowers on separate plants. The flowers are yellowish-brown, grouped on large multi-branched panicles. The inflorescence forms large clusters. *Phoenix* fruit develops from one carpel as a drupe (fig. 287).

Fig. 236.Coconut

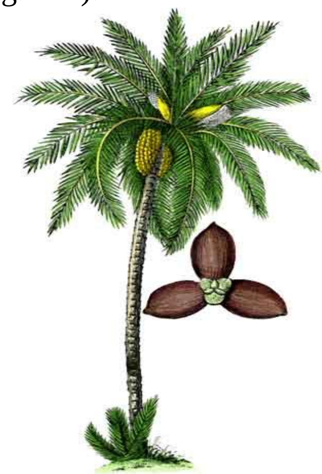


Fig.287 Date palm

ARUM (SWEET FLAG) FAMILY - ARACEAE

They are mostly small perennial herbs. Many of the species are aquatic, but a few grow in uplands. The leaves are simple, undivided, parallel - veined. The flowers are characteristically borne on a distinctive inflorescence known as a spadix and are usually surrounded by a single leaf-like bract, known as a spathe. Species are often rhizomatous or tuberous. The fruit is a berry. Many plants of this family are *thermogenic* (heat-producing). Their flowers can reach up to 45°C even when the surrounding air temperature is much lower.

Acorus calamus is used medicinally and as a perfume.

g. Sweet flag - Acorus L.

A perennial, aquatic plant with bright green, sword-shaped leaves growing from rhizomes. The leaves are aromatic with distinct midrib. The minute flowers are grouped together in small oblong spikes. The flowers are greenish-yellow arranged in a diamond-shaped pattern. The flowers are sweetly fragrant. The fruit is a berry (fig. 288).

Fig. 288. Sweet flag

GINGER FAMILY - ZINGIBERACEAE

The Zingiberaceae consist of perennial herbs. The stems are rhizomatous. The leaves are simple, sheething, petiolate, parallel - veined. The inflorescence is a spike or raceme. The flowers are bisexual, zygomorphic. The fruit is a dry or fleshy capsule.

g. Ginger - Zingiber L.

A herbaceous perennial herb with large leaves, developing from branched rhizomes. The flowers occur in a spike. Each flower has three yellowish-orange petals with an additional purplish, lip-like structure (fig. 289).

g. Turmeric - Curcuma (L.)

Turmeric is a rhizomatous herbaceous perennial plant of the ginger family (Zingiberaceae). Highly branched, yellow to orange, cylindrical, aromatic rhizomes are found. The leaves are alternate, elliptic, narrowing at the tip. The hermaphrodite flowers are zygomorphic. The sepals are fused, white, have fluffy hairs. The three bright-yellow petals are fused into a corolla tube. The fruit capsule opens with three compartments.

Extracts from turmeric have antifungal and antibacterial properties (fig. 290).

Fig.289.Ginger

Fig. 290.Turmeric

Chapter 18

HERBARIA AND PLANT PRESERVATION

The botanical resources of many universities and other institutions include herbaria (singular: herbarium). Herbaria are essential libraries of dried, pressed plants, algae, and fungi arranged and labeled so that specific specimens can be easily retrieved.

Methods

Fungi and bryophytes are usually dried and stored in small boxes or packets. The moisture content of flowers and other plant parts to be preserved, should be reduced as quickly as possible, with a minimum of distortion. This is usually done with the aid of a *plant press*. This simple device consists of two pieces of polywood (or other wood materials or thin metal plates) with dimensions of approximately 30×46 centimeters and a pair of webbing or leather straps to go around the boards. A number of felts (sheets of heavy blotting paper) are placed between the boards. A folded page of newspaper is placed between each blotter.

Any soil clinging to the roots of a specimen to be pressed is washed off, and the plant is laid out on one of the newspaper sheets. Leaves are carefully straightened out, as are petals and other plant parts, so that they are not folded during pressing. Notes on where, when, and by whom the specimen was collected are penciled on the newspaper. The newspaper is then folded over the specimen and placed between two blotters (felts).

Many specimens may be placed in a press at one time or, if there is space, between the same sheets of newspaper. Only one species should be placed in a single fold of newspaper. If the plant is small, press the entire plant, and try to have both upper and lower leaf or flower surfaces visible. If, however, the plant is large (e.g. a tree), press representative parts, especially flowers and/or fruits and it is left to dry in the sun or near a heater for 3 or 4 days. Unless the leaves were succulent or wet at the time they were placed in the press, they should be dry enough to mount on paper at this time. If a press is not available, plants may be pressed between newspapers and blotters by placing heavy weights on top of them. Herbarium paper normally measures 29×42 centimeters. The bottom right-hand corner of the paper should be kept clear for a label indicating the scientific name of the plant, collection information, the collector's name, and the collection date.

Flowers can also be dried in a shoe box without pressing. The bottom of the box is covered with about 2 centimeters of sand. The fresh flower is gently laid on the surface. After this, more sand is slowly drizzled by hand into the box, until the entire flower is buried, with care being taken not to create air pockets around any parts. Sand must be thoroughly washed several times to be certain it is perfectly clean before use. The sand also needs to be completely dry. It takes about 2 weeks to dry most flowers with sand.

Chapter 19

PLANT ECOLOGY

Plants and the environment

The interaction between organisms and their environment determines whether or not a species, or an individual member of a species, can survive and reproduce in a particular habitat. The environment of each habitat is determined by both living and nonliving factors. Living, or biotic factors include all the other organisms in the habitat with which the organism interacts. If we consider a maple tree in a forest, the biotic factors include the other maple trees that might provide pollen for reproduction, or the animals that might eat its leaves, or the fungi and other microorganisms, that are associated with its roots. The nonliving or abiotic factors in the environment include the wind, rain, sunlight, soil, and temperature, to which the maple tree is exposed during its lifetime. Each habitat in the world has a different combination of biotic and abiotic factors, with different habitats favoring different kinds of plants and animals. Thus, maples might grow well in places where there are freezing winters, while palm trees would not.

The fact that a particular species of plant can flourish in one habitat, but not another suggests that plants reflect and respond to their environment. For example, when a seed germinates, it must be capable of growing into a mature plant and also must reproduce in the same environment. When the plant reproduces, its genes pass along to the next generation; these genes allow it to grow in its environment. In other words, the plant is adapted to its environment, its seeds might germinate, but the plants would die before reproduction could occur.

Populations, Communities, and Ecosystems

We recognize that plants, animals, and other organisms tend to be associated in various ways with one another and also with their physical environment. For example, forests consist of populations (groups of individuals of the same species) of trees or other plants, that form a plant community (unit composed of all the populations of plants occurring in a given area). The lichen and moss flora on a rock also constitute a community. However, these communities also invariably have animals and other living organisms associated with them. It is preferable, therefore, to refer to the unit composed of all the populations of living organisms in a given area, as a biotic community. Considered together, the communities and their physical, chemical, and biological processes constitute ecosystems.

Population

Populations may vary in numbers, in density, in genetic diversity, and in the total mass of individuals. Depending on circumstances, a field biologist may investigate a population in various ways. If, for example, a conservation organization is concerned about the preservation of a rare or threatened species, the organization may simply count the number of individuals, although this may not always be feasible. If such a count is not feasible, the organization may estimate population density (number of individuals per unit volume-e.g. five blueberry bushes per square meter). If the individuals in a population vary greatly in size, or are unevenly scattered, a better estimate of the population's importance to the ecosystem may be calculated by determining the biomass (total mass of the living individuals present).

Communities

Communities are composed of populations of one to many species of organisms living together in the same location. Similar communities occur under similar environmental conditions, although actual species composition can vary considerably from one location to another. A community is difficult to define precisely, because species of one community may also occur in other communities. If individuals are transplanted to a second different community, where the same species occurs, the transplanted individuals may not necessarily be able to survive alongside their counterparts, that are adapted to this second community.

Analysis and classification of communities are important in the preparation of maps.

Ecosystems

Living organisms interacting with one another and with factors of the nonliving environment constitute an ecosystem. The nonliving factors of the environment (abiotic factors) include light, temperature, concentration of oxygen and other gases, air circulation, fire, precipitation, rocks, and soil type. The distribution of a plant species in an ecosystem is controlled mostly by temperature, precipitation soil type, and the effects of other living organisms (biotic factors). Biotic interactions, such as competition for light and grazing by the animal members of the biotic community, and abiotic factors, such as mineral nutrients and available water, also influence the distribution of plant species.

The leaves and other parts of plant species that occur naturally in the area of low precipitation and high temperature (xerophytes) generally are adapted to their particular environment through modifications that reduce transpiration. Similarly, plants that grow in water (hydrophytes) are modified for aquatic environments.

Ecosystems may sustain entirely through photosynthetic activity, energy flow through food chains and the recycling of nutrients. The organisms, called producers, are capable of carrying on photosynthesis (e.g. plants, algae) and store energy that may be released by other organisms. Animals such as cows, that feed directly on producers are called primary consumers. Secondary consumers, such as tigers, toads feed on primary consumers. Decomposers break down organic materials to forms that can be reassimilated by the producers in most ecosystems - bacteria and fungi.

Interactions Among Plants and Other Organisms

Some of the species of the Family Scrophulariaceae have no chlorophyll and depend entirely on their flowering plant hosts for their energy and other nutritional needs.

Mycorrhizal fungi are intimately associated with the roots of most woody and many other plants in such a way, that both organisms derive benefit (such associations, called mutualisms), are a major part of life in general. The fungi greatly increase the absorptive surface of the root, usually playing a major role in the absorption of phosphorus and other nutrients, while obtaining energy from root cells.

Thomas Belt, a naturalist of more than 100 years ago, first called attention to an association between tropical ants and thorny, rapidly growing species of Acacia. The Acacia has large, hollow thorns at the base of each leaf and is host to ants that feed on sugar, fats, and proteins produced by petiolar nectarines and special bodies at the tip of each leaflet. Ants live within the hollow thorns and vigorously attack any other organism, from insects to large animals, that come in contact with the plant. They also kill, by girdling, any plant that touches the Acacia cussed under “bridge grafting”. Experiments have shown that when ants are removed from these Acacia species, the plants grow very slowly and usually soon die from insect attacks or from shading by other plants.

Life Histories

Plants can be divided into three groups based on their reproductive strategies. Annuals, biennials, and perennials differ in their seasonal growth cycles. During the growing season, annuals grow vegetatively, with a reproductive growth occurring toward the end of the season. Once seeds have been produced, the plants die. Many weeds, wildflowers, and garden plants exhibit this type of growth. Biennials put all their energy into vegetative growth for one year. Then, during the second year, most energy is put into the production of reproductive structures. The plants include parsley, carrots, celery, foxglove. Perennial plants produce vegetative structures that survive for many years. Herbaceous perennials grow actively during periods of adequate temperature and moisture, but die back during unfavorable growing conditions such as a cold winter or a dry season. They survive through underground structures such as roots, rhizomes, bulbs, or tubers, which remain dormant until conditions are favorable for growth again. Examples of herbaceous perennials include coneflowers, tulips, and most grasses. Woody perennials do not die back during unfavorable periods in the growing season, but they do become dormant. Examples include trees, shrubs, and vines.

Natural Cycles

Water and elements such as carbon, nitrogen, and phosphorus are constantly cycling throughout nature. Such cycling involves transformation between organic and inorganic forms.

The water cycle

Most of living cells consist of water. In fact, life as we know can't exist without water. The earth's water is constantly being recycled, and the total amount remains stable. However, as we can see, the distribution of water across the globe can change over time.

Ninety-eight percent of the water is in oceans, rivers, lakes, and puddles that make up about two- thirds of the earth's surface. Most of the remaining water is in living organisms, glaciers, polar ice, water vapor, and the soil.

Some water that falls on land penetrates until it reaches an area of saturation known as the water table. Water in the water table may emerge from beneath the surface in the form of springs and artesian wells. Below the water table, porous rocks collect water and, when these rocks transmit water to wells and springs, they are called *aquifers*.

The water vapor rises into the atmosphere, condenses, and falls back to earth in the form of rain, snow, and hail in a constant cycle- the water cycle.

The carbon cycle

Photosynthesis, first by marine cyanobacteria, then by marine algae and finally by green land plants, has dramatically changed the carbon cycle and ultimately the earth. Plants have run the biological carbon cycle for 3 billion years in the ocean, and for the past 400 million years on land, using the process of photosynthesis to convert atmospheric CO_2 into carbon-rich carbohydrates and sugars, to feed themselves. And they are very good at it. They not only feed themselves, but also produce oxygen as a byproduct of photosynthesis, an element essential for animal life.

As land plants grow, they accumulate more and more carbon. Woody plants, such as trees, can sequester – pull carbon out of circulation – for dozens to hundreds of years. The CO_2 given off by decay of organic matter in the soil is released to the atmosphere, where it is consumed by plants in the continuing cycle. Plants have helped keep CO_2 levels from rising excessively because they keep using it to feed themselves. The carbon cycle has a number of self-regulating mechanisms that can compensate for small temporary increases in atmospheric CO_2. For example, plants initially tend to grow faster under higher CO_2 levels and their consumption of CO_2 rises accordingly.

The nitrogen cycle

Most of the nitrogen in living organisms is in the protoplasmic proteins of their cells. Nitrogen gas makes up about 78% of our atmosphere but constitutes only about 18% of the protein in living cells. Most of the nitrogen supply of plants is derived from the soil in the form of inorganic compounds and ions, taken in by the roots. Some nitrogen from the air is also fixed by various nitrogen-fixing bacteria. Some of these organisms gain access to various plants, particularly legumes (e.g. peas, beans, clover), through the root hairs, with the plant producing root nodules in which the bacteria multiply. Others live free in the soil. Bacteria and fungi can break down enormous quantities of dead leaves and other tissues within a few days to a few months. The activities of nitrogen-fixing bacteria and volcanoes also contribute to the natural replenishment of nitrogen by converting it to forms that can be utilized by plants.

Chapter 20

PLANT GEOGRAPHY

Plant geography is also known as phytogeography, geobotany, phytochorology, geographical botany, or vegetation science.

A flora is the collection of all plant species in an area, or in a period of time, independent of their relationships to one another. The species can be grouped into various kinds of floral elements, based on some common evolutionary origin; a migration element has a common route of entry into the territory; an ecological element is related to an environmental preference. An endemic species is restricted to a particular area, which is usually small and of some special interest. The collection of all interacting individuals of a given species in an area is called a **population**.

An **area** is the entire region of distribution of any species, element, or even an entire flora. The description of areas is the subject of *areography*, while *chorology* studies their development. On the basis of areas and their floristic relationships, the Earth's surface is divided into **floristic regions**, each with a distinctive flora. Floras and their distribution have been interpreted mainly in terms of their history and ecology. Basic plant growth forms (such as broad-leaved trees, stem-succulents, or forbs) have long represented convenient groups of species, based on obvious similarities, when these forms are interpreted as ecologically significant adaptation to environmental factors. They are generally called forms and may be interpreted as basic ecological types. Basic plant types may be seen as groups of plant taxa with similar form and ecological requirements, resulting from similar morphological responses to similar environmental conditions.

GEOBOTANY

Geobotany is a science concerned with the earth's vegetation as an aggregate of plant communities, or **phytocoenoses.** General geobotany mainly studies the structural patterns of plant communities reflected in species composition, the quantitative relations between species in vertical (layer structure) and horizontal (mosaic structure) divisions, the existence of ecologically similar specialized and relatively isolated plant groups, the relative position of individuals of different species, and the age composition of the species populations.

Geobotany is closely linked to some earth sciences - physical geography, meteorology, hydrology, climatology and soil science.

Geobotany focuses on five main issues:

- Floristic Geobotany;
- Historical Geobotany;
- Sociological Geobotany;
- Ecological Geobotany;
- Applied Geobotany.

Ecological Factors that Affect the Growth of plants

The ecological factors, that effect the growth of plants and determine the nature of plant communities, are divided into three types.

1. *Climatic factors* which include rainfall, atmospheric humidity, wind, atmospheric gases, temperature and light.

2. *Physiographic factors* (altitude, effect of steepness and sunlight on vegetation and direction of slopes).

3. *Biotic factors* (relationship between different plants of a particular area, interrelationship between plants and animals, between plants and soil microorganisms).

Biotic factors have their origin in the activities of living organisms, such as green and non-green plants, and all animals, including man. The activities of these living organisms have profound direct and indirect effects upon growth, structure, reproduction and distribution of plants on earth. There are some examples of plants to show mutual relationship between individual plants, growing in the same area:

1. **Lianas**

They are woody plants, rooted on ground, but climb up with the support of other trees and reach almost the top of the plant canopy. They are autotrophs and commonly found in tropical or dense forests (e.g. Entada gigas, Tinospora).

2. **Epiphytes**

They grow on other plants and are not attached to the soil. They are autotrophs and do not obtain food from the supporting plant, e.g. members of the family Orchidaceae, many mosses and ferns. They obtain water and minerals through their absorbing roots from the soil present in the cracks, on the surface of the supporting trees. Orchids absorb water from the saturated atmosphere with the help of special hanging roots.

3. **Parasites**

These plants exist on other autotrophic plants, called *host*, from where they (parasites) obtain their food. They have no contact with the soil. They have special sucking roots called *haustoria*.

4. **Symbiotic plants**

Lichens are the example of perfect symbiotic relationship between two plants – the algae (called phycobiont) and fungi (called mycobiont), live together and mutually provide benefits to each other. Here, the alga synthesizes organic food, whereas the fungus provides moisture and mineral elements. The abiotic factors that affect plant growth and development include topography, soil and climatic factors.

Floristic Kingdom

Floristic Kingdom or Region, any of six areas of the world, recognized by plant geographers. The chief difference is the recognition by plant geographers of the Cape region of South Africa because of Sots rich flora.

The six kingdoms (*Boreal, Neotropical, Paleotropical, South African, Australian and Antarctic*) are subdivided into more restricted units. The Paleotropical consists of three subkingdoms, each of which is subdivided into provinces. The other five kingdoms are also subdivided into provinces. There are 37 floristic provinces in total, almost all the provinces are further subdivided into floristic regions.

REFERENCES

1. Kingsley R. Stern, James E. Bidlack, Shelley H. Jansky "Introductory Plant Biology", (Eleventh Edition), 2008.
2. Hopkins W. G., N. P. A. Hüner "Introduction to plant physiology" (3-rd edition), 2004.
3. Davies P. J. "Plant hormones" (Kl. Academic Publ.), 1995.
4. Raven P. H., Evert R. F. and Eichhorn S. E. "Biology of plants" (7-th ed.), New York, 2005.
5. Southater Staff. "Foliage color", Summit, PA: National Book Network, 2002.
6. Ziegler E. G., Farquhar and Cowan I (Eds.) "Stomatal function", Pale Alto, 1987.
7. Dickison W. C. "Integrative plant anatomy", San Diego, CA, 2000.
8. Romberger J. A. "Plant structure: Functions and development", New York, 1993.
9. Molles M. C. "Ecology: Concepts and applications" (3-rd edition), 2005.
10. Jill Bailey "The facts on file dictionary of Botany", 2002.
11. Janice Glimn-Lacy, Peter B. Kaufman "Botany Illustrated: Introduction to plants, major groups, flowering plant families" (2-nd edition), 2006.
12. Pandey S. N., Ajanta Chadha "A textbook of Botany" (vol. I, II, III), 1996.
13. Ben – Erik van Wyk, Michael Wink "Medicinal plants of the world", 2005.
14. James D. Mauseth "Botany" (an introduction to plant biology) (3-rd ed.), 2003.
15. Brown R. G. "Dictionary of Medicinal Plants" Ivy Publishing House, Raleigh, 2002.
16. Chevallier A. "Encyclopedia of Medicinal Plants" (new ed.), Dorling Kindersley, London, 2001.

17. Duke J. A. “Handbook of Medicinal Herbs” (2-nd ed.) Boca Raton, 2002.

18. Foster S., Hobbs C. “Western Medicinal Plants and Herbs”, N.Y., 2002.

19. Michael G. Simpson “Plant Systematics” (2-nd ed.), 2010.

20. James G. Harris “Plant Identification Terminology: An illustrated glossary” (2-nd ed.), 2001.

21. Thomas J. Elpel “Botany in a day: The Patterns method of Plant identification”, 2013.

22. Margaret McKenny, Roger Tory Peterson “A field guide to wildflowers” (Peterson Fienld Guide), 1998.

23. Joan Compton “House plants”, 1972.

24. David Potterton, E. J. Shellard “Culpeper`s color herbal”, 1996.

25. Roger Phillips, Nicky Foy “The Random house book of herbs”, 1990.

26. David Burnie “Plant” (Eyewitness books).

27. Sue Minter “The healing garden”, 1995.

28. David E. Allen, Gabrielle Hatfield “Medicinal plants in folk tradition”, 2004.

29. James Mason “Awesome facts about plants”, 2004.

30. Carol Usher, John White, Colin Ridsdale “Trees”, 2005.

31. Lesley Bremness “Herbs” (Smithsonian handbooks), 1994.

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