NATIONAL OPEN UNIVERSITY OF NIGERIA

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COURSE TITLE: SEED PLANTS

BIO 210: SEED PLANTS

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MODULE 1 ORIGIN AND EVOLUTION OF SEED PLANTS

UNIT 1 INTRODUCTION TO SPERMATOPHYTE

CONTENTS

1.0 INTRODUCTION

The **spermatophytes**, which mean "seed plants", are some of the most important organisms on Earth. Life on land as we know it, is shaped largely by the activities of seed plants. Soils, forests, and food are three of the most apparent products of this group.

Seed-producing plants are probably the most familiar plants to most people, unlike mosses, liverworts, horsetails, and most other seedless plants which are overlooked because of their size or inconspicuous appearance. Many seed plants are large or showy. Conifers are seed plants; they include pines, firs, yew, redwood, and many other large trees. The other major groups of seed-plants are the flowering plants, including plants whose flowers are showy, but also many plants with reduced flowers, such as the oaks, Iroko, Mahogany, grasses, and palms.

Having introduced to you what Spermatopytes are, let us now take a look at the objectives we intend to achieve at the end of this unit.

Fig. 1.1a **Seed Plants**
(http://www.ucmp.berkeley.edu/seedplants/seedplants.html)

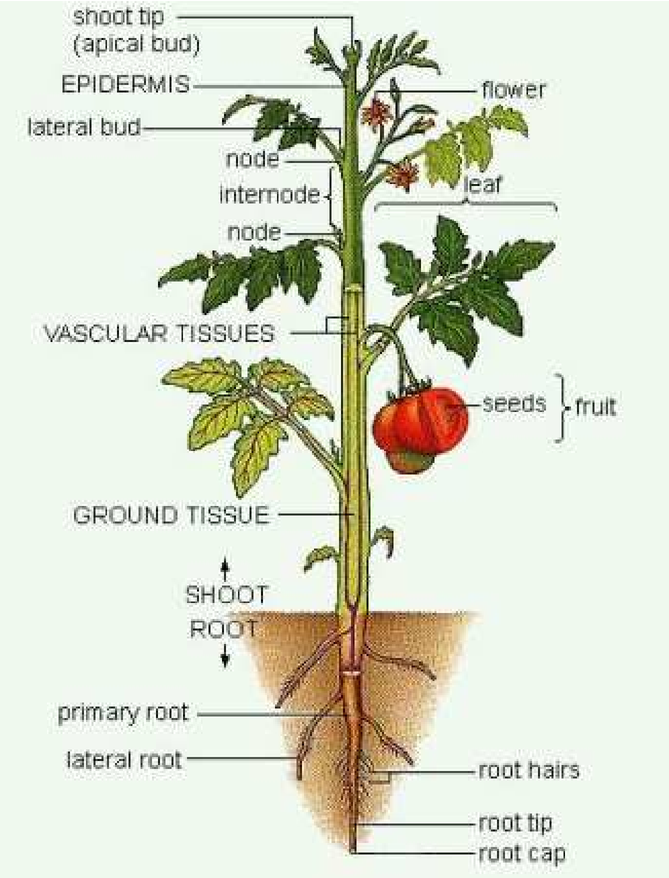

Fig 1.1b Seed Plant (http://universe-review.ca/R10-34-anatomy2.htm)

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- Classify seed plants
- Mention the various divisions in the classification of seed plants
- Outline the meanings of gymnosperms and angiosperms
- Differentiate between gymnosperms and angiosperms

3.0 MAIN CONTENT

3.1 Classification of Spermatophytes

The **spermatophytes** (also known as **phanerogams**) comprise those plants that produce seeds. They are a subset of the embryophytes or land plants. The living spermatophytes form five groups:

- cycads, a subtropical and tropical group of plants with a large crown of compound leaves and a stout trunk,
- *Ginkgo*, a single living species of tree,
- Conifers, cone-bearing trees and shrubs,
- Gnetophytes, woody plants in the genera *Gnetum*, *Welwitschia*, and *Ephedra*, and
- Angiosperms, the flowering plants, a large group including many familiar plants in a wide variety of habitats.

A traditional classification grouped all the seed plants in a single Division, with Classes for our five groups:

- Division **Spermatophyta**
  - **Cycadopsida**, the cycads
  - **Ginkgoopsida**, the ginkgo
  - **Pinopsida**, the conifers, ("Coniferopsida")
  - **Gnetopsida**, the gnetophytes
  - **Magnoliopsida**, the flowering plants, or **Angiospermopsida**

A more modern classification ranks these groups as separate divisions (sometimes under the **Superdivision Spermatophyta**):

- **Cycadophyta**, the cycads
- **Ginkgophyta**, the ginkgo
- **Pinophyta**, the conifers
- **Gnetophyta**, the gnetophytes
- **Magnoliophyta**, the flowering plants

We have seen the different classifications of the seed plants-spermatophytes; we shall now go ahead and take a look at the individual classes of gymnosperm and the flowering plants.

SAE

1. Outline the different classifications of seed plants

3.2 Gymnosperms—naked seed plants

Gymnosperms are plants that do not flower and do not bear their seeds in an enclosure such as a fruit. The seeds are produced on the surface of the sporophylls or similar structures until they are dispersed. The sporophylls are usually arranged in a spiral on the female strobili (cones) which develop at the same time as the smaller male strobili. The male strobili produce the pollens which will fertilize the ovules in the female cones. The ovule contains a nutritious nucellus which is itself enclosed in several layers of integument. The integument layers will eventually become the seed coat, after fertilization and further development of the embryo takes place.

3.2.1. Division: Pinophyta

Subdivision: *Pinicae* including Conifers. Conifers are pine trees and as evergreens to the layman.

Structure and Form—For the sake of discussion we will look at Pines, which are the largest genus of conifers. Pine needles are their leaf structures. They are usually arranged in clusters or bundles of two to five leaves (needles), although some species have as few as one or as many as eight leaves in a cluster, the clusters are sometimes referred to as fascicles. Each needle is covered with a thick cuticle over the epidermal layer and a layer of thick-walled cells just beneath the epidermis called the hypodermis. The stomata on the epidermal surface are sunken and are surrounded by an endodermis. The mesophyll cells do not have the wide air spaces as broadleaf and flowering plant leaves. Resin, and resin canals develop noticeably throughout the mesophyll cells. The canals are tubes in which resin is secreted. Resin is both aromatic and antiseptic and helps to prevent fungal infections and deter insect attacks. Some conifers produce resin in response to injury. The fascicles, needle clusters, will fall off every two to five years after maturing. They do not, however, fall off all at once and unless diseased, will not look bare like other flowering trees. The secondary xylem, wood, in conifers varies in hardness. Most gymnosperm wood consists of tracheids and has no vessel members or fibers as do flowering trees. Therefore the wood lacks thick walled cells. Conifer wood is considered to be softwood, while the wood of broadleaf trees is considered to be hardwood. The xylem rings in conifers are often fairly wide as a result of rapid growth. Both vertical and horizontal resin canals can be found throughout the wood. Pine phloem lacks companion cells, but has albuminous cells that perform similar function for the phloem. The roots of pine trees are always found in association with mycorrhizal fungi. The fungi perform functions for the roots, which enable normal growth. Pine trees can be found in all types of environments and ones of opposite extremes.

Fig 1.2a Diagram of Conifers(http://visual.merriam-webster.com/plants-gardening/plants/conifer/examples-conifers.php).

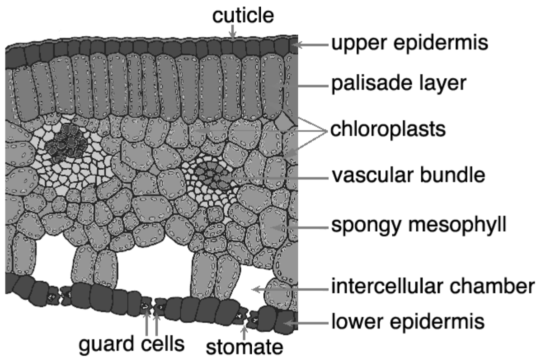

Fig 1.2b section of a dicot leaf (showing cuticle and epidermis)

There are 550 conifer species; because they are well adapted to harsh climates, they often form the tree line on mountains and in sub polar regions

Class *Ginkoatae*

Ginkgo trees have small fan-shaped leaves with veins that evenly fork. They have similar reproductive cycles to that of the conifers with the exception that the edible seeds are encased in a fleshy covering. The covering smells like rancid butter at seed maturity.

3.2.2 Division: Pinophyta

Subdivision *Cycadicae*

Cycads—these plants look like little palm trees with unbranched trunks and large crowns of pinnately divided leaves. Their strobili and cones are quite similar to those of conifers; however, their sperms have numerous flagella—much unlike conifers.

3.2.3 Division: Pinophyta

Fig 1.3 Diagram of a Cycad showing Cone and Strobili (http://en.wikipedia.org/wiki/File:Cycas_circinalis.jpg)

Subdivision: *Gneticae*

Gnetophytes—These plants have vessels in their xylem. Most of the species have jointed stems and leaves that are nothing more than scales. Sometimes the plants in this genus are called joint firs, as they look like jointed sticks. The plants in this subdivision are adapted to unusually dry environments. They produce tiny leaves in groups of twos and threes, which turn brown as soon as they appear. Male and female strobili may occur on the same plant.

Fig 1.4 Diagram of gymnosperms plants ((http://en. Wikipedia.org/wiki/Seed plant)

You have just been introduced to the different classifications of gymnosperms. Now , we shall take a look at another classification of the seed plants, the angiosperms which are generally referred to as flowering plants.

3.3 **Angiosperms—flowering seed plants (covered seed plants**)

Angiosperms are plants that have seeds encased in a protective covering. That covering is the ovary which is part of the flower structure and distinguishes angiosperms from gymnosperms. So it can be said that angiosperms are also flowering plants. There is one division of angiosperms, Magnoliophyta, which is divided into two classes: monocots and dicots. Angiosperms, like gymnosperms, are heterosporus, which means they produce two types of spores and their sporophytes are more dominant than those of gymnosperms. At maturity, the female gametophytes are reduced to a few cells and are completely enclosed within sporophyte tissue; while the male gametophytes consist of a binucleate cell with a tube nucleus which forms a pollen tube much like the one formed in gymnosperm pollination.

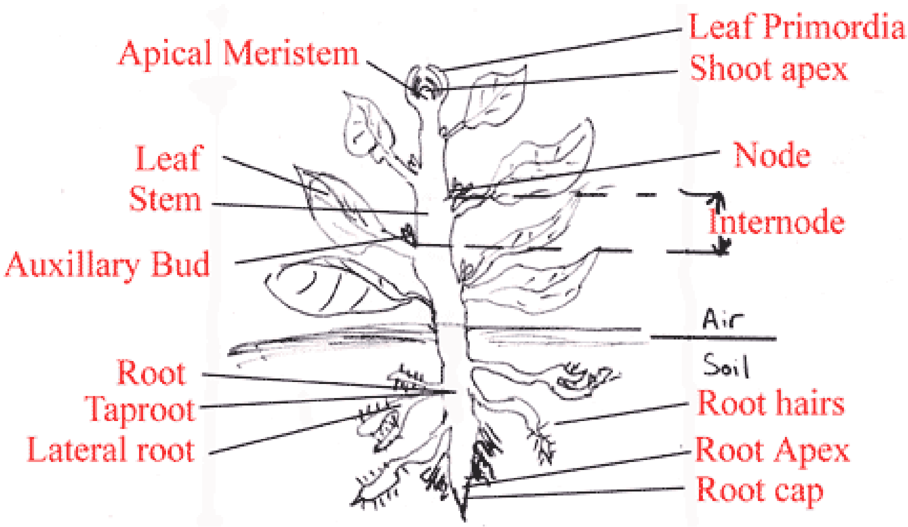

Fig 1.5 A Flowering (Seed) Plant (www.plant-biology.com/parts,php)

Having been introduced to both the gymnosperms and angiosperms, of what relevance are they to humans and the environment? Let us take a look at some of these.

3.4 Relevance of Seed Plants to Humans

Conifers are sources for paper products and lumber materials. The resin from conifers has historically been used as sealing pitch, turpentine, floor waxes, printer's ink, perfumes, menthol manufacture and rosin for musical instruments. Ginko leaves are used medicinally. Arrowroot starch was once purified from a cycad species. Teas have been made from conifers.

Beyond ornamental uses, flowering plants constitute much of what we eat, parts of the clothes we wear, the wood in our homes and furniture and the medicines we consume. Flowering plants are everywhere and thus have a million uses. All fruit comes from flowering plants, obviously, and think of how many just in the edible category there is, not to mention all of those that aren't for eating. Stop and think for a minute on the plants that you encounter in daily life, chances are good they came from a flowering plant

4.0 CONCLUSION

Seeds Plants, also known as Spermatophytes or Phanerogams are well diversed , well established and the most developed in the whole of the plant kingdom

n5.0 SUMMARY

In this unit, you have learnt that:

- Seed plants is composed of the gymnosperms and angiosperms
- Gymnosperms has naked seeds

- The seeds of angiosperms are covered
- Angiosperms are the flowering plants
- Seed plants are very useful to humans in many ways e.g. for food, cloth, furniture and medicine.

6.0 TUTOR MARKED ASSIGNMENT

1. Of what relevance are the seed plants to humans?
2. What distinguishes a gymnosperm from an angiosperm?

7.0 REFERENCES/FURTHER READING

- Introduction to the Seed Plants from http://www.ucmp.berkely.edu/seedplants/seedplants.html
- Seed Plants Tutorials-Biology Online from http://www.biology-online.org/11/14_seed_plants.html
- Spermatophyte – Wikipedia, the free encyclopedia from http://en.wikipedia.org/wiki/Seed_plant

UNIT 2 THE ORIGIN AND EVOLUTION OF SEED PLANTS

CONTENTS

1.0 INTRODUCTION

In unit 1, we looked at the general overview of seed plants which are also known as spermatophytes or phanerogams. We saw their various classifications and divisions with named examples. In this unit, we shall be looking at the fossil records of seed plants especially the angiosperms. The origin and evolution of angiosperms; when, where and how did the angiosperms evolve?

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- Outline the origin of seed plants
- Explain how seed plants evolved based on fossil records
- Explain when, where and how the angiosperms evolved
- Outline the factors that may have been responsible for the success in the evolution of angiosperms

3.0 MAIN CONTENT

3.1 Fossil Record of Seed Plants

Today, the seed plants are some of the most important organisms on earth. Life on land as we know it is shaped largely by the activities of seed plants. This large and important group appeared early in the evolution of vascular plants, and throughout the Late Paleozoic shared dominance of the land flora with ferns, lycophytes, and sphenopsids. Since the beginning of the Mesozoic, however, most trees and forests have consisted of seed plants.

3.1.1 The Late Devonian Seed Plants

The oldest known seed plant is *Elkinsia polymorpha*, a "seed fern" from Late Devonian (Famennian) of West Virginia. Though the fossils consist only of small seed-bearing shoots, these fragments are quite well-preserved. This has allowed us to learn details about the evolutionary development of the seed. Another such fossil from about this time is *Archaeosperma*, also known only from fragments.

The earliest seed plants produced their seeds along their branches without specialized structures, such as cones or flowers, unlike most living seed plants. The seeds were produced singly or in pairs, and were surrounded by loose **cupules**. This small cup-like structure was lobed in the earliest seeds, producing a somewhat sheltered chamber at one end of the seed. Within these cupules, the seed was enclosed by a more tightly appressed tissue called the **integument**. The integument is a layer of tissue found in all seeds; it is produced by the parent plant, and develops into the seed coat. As the integument evolved to enclose the seed more tightly, an opening was left at one end, called the **micropyle**, which permitted pollen to enter and provide sperm to fertilize the egg cell. Both the integuments and cupules are believed to be the result of reduced and fused branches or leaves.

In later seed plants, a small pollen chamber appears just inside the micropyle. In modern cycads and conifers, this chamber exudes sticky fluids to aid in pollen capture, and as the fluid dries, it pulls the pollen inside the micropyle. This structure is preserved in detail in a number of recently discovered **per mineralized** Devonian seeds. Besides preserving the pollen drop, minerals replaced the original tissues gradually, such that fine detail of the cell walls can be studied -- a few Permian seeds even have preserved embryos. Presented below are some seeds of *Trigonocarpus* from the Carboniferous age

Fig 2.1 Fossil Seeds: These are the permineralized seeds of a medullosan seed fern; such permineralized seeds are classified in the form genus *Trigonocarpus*. These particular fossils come from the Francis Creek Shale in Illinois, and are more than 300 million years old (http://www.ucmp.berkeley.edu/seedplants/seedplantsfr.html)

3.1.2 The Late Paleozoic Seed Plants

By the end of the Devonian, a variety of early seed plants collectively known as **"lyginopterids"** appeared. These include *Sphenopteris*, a plant with fern-like leaves, but which bore seeds and cupules. It is not clear whether Sphenopteris is a single group of closely related plants, or several with similar leaves.

The Carboniferous age saw an increase in the number and kinds of seed plants. In the coal swamps of North America grew pteridosperms like Medullosa, a seed plant that resembles modern tree-ferns, but which bore seeds. Cordaites also grew in these swamps, and in a number of other habitats including ocean-edge environments similar to that of the modern mangrove. However, the cordaites are believed to be closer relatives of modern conifers. Both the medullosans and cordaites were small trees when compared to the great scale-trees which dominated these Late Paleozoic coal swamps. Seed plants were thus overshadowed in their early evolution by plants which did not produce seeds.

By the Westphalian (Late Carboniferous), the Voltziales first show up. These are believed to be the closest relatives of modern conifers, and in fact some paleobotanists classify them as conifers. By the Permian, the seed plants were beginning to produce large trees, and by the Triassic, all major groups of seedplants had appeared, except for the flowering plants. (Gastaldo,1986, Stewart et al, 1993)

Having learnt about the evolution of the gymnosperm, let us take a look at that of the angiosperms.

3.2 The Fossil Record of Angiosperms

Most plants from the past decomposed without leaving a trace of their existence. Indeed, the fossil record of plant species may be only 1% complete and that at least 90% of the species that ever existed are extinct. Nevertheless, the fossil record of plants does provide a basis for some general ideas about where flowering plants came from and how they might have evolved.

The first fossils of vascular plants are more than 420 million years old, and the first seeds appeared as long as 360 million years ago. However, fossils of plant fragments that probably came from angiosperms are not known before the early Cretaceous period, about 135 million years ago. Unfortunately, most of the oldest of these fossils are so fragmented and incomplete that paleobotanist are not certain that they are angiosperms at all. Nevertheless, one particular fossil stands out because it consists of all the parts of a flower attached to a reasonable intact plant. This flowering plant is from a 120million year old fossil deposit near Koonwarra, Australia. Paleobotanists believe that this plant represents the ancestral type of flower. If this is true, then the features shared by the Koonwarra angiosperm and certain modern angiosperms may show which living plants are closest to the ancestral origin of the group. (Randi *et al*, 1998)

3.2.1 The Koonwarran Angiosperm

The fossil of the world's earliest known flower was discovered in 1986. The Koonwarra angiosperm had several features that are typical of many modern angiosperms. For example, it had small flowers without petals, a spikelike inflorescence, single carpel ovaries with short stigmas and no styles, and imperfect flowers with several bracts at their bases. These features occur in present-day members of the Lizard's tail family (Saururaceae), the pepper family (Piperaceae), and the chloranthus family (Chloranthaceae), all of which are dicotyledonous plants (dicots)

The Koonwarra angiosperm shows how the ancestor of flowering plants may have looked: a small, rhizome-bearing herb that had secondary growth, small reproductive organs, and simple, imperfect flowers with complexes of bracts at their bases. Families of living plants that share several features with the Koonwarra angiosperm are believed to be primitive members of the dicots and monocots. Furthermore, the appearance of this plant near the apparent beginning of the evolution of angiosperms and its similarities to dicot and monocot suggest that the Koonwarra angiosperm evolved before the divergence between monocots and dicots. This implies that the monocots and dicots separated into two evolutionary lineages less than 120millions ago, probably from an ancestor similar to the Koonwarra angiosperm.

The Koonwarra angiosperm is the earliest intact fossil of a flower. It has features that occur in several modern families of flowering plants. The early evolution of certain floral features is known from fragments of angiosperms, beginning at about the time of the Koonwarra angiosperm and continuing through the Cretaceous period and the Tertiary period. (Randi *et al*, 1998)

3.3 The Origin of Angiosperms

Although the Koonwarra angiosperm is the oldest known flower, it is probably not the oldest flowering plant. Nobody knows just how long ago the first angiosperm lived, but fossil pollen from the early Cretaceous period, perhaps 10million years older than the Koonwarra angiosperm, may have come from angiosperms.

3.3.1 WHEN DID ANGIOSPERM EVOLVE?

Assuming gradual evolution, the sudden appearance of a diversity of angiosperms in the Cretaceous period suggests that the evolution of flowering plants began much earlier, perhaps as much as 100million years before the oldest known angiosperm fossil. If so, then the beginning of the flowering plants may be found among cycadeoids or other extinct group that may have shared ancestors with the angiosperms.

Of special importance in explaining when angiosperms evolved is determining the when the carpel arose. One hypothesis is that the carpel developed from the cupule of the seed fern like caytonia According to this hypothesis, cupule tissue surrounding the seeds fused to form a closed carpel. Seed ferns were prominent in the carboniferous period, but few persisted into the Mesozoic era. This means that the carpel, or a precarpel, may have originated as early as 200million years ago. However, several other hypotheses exist.

Cycadeoids were once considered to be the ancestors of angiosperms, partly because the microsporangia and ovules of cycadeoids occur in the same one. Such an arrangement simulates perfect flowers, that is, flowers with both stamens and carpel on the same receptacle, which are the most common type of flower in angiosperms.

More recently, botanists have used the methods of cladistics to show how angiosperms may have descended rather directly from seed-fern ancestors in a line parallel to cycadeoids. If this were the case, then angiosperms could have originated in the Triassic period at about the same time the cycadeoids first appeared in the fossil record.

3.3.2 WHERE DID ANGIOSPERMS EVOLVE?

Pre-Cretaceous angiosperms were well adapted to cool, dry climates. These plants were also probably small, with tough leaves, seed coats, and vessels in their secondary xylem. Most of them were probably deciduous and thus avoided seasonal drying. These hypotheses represent guesswork based on the fossils of more recent Cretaceous angiosperms, and if correct, they suggest that the most likely places for angiosperms to have evolved were in the semi-arid central regions of western Gondwanaland. Unfortunately, the drier conditions in these upland regions, unlike the wet conditions along shorelines and in lowland basins, did not allowed much chance for plants to be preserved in the fossil record.

Angiosperms apparently began to invade the lowland basins from the Triassic, Jurassic, and Cretaceous periods by the early Tertiary period, less than 6million years ago. The more recent invasion of angiosperms into these lowland areas can be explained by climatic and geologic changes at the end of the Mesozoic era.

3.3.3 HOW DID ANGIOSPERMS EVOLVE?

Insects played a prominent role in how the angiosperms evolved into the largest and most diverse group of plants. Early in seed-plant evolution, insects became pollen carriers as the searched for food. In turn, plants evolved floral nectar and odors for attracting insects to carry pollen. The earliest, unequivocal angiosperm nectaries are from the late Cretaceous period, but they probably evolved even earlier. Some of these insects include beetles, bees, butterflies and moths. (Randi *et al*, 1998)

SAE

- What are the characteristics of the Koonwarran Angiosperms?

3.4 Why Angiosperms were Successful

Angiosperms first appeared in the fossil record about 135 million years ago. By about 90 million years ago, angiosperms had probably begun to outnumber gymnosperms. What led to the success of this new kind of plant? Several factors were probably involved. These factors may have included:

- In many angiosperms, seeds germinate and produce mature plants, which in turn produce new seeds, all in one growing season. In the case of gymnosperms, it often takes 10 or more years to reach maturity and produce seeds
- Fruits of flowering plants protect seeds and aid in their dispersal.
- Angiosperms have a more efficient vascular system and are more likely to be associated with mycorrhizae than gymnosperms are.
- Angiosperms also may gain an advantage by using animal pollination rather than less efficient wind pollination used by gymnosperms. However, wind pollination is used by many successful angiosperms, such as grasses and many deciduous trees.
- Angiosperms occupy more niches, such as in aquatic, epiphytic, and parasitic environment. Hence, they are more diverse than gymnosperms

4.0 CONCLUSION

Seedlike structures first appeared about 360 million years ago in progymnosperms. Pollen arose more than 150 million years after the origin of seeds. Seed plants diverged and flourished throughout the carboniferous period; and the Jurassic period was dominated by cycads, cycadeoids and early members of the Pinophyta. The angiosperms which are the most dominant plants on earth, are also called flowering plant. Fossils of carpels and other parts of flower are known from Cretaceous deposits that are at least 135 million years old, but the first complete fossil flower is about 120 million years old.

5.0 SUMMARY

At the end of this unit, you have learnt that:

- The oldest known seed plant is *Elkinsa polymorpha*, a seed fern from the late Devonian West Virginia
- The seed plants produced their seeds along their branches without specialized structures
- The integument is a layer of tissue found in all seeds; it is produced by the parent plant, and develops into the seedcoat
- By the end of the Devonian, a variety of early seed plants collectively known as Lyginopterids appeared
- The Carboniferous period saw an increase in the number and kinds of seed plants
- The angiosperms are the most dominant plants on earth
- The angiosperms have flowers that include seeds in a Carpel
- The main force behind he rapid evolutionary radiation of angiosperms may have been pollination by insects and the availability of habitats left open by the disappearance of many gymnosperms
- The first flowers were probably pollinated by beetles; later angiosperms attracted butterflies and bees.

6.0 TUTOR MARKED ASSIGNMENTS

- What is the fossil evidence that angiosperms originated at least about 200 million years ago

7.0 REFERENCES/FURTHER READINGS

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MODULE 2 LIFE CYCLE OF SEED PLANTS

UNIT 3 Reproductions in Gymnosperms

CONTENTS

1.0 INTRODUCTION

We have generally learnt about the Spermatophytes: their classification, divisions, origin and evolution in module2. In this module, generally, we shall be considering the life cycle of seed plants, the mode of reproduction in gymnosperms and angiosperms. In this unit, we shall be looking, specifically, at reproduction in gymnosperms.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- Explain the reproduction pattern in gymnosperm

- Outline the roles of sporophyte and gametophyte in the reproductive process of gymnosperms
- Describe pollination and fertilization in gymnosperms
- Explain seed formation in gymnosperms

3.0 MAIN CONTENT

3.1 Generalized Life cycle of seed Plants

Seed plants are ***heterosporou***s that is they have 2 different spore sizes namely, the megaspores and microspores.

The generalized life cycle of plants has been modified (Fig 2.1) to illustrate plants which have separate male and female gametophytes (***megagametophyte*** and ***microgametophyte***) produced by different sized spores (***megaspores*** and ***microspores***).

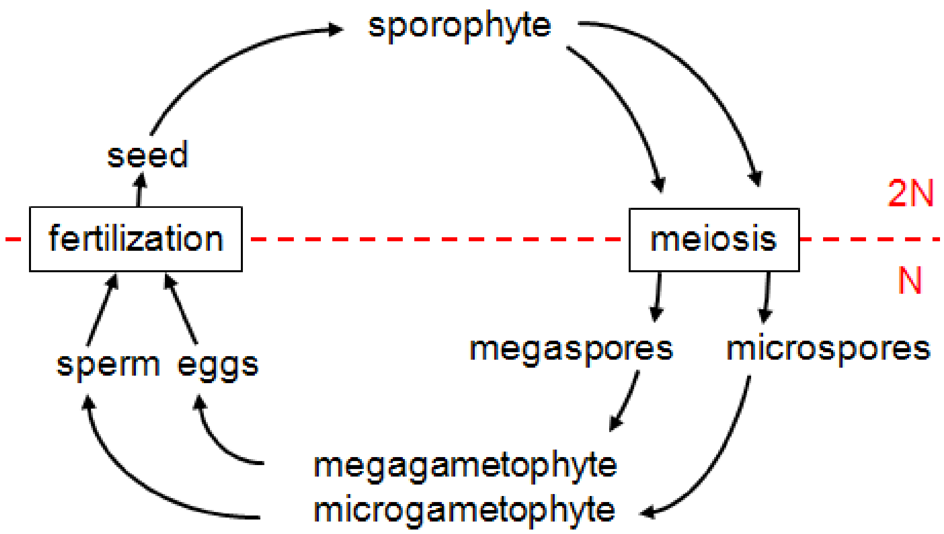

Fig 3.1 Generalised life cycle of a seed plant (http://en.wikipedia.org/wiki/seedplant

The evolutionary trend from nonvascular plants to seedless vascular plants to seed plants has been a reduction in the size of the gametophyte. In seed plants, the gametophyte is usually microscopic and is retained within the tissues of the sporophyte.

The megasporangium is surrounded by layers of sporophyte tissue called the ***integument***. The integument and the structures within (megasporangium, megaspore) are the ***ovule***.

Microspores germinate within the sporophyte tissue and become pollen grains. The microgametophyte is contained within the tough, protective coat of the pollen grain.

The entire microgametophyte (pollen grain) is transferred to the vicinity of the megagametophyte by a process of pollination. Wind or animals usually accomplish this transfer.

When pollen reaches the female gametophyte, it produces an elongate structure (pollen tube) that grows to the egg cell. Sperm are transferred directly through this tube to the

egg. The advantage of this process is that sperm do not have to swim long distances as they do in seedless plants

The seeds of gymnosperms contain the sporophyte embryo, food for the embryo, and a protective coat.The embryo within the seed is dormant; it can survive for long periods without additional food or water. When conditions become favourable, the embryo resumes growth as the seed germinates. Gymnosperms have naked seeds.

3.2 Reproduction in Gymnosperm (Pine)

3.2.1. *Microsporangia and Megasporangia*

Spores (mega and micro) are produced by meiosis. Microspores are produced within protective structures called ***microsporangia***; megaspores are produced within ***megasporangia***.

In Fig 3.2 below, in pine, microsporangium is found within pollen cones.

Fig 3.2a Microsporangium: Male reproductive structure ((http://en.wikipedia.org/wiki/seedplant)

Fig 3.2b Megasporangium: Female reproductive structures in a Pine ((http://en.wikipedia.org/wiki/seedplant)

Self Assessment Exercise (SAE)

1. Why are seed plants heterosporous?

Seed cones contain ovules. The structure diagrammed below (Fig 3.3a) is an ***ovule*** and will develop into a seed. The ***integument*** will become the seed coat.

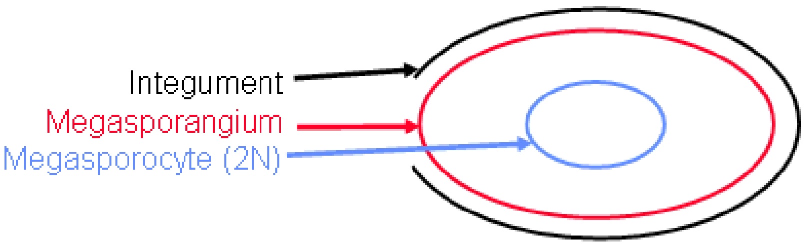

Fig 3.3a Diagrammatic structure of an ovule

Megasporocytes (megaspore mother cells) are cells contained within the ovule produce four megaspores by ***meiosis*** *(Fig 3.3b)*

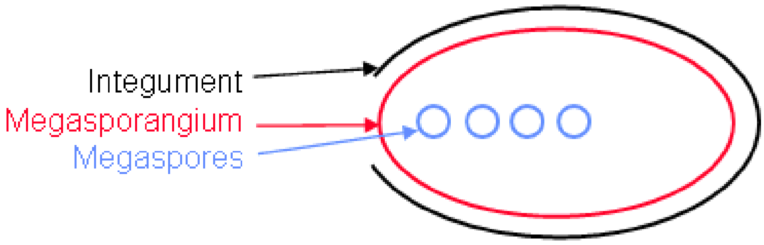

Fig 3.3b Megasporocyte containing four megaspore

Three of the megaspores die (fig 3.3c)

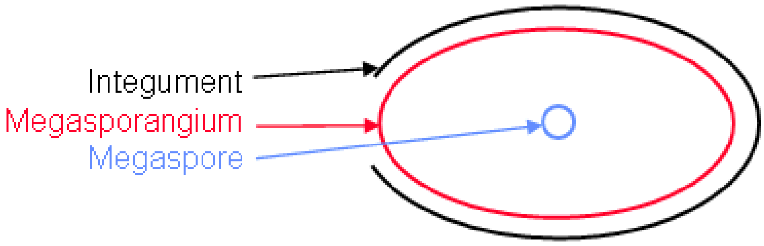

Fig 3.3c Megasporocyte containing only one megaspore

The remaining one develops into a ***female gametophyte*** without being released from the megasporangium (fig 3.3d)

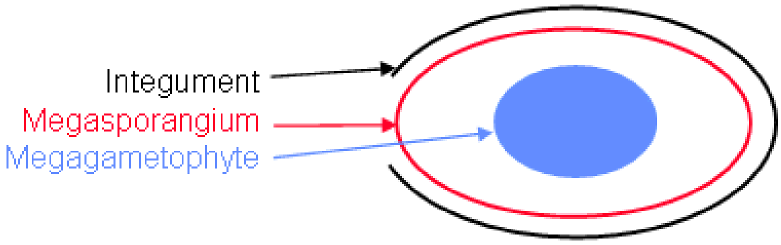

Fig 3.3d Megasporangium containing the gametophyte

Female gametophytes function to produce ***eggs.*** (Fig 3.3f)

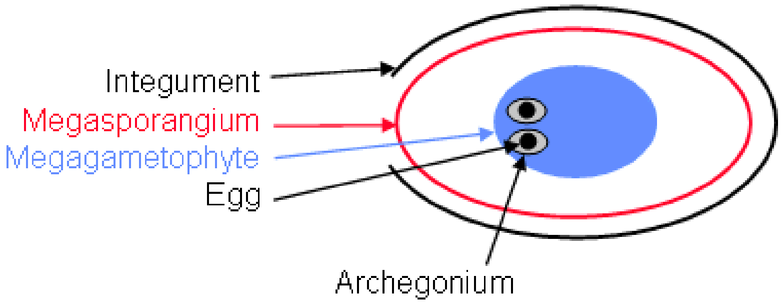

Fig 3.3f Eggs formation by the gametophyte

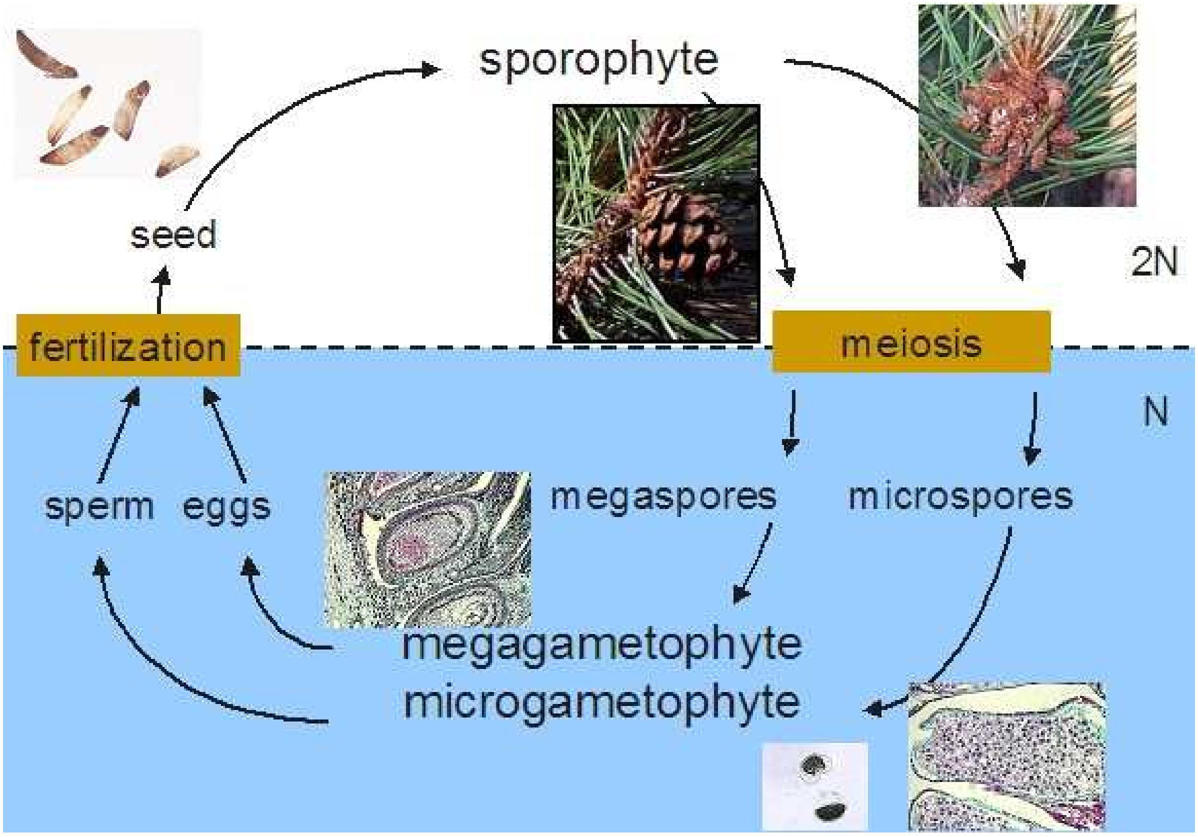

Fig 3.4. Diagrammatic illustration of Pine life cycle
(http://en.wikipedia.org/wiki/seedplant)

We have studied the development of ovules to the point of egg formation in gymnosperm. Lets briefly take a look at how the flowers are pollinated and the subsequent fertilization of the egg

3.3 Pollination *and* Fertilization in Gymnosperm

The male gametophyte (pollen grains) consists of two cells. One small and is called a generative cell. The other, larger cell is a tube cell. The generative cell will later divide to produce two sperm.Pollination refers to the transfer of pollen to the vicinity of the egg. The two wing-like structures on the pollen grain aid in enabling the pollen to be carried by the wind. After being transported by wind to a seed cone, the tube cell grows toward the egg, producing a pollen tube. The two sperm produced by the generative cell enter the pollen tube and move toward the egg.

Water is not required for reproduction. During pollination, the entire male gametophyte is transferred from the pollen cone to the seed cone. The sperm are not flagellated, so they remain within the tube cell and rely on the growth of a pollen tube to deliver them to the egg cell.The fertilized egg (zygote) develops into an embryo which is contained within the seed. Seeds function as a mechanism of dispersal in seed plants. Seeds contain food and a protective coat (Seed Plant).

4.0 CONCLUSION

Gymnosperms are plants with naked seeds (no fruit). The sporophyte and gametophyte are the reproductive structures in the gymnosperms. The usual or normal reproductive processes take place in gymnosperms resulting in the formation of naked seeds

5.0 SUMMARY

At the end of this unit, you have learnt that:

- Seed plants have 2 different spore-size types: Megaspore and Microspore
- The megaspore and the microspore are enclosed in a protective structure called Megasporangia and Microsporangia respectively
- Male gametophytes are produced from the microspore
- Female gametophytes are produced from the megaspore
- The integument becomes the seed coat
- Seed cones contain ovules
- Fertilized egg develops into an embryo
- Gymnosperms are plants with naked seeds

6.0 TUTOR MARKED ASSIGNMENT

- With the aid of a diagram, describe the life cycle of a named gymnosperm

7.0 REFERENCES/ FURTHER READING

Seed Plants: http://faculty.clintoncc.suny.edu/faculty/Michael.Gregory/files/Bio%2...

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UNIT 4 REPRODUCTION IN ANGIOSPERMS

CONTENTS

5.0 Tutor Marked Assignment

6.0 Summary

7.0 References/Further Readings

1.0 INTRODUCTION

In the last unit we studied the origin and evolution of seed plants. In this unit we shall be considering reproduction in angiosperms.

Angiosperms are flowering plants. They are the largest group of plants with about 90% of all plant species. They evolved from gymnosperms during the Mesozoic and became widespread during the Cenozoic. The seeds of angiosperms are covered by a fruit. In many species, the fruit helps with dispersal of the seeds by attracting animals to consume them. Flowers may have contributed to the enormous success of angiosperms. The flowers of many species attract insect and animal pollinators which carry pollen to other individuals of the same species

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- Classify angiosperms
- Explain the development of gametophytes
- Describe fertilization in angiosperms
- Explain embryonic development in angiosperms
- Mention the various asexual means of reproduction in angiosperms

3.0 MAIN CONTENT

3.1 Main groups of Angiosperms

Angiosperms can be simply classified into two groups. They are the monocotyledonous (monocots) and the dicotyledonous plants (dicots).

Table 1: Characteristics of monocotyledonous and dicotyledonous plants

Dicotyledonous plants	**Monocotyledonous plants**
May be woody or herbaceous	Herbaceous
Flower parts in multiples of four or five	Flower parts in multiples of three

Net-veined leaves	Parallel-veined leaves
Vascular tissue in the stem forms rings	Bundles of vascular tissue are scattered throughout the stem
Two cotyledons (seed leaves)	One cotyledon

3.2 SEXUAL REPRODUCTION IN ANGIOSPERMS

The life cycle of flowering plants is similar to that of gymnosperms. It involves alternation of generations. A diploid ***sporophyte*** alternates with a haploid ***gametophyte***.

3.2.1 Morphology of Flowers

Flowering plants are *heterosporangiate*, producing two types of reproductive spores. The pollen (male spores) and ovules (female spores) are produced in different organs, but the typical flower is a *bisporangiate strobilus* in that it contains both organs.

A flower is regarded as a modified stem with shortened internodes and bearing, at its nodes, structures that may be highly modified leaves (Eames, 1961). In essence, a flower structure forms on a modified shoot or *axis* with an apical meristem that does not grow continuously (growth is *determinate*). Flowers may be attached to the plant in a few ways. If the flower has no stem but forms in the axil of a leaf, it is called sessile. When one flower is produced, the stem holding the flower is called a peduncle. If the peduncle ends with groups of flowers, each stem that holds a flower is called a pedicel. The flowering stem forms a terminal end which is called the *torus* or receptacle. The parts of a flower are arranged in whorls on the torus. The four main parts or whorls (starting from the base of the flower or lowest node and working upwards) are as follows:

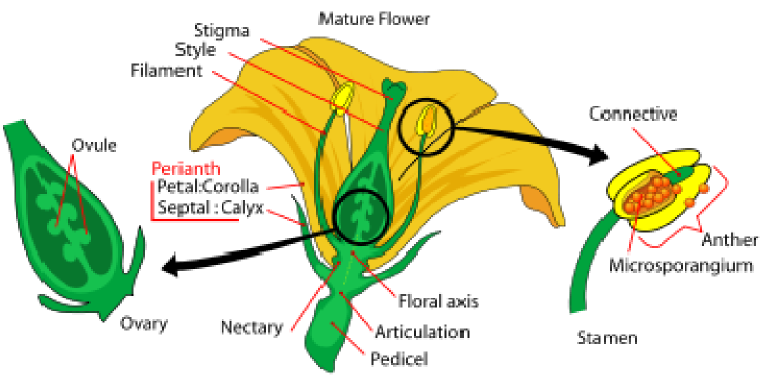

Fig 4.1 Diagram showing the main parts of a mature flower (http://en.wikipedia.org/wiki/Flower)

3.2.2 Floral Structures

- *Calyx*: the outer whorl of *sepals*; typically these are green, but are petal-like in some species.
- *Corolla*: the whorl of *petals*, which are usually thin, soft and colored to attract animals that help the process of pollination. The coloration may extend into the ultraviolet, which is visible to the compound eyes of insects, but not to the eyes of birds.
- *Androecium* (from Greek *andros oikia*: man's house): one or two whorls of stamens, each a filament topped by an anther where pollen is produced. Pollen contains the male gametes.
- *Gynoecium* (from Greek *gynaikos oikia*: woman's house): one or more pistils. The female reproductive organ is the carpel: this contains an ovary with ovules (which contain female gametes). A pistil may consist of a number of carpels merged together, in which case there is only one pistil to each flower, or of a single individual carpel (the flower is then called *apocarpous*). The sticky tip of the pistil, the stigma, is the receptor of pollen. The supportive stalk, the style becomes the pathway for pollen tubes to grow from pollen grains adhering to the stigma, to the ovules, carrying the reproductive material.

Although the floral structure described above is considered the "typical" structural plan, plant species show a wide variety of modifications from this plan. These modifications have significance in the evolution of flowering plants and are used extensively by botanists to establish relationships among plant species. For example, the two subclasses of flowering plants may be distinguished by the number of floral organs in each whorl: dicotyledons typically having 4 or 5 organs (or a multiple of 4 or 5) in each whorl and monocotyledons having three or some multiple of three. The number of carpels in a compound pistil may be only two, or otherwise not related to the above generalization for monocots and dicots.

In the majority of species individual flowers have both pistils and stamens as described above. These flowers are described by botanists as being *perfect*, *bisexual*, or *hermaphrodite*. However, in some species of plants the flowers are *imperfect* or *unisexual*: having only either male (stamens) or female (pistil) parts. In the latter case, if an individual plant is either female or male the species is regarded as *dioecious*. However, where unisexual male and female flowers appear on the same plant, the species is considered *monoecious*.

In those species that have more than one flower on an axis—so-called *composite flowers*—the collection of flowers is termed an *inflorescence*; this term can also refer to the specific arrangements of flowers on a stem. In this regard, care must be exercised in considering what a ‘‘flower’’ is. In botanical terminology, a single daisy or sunflower for example, is not a flower but a flower *head*—an inflorescence composed of numerous tiny flowers (sometimes called florets). Each of these flowers may be anatomically as described above. Many flowers have a symmetry, if the perianth is bisected through the central axis from any point, symmetrical halves are produced—the flower is called regular or actinomorphic, e.g. rose or trillium. When flowers are bisected and produce only one line that produces symmetrical halves the flower is said to be irregular or zygomorphic. e.g. snapdragon or most orchids.

3.2.3 Floral formula

A *floral formula* is a way to represent the structure of a flower using specific letters, numbers, and symbols. Typically, a general formula will be used to represent the flower structure of a plant family rather than a particular species. The following representations are used:

Ca = calyx (sepal whorl; e. g. Ca^5 = 5 sepals)
Co = corolla (petal whorl; e. g., $Co^{3(x)}$ = petals some multiple of three)
Z = add if *zygomorphic* (e. g., CoZ^6 = zygomorphic with 6 petals)
A = *androecium* (whorl of stamens; e. g., A^∞ = many stamens)
G = *gynoecium* (carpel or carpels; e. g., G^1 = monocarpous)

x: to represent a "variable number"
∞: to represent "many"

A floral formula would appear something like this:

$$\mathbf{Ca^5Co^5A^{10-\infty}G^1}$$

3.2.4 Pollination

The primary purpose of a flower is reproduction. Since the flowers are the reproductive organs of plant, they mediate the joining of the sperm, contained within pollen, to the ovules - contained in the ovary. Pollination is the movement of pollen from the anthers to the stigma. The joining of the sperm to the ovules is called fertilization. Normally pollen is moved from one plant to another, but many plants are able to self pollinate. The fertilized ovules produce seeds that are the next generation. Sexual reproduction produces genetically unique offspring, allowing for adaptation. Flowers have specific designs which encourage the transfer of pollen from one plant to another of the same species. Many plants are dependent upon external factors for pollination, including: wind and animals, and especially insects. Even large animals such as birds, bats, and pygmy possums can be employed. The period of time during which this process can take place (the flower is fully expanded and functional) is called *anthesis*.

Fig 4.2 Grains of pollen sticking to this bee will be transferred to the next flower it visits. (http://en.wikipedia.org/wiki/Flower)

3.2.4.1 Pollination Attraction Methods

Plants can not move from one location to another, thus many flowers have evolved to attract animals to transfer pollen between individuals in dispersed populations. Flowers that are insect-pollinated are called *entomophilous*; literally "insect-loving" in Latin. They can be highly modified along with the pollinating insects by co-evolution. Flowers commonly have glands called *nectaries* on various parts that attract animals looking for nutritious nectar. Birds and bees have color vision, enabling them to seek out "colorful" flowers. Some flowers have patterns, called nectar guides, that show pollinators where to look for nectar; they may be visible only under ultraviolet light, which is visible to bees and some other insects. Flowers also attract pollinators by scent and some of those scents are pleasant to our sense of smell. Not all flower scents are appealing to humans, a number of flowers are pollinated by insects that are attracted to rotten flesh and have flowers that smell like dead animals, often called Carrion flowers including *Rafflesia*, the titan arum. Flowers pollinated by night visitors, including bats and moths, are likely to concentrate on scent to attract pollinators and most such flowers are white.

3.2.4.2 Pollination mechanism

The pollination mechanism employed by a plant depends on what method of pollination is utilized. Most flowers can be divided between two broad groups of pollination methods:

Entomophilous: flowers attract and use insects, bats, birds or other animals to transfer pollen from one flower to the next. Often they are specialized in shape and have an arrangement of the stamens that ensures that pollen grains are transferred to the bodies of the pollinator when it lands in search of its attractant (such as nectar, pollen, or a mate).

In pursuing this attractant from many flowers of the same species, the pollinator transfers pollen to the stigmas—arranged with equally pointed precision—of all of the flowers it visits. Many flowers rely on simple proximity between flower parts to ensure pollination.

Anemophilous: flowers use the wind to move pollen from one flower to the next, examples include the grasses, Birch trees, Ragweed and Maples. They have no need to attract pollinators and therefore tend not to be "showy" flowers. Whereas the pollen of entomophilous flowers tends to be large-grained, sticky, and rich in protein (another "reward" for pollinators), anemophilous flower pollen is usually small-grained, very light, and of little nutritional value to insects, though it may still be gathered in times of dearth. Honeybees and bumblebees actively gather anemophilous corn (maize) pollen, though it is of little value to them.

Some flowers are self pollinated and use flowers that never open or are self pollinated before the flowers open, these flowers are called cleistogamous. Many Viola species and some Salvia have these types of flowers.

3.2.5 Uses of Flowers

In modern times, people have sought ways to cultivate, buy, wear, or otherwise be around flowers and blooming plants, partly because of their agreeable appearance and smell. Around the world, people use flowers for a wide range of events and functions that, cumulatively, encompass one's lifetime. This includes:

- For new births or Christenings
- As tokens of love or esteem
- For wedding flowers for the bridal party, and decorations for the hall
- As brightening decorations within the home
- As a gift of remembrance for bon voyage parties, welcome home parties, and "thinking of you" gifts
- For funeral flowers and expressions of sympathy for the grieving
- For worshiping goddesses. in Hindu culture it is very common to bring flowers as a gift to temples.

People therefore grow flowers around their homes, dedicate entire parts of their living space to flower gardens, pick wildflowers, or buy flowers from florists who depend on an entire network of commercial growers and shippers to support their trade.

Hundreds of fresh flowers are edible but few are widely marketed as food. They are often used to add color and flavor to salads. Squash flowers are dipped in breadcrumbs and fried. Edible flowers include nasturtium, chrysanthemum, carnation, cattail, honeysuckle, chicory, cornflower, Canna, and sunflower. Some edible flowers are sometimes candied such as daisy and rose (you may also come across a candied pansy).

Flowers can also be made into herbal teas. Dried flowers such as chrysanthemum, rose, jasmine, camomile are infused into tea both for their fragrance and medical properties. Sometimes, they are also mixed with tea leaves for the added fragrance.

Retrieved from "http://en.wikipedia.org/wiki/Flower

3.2.6 Fruit development

A fruit is a ripened ovary. Inside the ovary is one or more ovules where the megagametophyte contains the mega gamete or egg cell. The ovules are fertilized in a process that starts with pollination, which involves the movement of pollen from the stamens to the stigma of flowers. After pollination, a tube grows from the pollen through the stigma into the ovary to the ovule and sperm are transferred from the pollen to the ovule, within the ovule the sperm unites with the egg, forming a diploid zygote. Fertilization in flowering plants involves both plasmogamy, the fusing of the sperm and egg protoplasm and karyogamy, the union of the sperm and egg nucleus.(Mauseth,2003). When the sperm enters the nucleus of the ovule and joins with the megagamete and the endosperm mother cell, the fertilization process is completed.(Rost et al, 1979). As the developing seeds mature, the ovary begins to ripen. The ovules develop into seeds and the ovary wall, the *pericarp*, may become fleshy (as in berries or drupes), or form a hard outer covering (as in nuts). In some cases, the sepals, petals and/or stamens and style of the flower fall off. Fruit development continues until the seeds have matured. In some multiseeded fruits, the extent to which the flesh develops is proportional to the number of fertilized ovules. (Mauseth. Botany. Chapter 9: Flowers and Reproduction) The wall of the fruit, developed from the ovary wall of the flower, is called the *pericarp*. The *pericarp* is often differentiated into two or three distinct layers called the *exocarp* (outer layer, also called epicarp), *mesocarp* (middle layer), and *endocarp* (inner layer). In some fruits, especially simple fruits derived from an inferior ovary, other parts of the flower (such as the floral tube, including the petals, sepals, and stamens), fuse with the ovary and ripen with it. The plant hormone ethylene causes ripening. When such other floral parts are a significant part of the fruit, it is called an *accessory fruit*. Since other parts of the flower may contribute to the structure of the fruit, it is important to study flower structure to understand how a particular fruit forms. (Mauseth, 2003).

3.2.7 Types of Fruits

Fruits are so diverse that it is difficult to devise a classification scheme that includes all known fruits. Many common terms for seeds and fruit are incorrectly applied, a fact that complicates understanding of the terminology. Seeds are ripened ovules; fruits are the ripened ovaries or carpels that contain the seeds.

There are three basic types of fruits

1. Simple fruit
2. Aggregate fruit
3. Multiple fruit

3.2.7.1 Simple fruit

Fig 4.3 Epigynous berries are simple fleshy fruit. (http://en.wikipedia.org/wiki/Fruit)

Simple fruits can be either dry or fleshy, and result from the ripening of a simple or compound ovary with only one pistil. Dry fruits may be either dehiscent (opening to discharge seeds), or indehiscent (not opening to discharge seeds). (Schlegel. Encyclopedia Dictionary.pp.123).

Types of dry, simple fruits, with examples of each, are:

- achene – (dandelion seeds, strawberry seeds)
- capsule – (Brazil nut)
- caryopsis – (wheat)
- fibrous drupe – (coconut, walnut)
- follicle – (milkweed, magnolia)
- legume – (pea, bean, peanut)
- loment
- nut – (hazelnut, beech, oak acorn)
- samara – (elm, ash, maple key)
- schizocarp – (carrot seed)
- silique – (radish seed)
- silicle – (shepherd's purse)
- utricle – (beet)

Fig 4.4 *Lilium* unripe capsule fruit (http://en.wikipedia.org/wiki/Fruit)

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

- berry – (redcurrant, gooseberry, tomato, avocado)
- stone fruit or drupe (plum, cherry, peach, apricot, olive)
- false berry – Epigynous accessory fruits (banana, cranberry, strawberry (edible part).)
- pome – accessory fruits (apple, pear, rosehip, saskatoon berry)

3.2.7.2 Aggregate fruit

.
An aggregate fruit, or *etaerio*, develops from a flower with numerous simple pistils. An example is the raspberry, whose simple fruits are termed *drupelets* because each is like a small drupe attached to the receptacle. In some bramble fruits (such as blackberry) the receptacle is elongated and part of the ripe fruit, making the blackberry an *aggregate-accessory* fruit. (McGee. On Food and Cooking. pp. 361-362)The strawberry is also an aggregate-accessory fruit, only one in which the seeds are contained in achenes. (McGee. On Food and Cooking. Pp.364-365). In all these examples, the fruit develops from a single flower with numerous pistils.

3.2.7.3 Multiple fruit

A multiple fruit is one formed from a cluster of flowers (called an *inflorescence*). Each flower produces a fruit, but these mature into a single mass. (Schlegel,2003). Examples are the pineapple, edible fig, mulberry, osage-orange, and breadfruit.

There are also many dry multiple fruits, e.g.

- Tuliptree, multiple of samaras.

- Sweet gum, multiple of capsules.
- Sycamore and teasel, multiple of achenes.
- Magnolia, multiple of follicles.

3.2.7.4 Seedless fruits

Seedlessness is an important feature of some fruits of commerce. Commercial cultivars of bananas and pineapples are examples of seedless fruits. Some cultivars of citrus fruits (especially navel oranges), satsumas, mandarin oranges table grapes, grapefruit, and watermelons are valued for their seedlessness. In some species, seedlessness is the result of *parthenocarpy*, where fruits set without fertilization. Parthenocarpic fruit set may or may not require pollination. Most seedless citrus fruits require a pollination stimulus; bananas and pineapples do not. Seedlessness in table grapes results from the abortion of the embryonic plant that is produced by fertilization, a phenomenon known as *stenospermocarpy* which requires normal pollination and fertilization (Spiegel et al, 1996)

Fig 4.5 An arrangement of fruits commonly thought of as vegetables, including tomatoes and various squash (http://en.wikipedia.org/wiki/Fruit)

3.2.7.5 Uses of Fruits

Many hundreds of fruits, including fleshy fruits like apple, peach, pear, kiwifruit, watermelon and mango are commercially valuable as human food, eaten both fresh and as jams, marmalade and other preserves. Fruits are also in manufactured foods like cookies, muffins, yoghurt, ice cream, cakes, and many more. Many fruits are used to make beverages, such as fruit juices (orange juice, apple juice, grape juice, etc) or alcoholic beverages, such as wine or brandy (McGee, 2004). Apples are often used to make vinegar. Fruits are also used for gift giving, Fruit Basket and Fruit Bouquet are some common forms of fruit gifts.

3.2.8 Seed Dissemination/Dispersal

Variations in fruit structures largely depend on the mode of dispersal of the seeds they contain. This dispersal can be achieved by animals, wind, water, or explosive dehiscence. (Capon, 2005)

Some fruits have coats covered with spikes or hooked burrs, either to prevent themselves from being eaten by animals or to stick to the hairs, feathers or legs of animals, using them as dispersal agents. Examples include cocklebur and unicorn plant. (Heiser, 2003)

The sweet flesh of many fruits is "deliberately" appealing to animals, so that the seeds held within are eaten and "unwittingly" carried away and deposited at a distance from the parent. Likewise, the nutritious, oily kernels of nuts are appealing to rodents (such as squirrels) who hoard them in the soil in order to avoid starving during the winter, thus giving those seeds that remain uneaten the chance to germinate and grow into a new plant away from their parent. (McGee, 2004)

Other fruits are elongated and flattened out naturally and so become thin, like wings or helicopter blades, e.g. maple, tuliptree and elm. This is an evolutionary mechanism to increase dispersal distance away from the parent via wind. Other wind-dispersed fruit have tiny *parachutes*, e.g. dandelion and salsify.

Coconut fruits can float thousands of miles in the ocean to spread seeds. Some other fruits that can disperse via water are nipa palm and screw pine (Capon, 2005)

Some fruits fling seeds substantial distances (up to 100 m in sandbox tree) via explosive dehiscence or other mechanisms, e.g. impatiens and squirting cucumber. (Feldkamp, 2002)

SAE

- What structure of the flower is involved in reproduction?

- Define the followings: parthenocarpy; inflorescence

We have just studied the reproductive structure of a plant i.e. the flower. Now, lets take a look at how gametes are developed in this reproductive structure.

3.3 DEVELOPMENT OF GAMETOPHYTES

The diagram below shows the parts of the life cycle that is located within the ovary and within the anther. The ovary and the anther represent the female and the male reproductive structures, respectively.

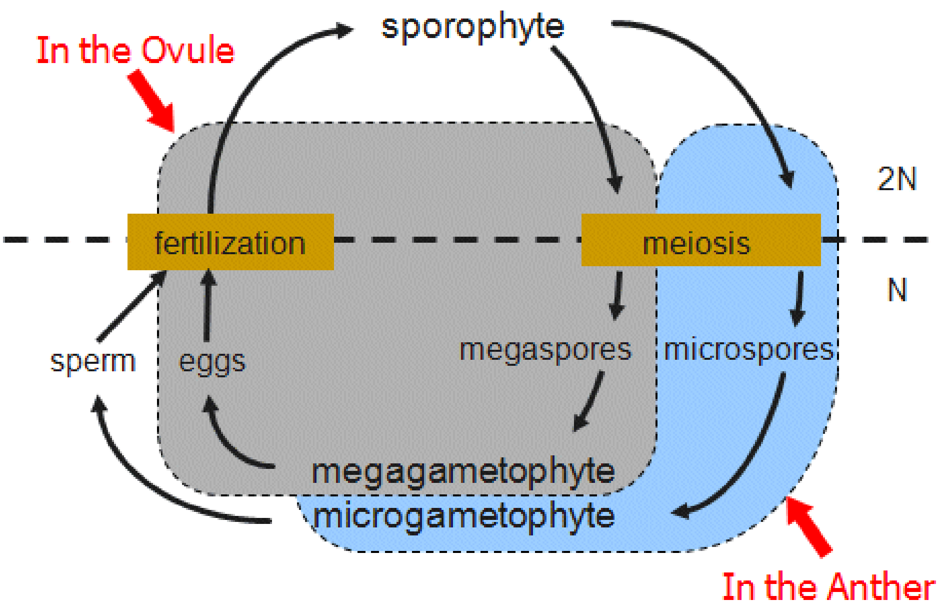

Fig 4.6 **Diagrammatic Illustration of the Life Cycle of an Angiosperm (http://wikipedia.org/wiki/seedplant)**

3.3.1 The megasporangium:

A ***sporangium*** is a structure that produces spores (see the diagram of an ovule below in Fig 4.7). Two protective layers called ***integuments*** surround the ***megasporangium*** of flowering plants (angiosperms). The entire structure including the integuments is the ***ovule*** and is destined to become the ***seed***. The integuments will become t./ he seed coat.

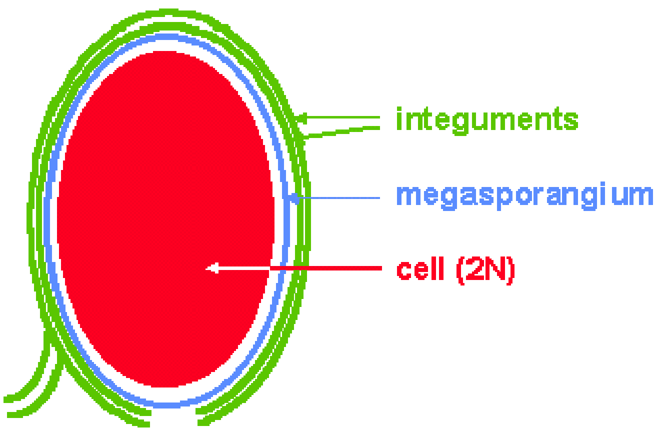

Fig 4.7a Ovule of an angiosperm plant ((http://wikipedia.org/wiki/seedplant)

The diploid cell within the megasporangium will divide by meiosis to produce four megaspores (fig 4.7b)

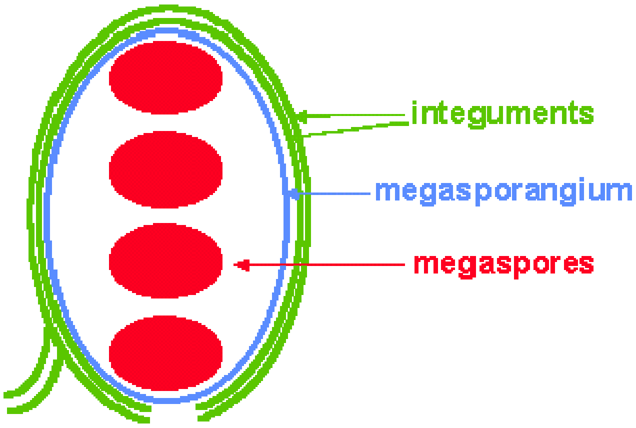

Fig 4.7b Ovule

Three of the megaspores disintegrate.(fig 4.7c)

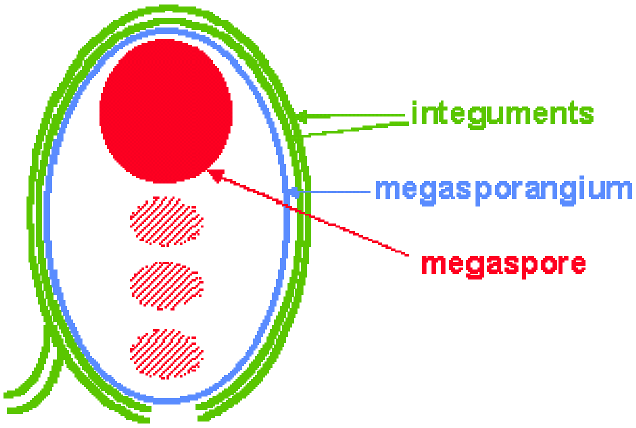

Fig 4.7c Ovule

The remaining megaspore nucleus divides 3 times to produce a cell with **8 nuclei.** Cell walls form around them producing a gametophyte that has 7 cells and 8 nuclei. One of the cells contains two nuclei (Fig 4.7d).The **micropyle** is the opening in the integuments near the egg cell. Eventually, sperm pass through this opening.

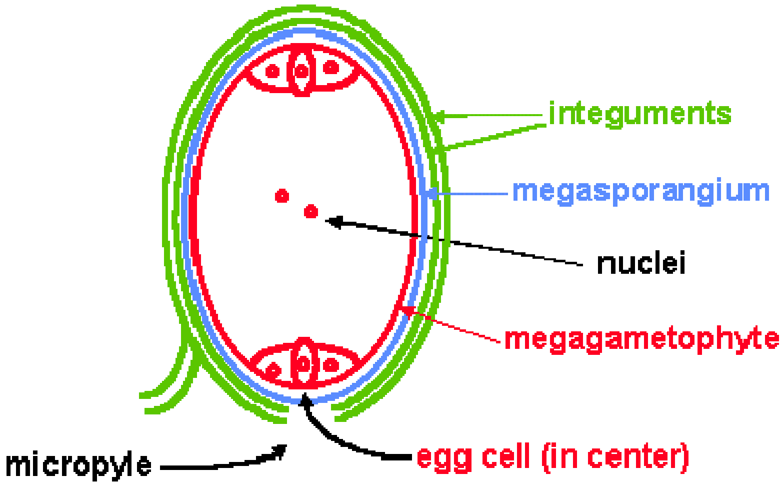

Fig. 4.7d

3.3.2 within the microsporangium:

An anther has 4 microsporangia (pollen sacs). Each contains many ***microsporocytes*** that will divide by meiosis to produce 4 ***microspores*** each.

The diagram below shows a cross-section of an anther at three different stages of development. Initially, ***microsporangia*** contain diploid cells. The sporangia and cells are part of the sporophyte (2N) plant.

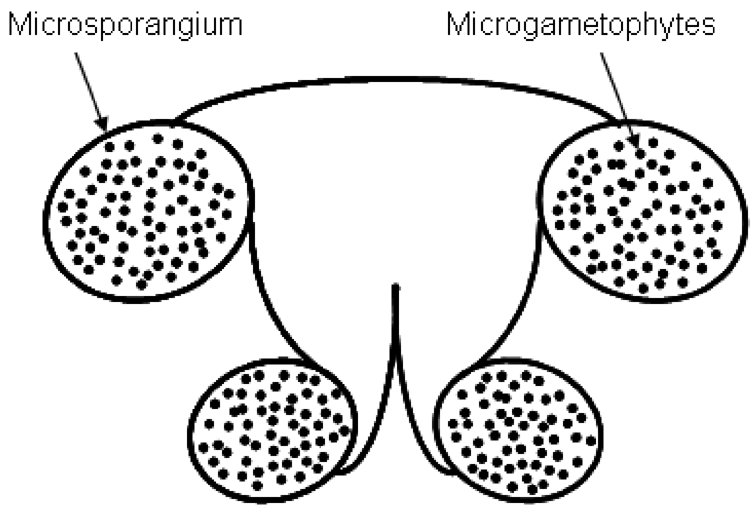

Fig 4.8 Microspores are produced by meiosis. (**(http://wikipedia.org/wiki/seedplant)**

The microspore produces a 2-celled microgametophyte and the microsporangia rupture to release pollen.

3.3.3 Pollen

In Fig.4.9, Pollen contains two nuclei, a generative nucleus and a tube nucleus. A membrane surrounds the generative nucleus and so it is technically a cell, but it contains very little cytoplasm. The ***generative cell*** is contained within the larger ***tube cell***.

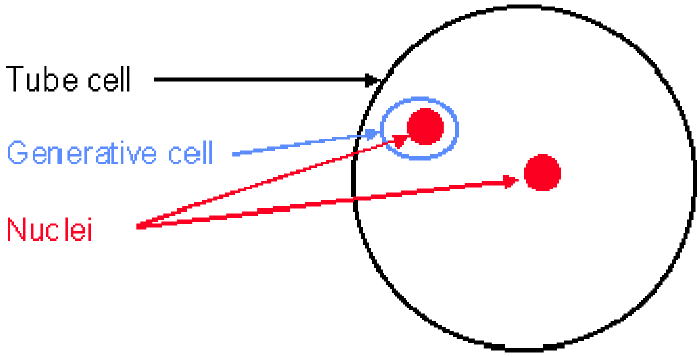

Fig 4.9 the Pollen of an angiosperm ((http://wikipedia.org/wiki/seedplant)

3.3.4 Pollination and Fertilization in Angiosperms

3.3.4.1 Pollination

Pollination is the transfer of pollen to the stigma .After landing on the stigma of a flower (pollination), the tube cell elongates to produce a ***pollen tube***, which grows from the stigma through the style and through the micropyle to the egg. The generative cell will divide by mitosis to produce two sperm. As in gymnosperms, the sperm of angiosperms are contained within the pollen tube and therefore do not require water.

3.3.4.2 Fertilization

Double Fertilization: One sperm fertilizes the egg the other one combines with the two polar nuclei forming a triploid (3N) cell.

The zygote grows by mitosis to form an embryo.

The 3N cell divides by mitosis and becomes **endosperm**, a food-containing material for the developing embryo.

The ovary, sometimes with other floral parts, develops into a fruit. It usually contains seeds.

3.5 Embryonic Development

During embryo development, the suspensor anchors and transfers nutrients to the developing embryo. In dicots, two heart-shaped cotyledons develop and absorb endosperm, which will be used as food when the seed germinates. Monocot cotyledons do not store endosperm. Instead, when the seed germinates, the cotyledon absorbs and transfers nutrients to the embryo.

The ovary of flowering plants becomes the fruit. Seeds are contained within the fruit. Gymnosperms do not produce fruit.

The wall of the ovary thickens to become the ***pericarp*** of the fruit.

Fruits can be either fleshy or dry. Peaches, tomatoes, and oranges are fleshy fruits. Nuts and grains are dry fruits.

3.6 Asexual Reproduction in Angiosperms

- **Stems**

New plants can grow from horizontal stems.

Aboveground horizontal stems are called stolons (runners).

Fig 4.10a Stolons from the corm of a Crocosmia are stems that emerged from axillary buds at the nodes of the tunic leaves. (http://en.wikipedia.org/wiki/Stolon)

Fig 4.10b Stolon of a bermudagrass (stolons located above the soil surface) (http://www.pssc.ttu.edu/pss1321/Web%20topics/cpa1.htm).

Underground horizontal stems are called rhizomes.

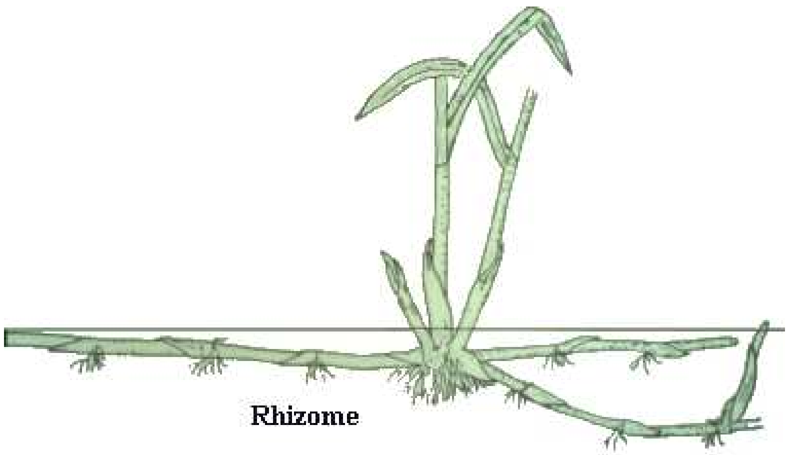

Fig 4.10c Rhizome of a bermudagrass (horizontal underground stem) (http://www.pssc.ttu.edu/pss1321/Web%20topics/cpa1.htm)

White potatoes are underground stems. They eyes are buds and can be used to produce new plants.

- **Roots**

Sweet potatoes are modified roots and can be used to produce new plants.

The roots of some trees (apple, cherry) produce suckers (small plants) that can produce a new tree.

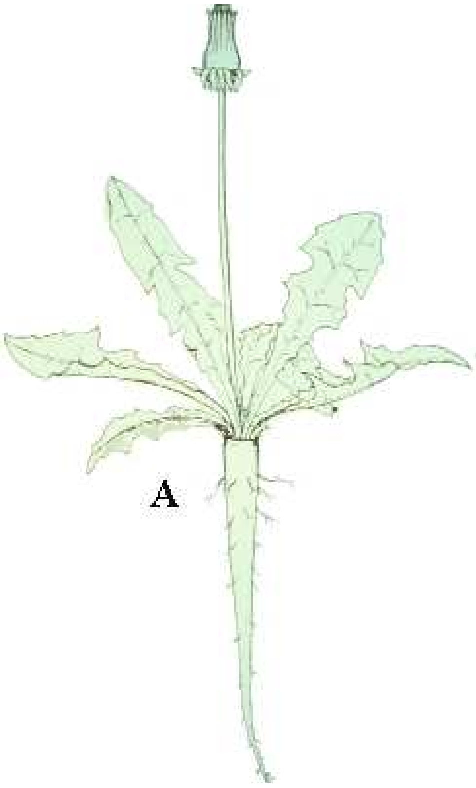

Fig 4.11a Tap root of a dandelion plant
((http://www.pssc.ttu.edu/pss1321/Web%20topics/cpa1.htm)

Fig 4.11b **fibrous root system which is characteristic of monocot plants** (http://www.pssc.ttu.edu/pss1321/Web%20topics/cpa1.htm)

- **Cuttings**

Cut stems can be treated with hormones and to encourage root growth. Examples of this are many in Nigeria. Cassava and flower stem cuttings produce new plants

Stems can be grafted to plants that have roots while yam and potato stem cuttings also produce new plants

Axillary buds can be grafted to another plant to produce new branches from the grafted bud.

- **Tissue Culture**

Plant tissue is grown on special culture and treated with hormones to stimulate the cells to grow into plants. This is a specialized technique that requires special equipment and expertise. This technique is usually carried out in dedicated laboratories for tissue culture studies. Many plants can be produced from a few cells.

- **Genetic Engineering**

Genetic engineering is concerned with modifying the DNA of organisms. Plants have been genetically engineered to produce species that are resistant to freezing, fungi and bacteria infections, insect pests, herbicides, stresses and spoilage.

Transgenic plants contain DNA from a different species.

The information above on sexual reproduction were obtained from anonymous 2010

4.0 CONCLUSION

Angiosperms are plants that produce flowers. The latter are pollinated by different agents which results in fertilization and the production of fruits containing seeds. The seeds are also wildly dispersed contributing to the huge success of the angiosperms on earth. The angiosperms can also be asexually reproduced by various technique/methods such as stems, roots cuttings, tissue culture and genetic engineering.

5.0 SUMMARY

At the end of this unit, you have learnt that:

- Angiosperms are classified into monocot and dicot
- The life cycle of flowering plants involve alternation of generations- a diploid sporophyte alternating with a haploid gametophyte
- Flower parts are modified leaves attached to a stem tip called the receptacle
- Monocots have flowers in multiple of threes; dicot parts are in multiples of fours or fives
- Stamens are composed of an anther and a filament which are the male reproductive parts
- The anther contain the microsporangium which produces the microspores
- Ovules are structures that will become the seeds
- All of the female reproductive structures form the pistils
- The bottom portion of a pistil is the ovary
- Plants can reproduce asexually by stem, tissue culture, cuttings, roots, and genetic engineering

6.0 TUTOR MARKED ASSIGNMENT

- Describe Double Fertilization in Angiosperms
- In the development of gametophytes in angiosperms, describe the events that happens in the megasporangium
- Outline the importance of flowers to seed plants

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MODULE 3 MORPHOLOGY AND ANATOMY OF SEED PLANTS

UNIT 5 VEGETATIVE STRUCTURE OF SEED PLANTS: STEM

1.0 INTRODUCTION

In the previous units in module 2, we looked at the mode of reproduction in seed plants. In this module we shall be looking at the morphological and anatomical forms of seed plants, especially the flowering plants.

Plant Morphology or Phytomorphology is the general term for the study of the physical form and external structure of plants (Raven et al, 2005), while Plant Anatomy or Phytotomy is the study of the internal structure of plants.

In this unit, we shall be looking at a seed plants vegetative structure, the STEM. The vegetative or somatic structure of vascular plants includes two major organ systems namely:

(1) The Shoot System composed of stems and leaves

(2) The Root System.

2.0 OBJECTIVES

At the end the end of this unit, you should be able to:

- know what constitutes a stem
- itemize the functions of a stem
- define the different modifications of stem
- describe the structure a stem
- know the economic uses of stem

3.0 MAIN CONTENT

3.1 Stem

A **stem** is one of two main structural axes of a vascular plant. The stem is normally divided into nodes and internodes, the nodes hold buds which grow into one or more leaves, inflorescences (flowers), cones or other stems etc. The internodes act as spaces that distance one node from another. The term shoots is often confused with stems; shoots generally refer to new fresh plant growth and does include stems but also to other structures like leaves or flowers. The other main structural axis of plants is the root. In most plants stems are located above the soil surface but some plants have underground stems.

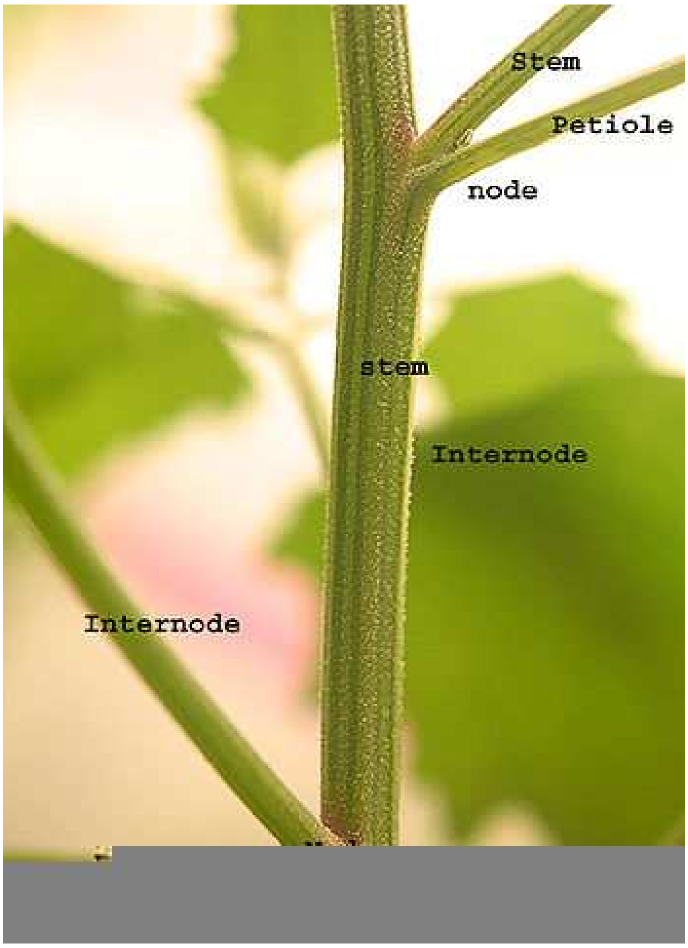

Fig 5.1 Stem showing internode and nodes plus leaf petiole and new stem rising from node (http://en.wikipedia.org/wiki/stem).

According to Raven et al, 1981, stems have four main functions which are (Raven et al, 1981)

- Support for and the elevation of leaves, flowers and fruits. The stems keep the leaves in the light and provide a place for the plant to keep its flowers and fruits.
- Transport of fluids between the roots and the shoots in the xylem and phloem.
- Storage of nutrients.

- The production of new living tissue. The normal life span of plant cells is one to three years. Stems have cells called meristems that annually generate new living cells.

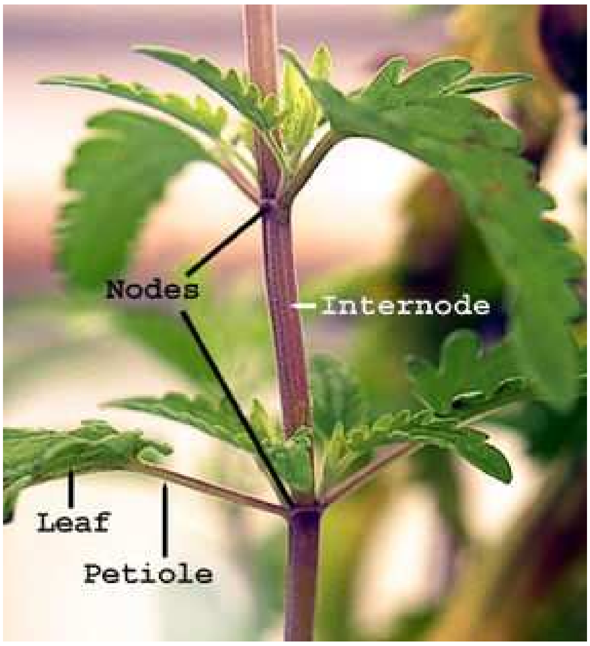

Fig 5.2 Stem showing internode and nodes plus leaf petioles
(http://en.wikipedia.org/wiki/stem)

3.1.1 Specialized Terms for Stems

Stems are often specialized for storage, asexual reproduction, protection or photosynthesis. Other specialized functions include:

- Acaulescent - plants with very short stems that appear to have no stems. The leaves appear to rise out of the ground, e.g. some Viola.
- Arborescent - tree like with woody stems normally with a single trunk.
- Bud - an embryonic shoot with immature stem tip.
- Bulb - a short vertical underground stem with fleshy storage leaves attached, e.g. Onion, Daffodil, Tulip. Bulbs often function in reproduction by splitting to form new bulbs or producing small new bulbs termed bulblets. Bulbs are a combination of stem and leaves so may better be considered as leaves because the leaves make up the greater part.
- Caespitose - when stems grow in a tangled mass or clump or in low growing mats.
- Cladophyll - a flattened stem that appears leaf like and is specialized for photosynthesis, e.g. Asparagus, Cactus pads.
- Climbing - stems that cling or wrap around other plants or structures.
- Corm - a short enlarged underground, storage stem, e.g. Taro, Crocus, Gladiolus.
- Decumbent - stems that lie flat on the ground and turn upwards at the ends.
- Fruticose - stems that grow shrub like with woody like habit.
- Herbaceous - non woody, they die at the end of the growing season.
- Pseudostem - A false stem made of the rolled bases of leaves, which may be 2 or 3 m tall as in Banana

- Rhizome - a horizontal underground stem that functions mainly in reproduction but also in storage, e.g. most Ferns, Iris
- Runner (plant part) - a type of stolon, horizontally growing on top of the ground and rooting at the nodes. e.g. Strawberry, Spider plant.
- Scape - a stem that holds flowers that comes out of the ground and has no normal leaves. Hosta, Lily, Iris.
- Stolons - a horizontal stem that produces rooted plantlets at its nodes and ends, forming near the surface of the ground.
- Tree - a woody stem that is longer than 5 meters with a main trunk.
- Thorns - a reduced stem with a sharp point and rounded shape. e.g. honey locust, Hawthorn.
- Tuber - a swollen, underground storage stem adapted for storage and reproduction, e.g. Potato.
- Woody - hard textured stems with secondary xylem.

3.1.2 Stem Structure

Stem usually consist of three tissues, dermal tissue, ground tissue and vascular tissue. The dermal tissue covers the outer surface of the stem and usually functions to waterproof, protect and control gas exchange. The ground tissue usually consists mainly of parenchyma cells and fills in around the vascular tissue. It sometimes functions in photosynthesis. Vascular tissue provides long distance transport and structural support. Most or all ground tissue may be lost in woody stems. The dermal tissue of aquatic plants stems may lack the waterproofing found in aerial stems. The arrangement of the vascular tissues varies widely among plant species.

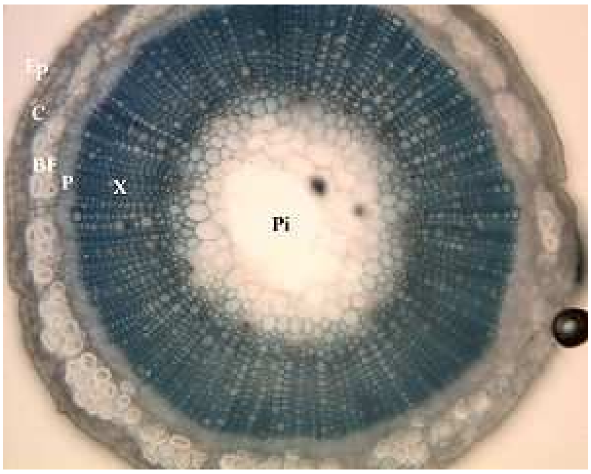

Fig 5.3 Photomicrograph of the cross-section of Flax stem, showing locations of underlying tissues. Ep = Epidermis; C = Cortex; BF = Bast fibres; P = Phloem; X = Xylem; Pi = Pith ((http://en.wikipedia.org/wiki/stem)

3.1.3 Dicot stems

Dicot stems with primary growth have pith in the center, with vascular bundles forming a distinct ring visible when the stem is viewed in cross section. The outside of the stem is covered with an epidermis, which is covered by a waterproof cuticle. The epidermis also may contain stomata for gas exchange and hairs. A cortex of parenchyma cells lies between the epidermis and vascular bundles.

Woody dicots and many nonwoody dicots have secondary growth originating from their lateral or secondary meristems: the vascular cambium and the cork cambium or phellogen. The vascular cambium forms between the xylem and phloem in the vascular bundles and connects to form a continuous cylinder. The vascular cambium cells divide to produce secondary xylem to the inside and secondary phloem to the outside. As the stem increases in diameter due to production of secondary xylem and secondary phloem, the cortex and epidermis are eventually destroyed. Before the cortex is destroyed, a cork cambium develops there. The cork cambium divides to produce waterproof cork cells externally and sometimes phelloderm cells internally. Those three tissues form the periderm, which replaces the epidermis in function. Areas of loosely-packed cells in the periderm that function in gas exchange are called lenticels.

Secondary xylem is commercially important as wood. The seasonal variation in growth from the vascular cambium is what creates yearly tree rings in temperate climates. Tree rings are the basis of dendrochronology, which dates wooden objects and associated artifacts. Dendroclimatology is the use of tree rings as a record of past climates. The aerial stem of an adult tree is called a trunk. The dead, usually darker inner wood of a large diameter trunk is termed the heartwood. The outer, living wood is termed the sapwood.

Fig 5.4 The trunk of this redwood tree is its stem (http://en.wikipedia.org/wiki/Flower)

Vascular bundles are present throughout the monocot stem, although concentrated towards the outside. This differs from the dicot stem that has a ring of vascular bundles and often none in the center. The shoot apex in monocot stems is more elongated. Leaf sheathes grow up around it, protecting it. This is true to some extent of almost all monocots. Monocots rarely produce secondary growth and are therefore seldom woody. However, many monocot stems increase in diameter via anamolous secondary growth.

3.1.4 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. Woody dicots are called hardwoods, e.g. Oak, Iroko Mahogany, Teak and Walnut. In contrast, softwoods are gymnosperms, such as pine, spruce and fir.

SAE

- What are the tissues that constitute the stem structure?
- Why is a stem referred to as climbing, and another as herbaceous?

3.1.5 Economic importance of Stems

Fig 5.5 White and green asparagus - crispy stems are the edible parts of this vegetable (http://en.wikipedia.org/wiki/stem)

There are thousands of species whose stems have economic uses. Stems provide a few major staple crops such as potato and taro. Sugarcane stems are a major source of sugar. Maple sugar is obtained from trunks of maple trees. Vegetables from stems are Asparagus, Bamboo shoots, cactus pads or Nopalitos, kohlrabi, and water chestnut. The spice, cinnamon is bark from a tree trunk. Cellulose from tree trunks is a food additive in bread, grated Parmesan cheese, and other processed foods. Gum arabic is an important food additive obtained from the trunks of *Acacia senegal* trees. Chicle, the main ingredient in chewing gum, is obtained from trunks of the chicle tree.

Medicines obtained from stems include quinine from the bark of Cinchona trees, Camphor distilled from wood of a tree in the same genus that provides cinnamon, and the muscle relaxant curare from the bark of tropical vines.

Wood is a used in thousands of ways, e.g. buildings, furniture, boats, airplanes, wagons, car parts, musical instruments, sports equipment, railroad ties, utility poles, fence posts, pilings, toothpicks, matches, plywood, coffins, shingles, barrel staves, toys, tool handles, picture frames, veneer, charcoal and firewood. Wood pulp is widely used to make paper, cardboard, cellulose sponges, cellophane and some important plastics and textiles, such as cellulose acetate and rayon. Bamboo stems also have hundreds of uses, including paper, buildings, furniture, boats, musical instruments, fishing poles, water pipes, plant stakes, and scaffolding. Trunks of palm trees and tree ferns are often used for building. Reed stems are also important building materials in some areas.

Tannins used for tanning leather are obtained from the wood of certain trees, such as quebracho. Cork is obtained from the bark of the cork oak. Rubber is obtained from the trunks of *Hevea brasiliensis*. Rattan, used for furniture and baskets, is made from the stems of tropical vining palms. Bast fibers for textiles and rope are obtained from stems include flax, hemp, jute and ramie. The earliest paper was obtained from the stems of papyrus by the ancient Egyptians.

Amber is fossilized sap from tree trunks; it is used for jewelry and may contain ancient animals. Resins from conifer wood are used to produce turpentine and rosin. Tree bark is often used as a mulch and in growing media for container plants (Raven et al, 1981).

4.0 CONCLUSION

Stems are structural axes of a vascular plant with specialized functions, and of highly economic importance.

5.0 SUMMARY

At the end of this unit, you have learnt that:

- A stem is a structural axes of a vascular plant
- A stem is normally divided into nodes and internodes
- Stems have four major functions: support, transportation, storage and production of living tissues
- Stems have specialized functions
- Stems consist of three tissues: dermal, ground and vascular tissues
- Stems normally undergo secondary growth
- Stems are of highly economic importance

6.0 TUTOR MARKED ASSIGNMENT

- Mention and define ten specialized functions of the stem
- Differentiate between a dicotyledonous stem and a monocotyledonous stem

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UNIT 6 VEGETATIVE STRUCTURE OF SEED PLANTS: LEAF

INTRODUCTION

You have studied a vegetative structure, stem in the last unit. In this unit, we shall be looking at another vegetative structure, Leaf.

A **leaf** is an above-ground plant organ specialized for photosynthesis. For this purpose, a leaf is typically flat (laminar) and thin. There is continued debate about whether the flatness of leaves evolved to expose the chloroplasts to more light or to increase the absorption of carbon dioxide. In either case, the adaption was made at the expense of water loss. In the Devonian period, when carbon dioxide concentration was at several times its present value, plants did not have leaves or flat stems. The leaves of gymnosperms, and angiosperms are variously referred to as macrophyll, megaphylls, or euphylls. Leaves are also the sites in most plants where transpiration and guttation take place. Leaves can store food and water, and are modified in some plants for other purposes. The comparable structures of ferns are correctly referred to as fronds. Furthermore, leaves are prominent in the human diet as leaf vegetables.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- Describe the anatomy of leaf
- Explain the morphology of leaves

- Explain certain leaf terminologies

3.0 MAIN CONTENT

3.1 Anatomy of Leaf

A structurally complete leaf of an angiosperm consists of a petiole (leaf stem), a *lamina* (leaf blade), and stipules (small processes located to either side of the base of the petiole). The petiole attaches to the stem at a point called the "leaf axil." Not every species produces leaves with all of the aforementioned structural components. In some species, paired stipules are not obvious or are absent altogether. A petiole may be absent, or the blade may not be laminar (flattened). The tremendous variety shown in leaf structure (anatomy) from species to species is presented in detail below (Fig 3.7). After a period of time (*i.e.* seasonally, during the autumn), deciduous trees shed their leaves. These leaves then decompose into the soil.

Fig 6.6a The leaves of a Beech tree (http://en.wikipedia.org/wiki/leaf)

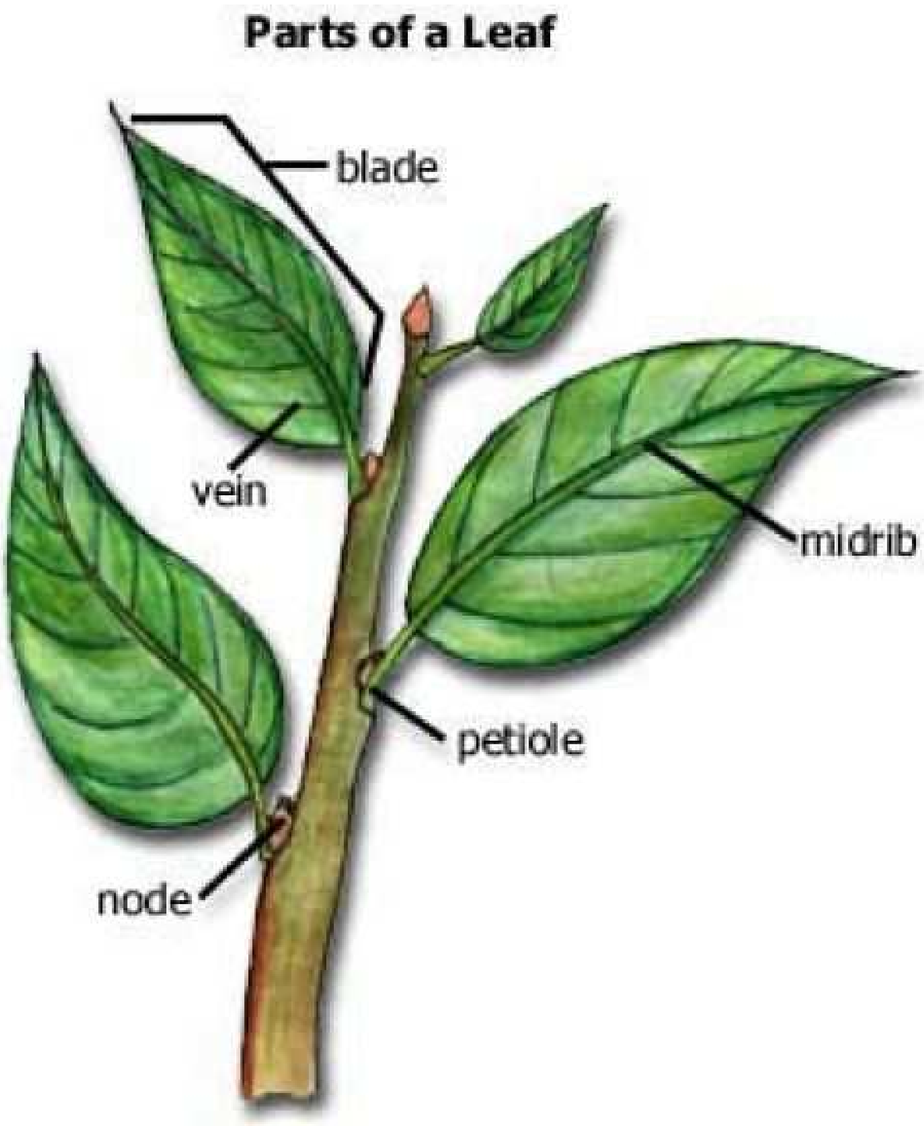

Fig 6.6b Basic diagram of a leaf (http://masterman535.hubpages.com/hub/Labeled-Diagram-Of-A-Leaf)

A leaf is considered a plant organ and typically consists of the following tissues as shown in fig. 6.7:

1. An **epidermis** that covers the upper and lower surfaces
2. An interior *chlorenchyma* called the **mesophyll**
3. An arrangement of **veins** (the vascular tissue)

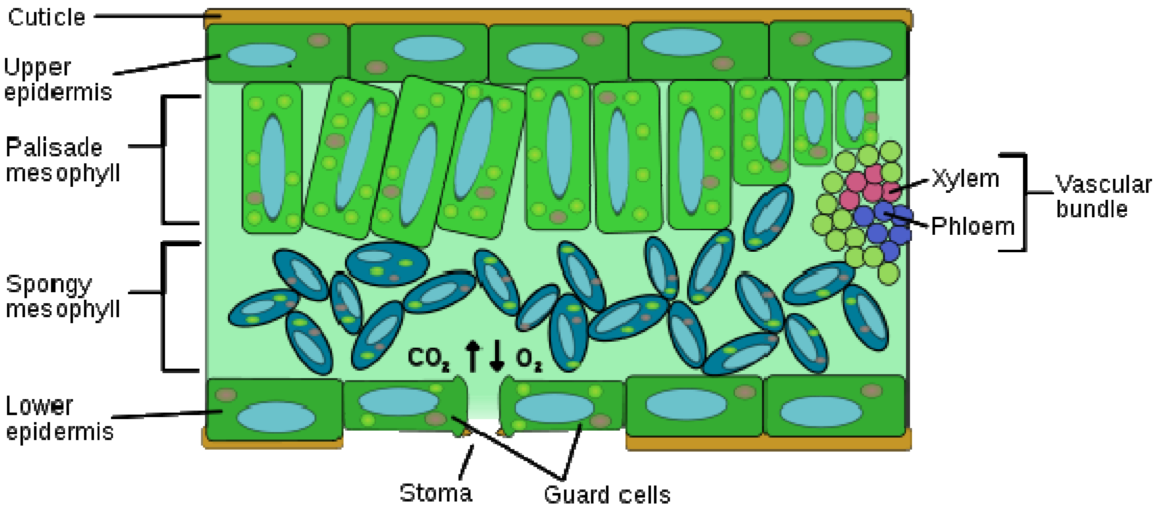

Fig 6.7 Internal Structure of a Leaf ((http://en.wikipedia.org/wiki/leaf)

3.1.1 Epidermis

The epidermis is the outer multi-layered group of cells covering the leaf. It forms the boundary separating the plant's inner cells from the external world. The epidermis serves several functions: protection against water loss, regulation of gas exchange, secretion of metabolic compounds, and (in some species) absorption of water. Most leaves show dorsoventral anatomy: the upper (adaxial) and lower (abaxial) surfaces have somewhat different construction and may serve different functions.

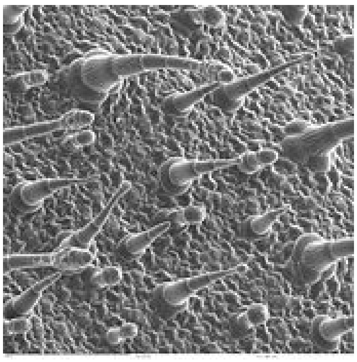

Fig 6.7. Scan Electron Microscope (SEM) image of *Nicotiana alata* leaf's epidermis, showing trichomes (hair-like appendages) and stomata (eye-shaped slits) ((http://en.wikipedia.org/wiki/leaf)

The epidermis is usually transparent (epidermal cells lack chloroplasts) and coated on the outer side with a waxy cuticle that prevents water loss. The cuticle is in some cases thinner on the lower epidermis than on the upper epidermis, and is thicker on leaves from dry climates as compared with those from wet climates.

The epidermis tissue includes several differentiated cell types: epidermal cells, guard cells, subsidiary cells, and epidermal hairs (trichomes). The epidermal cells are the most numerous, largest, and least specialized. These are typically more elongated in the leaves of monocots than in those of dicots.

The epidermis is covered with pores called *stomata*, part of a stoma complex consisting of a pore surrounded on each side by chloroplast-containing guard cells, and two to four subsidiary cells that lack chloroplasts. The stoma complex regulates the exchange of gases and water vapor between the outside air and the interior of the leaf. Typically, the stomata are more numerous over the abaxial (lower) epidermis than the adaxial (upper) epidermis.

3.1.2 Mesophyll

Most of the interior of the leaf between the upper and lower layers of epidermis is a *parenchyma* (ground tissue) or *chlorenchyma* tissue called the **mesophyll** (Greek for "middle leaf"). This assimilation tissue is the primary location of photosynthesis in the plant. The products of photosynthesis are called "assimilates".

In most flowering plants the mesophyll is divided into two layers:

- An upper **palisade layer** of tightly packed, vertically elongated cells, one to two cells thick, directly beneath the adaxial epidermis. Its cells contain many more chloroplasts than the spongy layer. These long cylindrical cells are regularly arranged in one to five rows. Cylindrical cells, with the *chloroplasts* close to the walls of the cell, can take optimal advantage of light. The slight separation of the cells provides maximum absorption of carbon dioxide. This separation must be minimal to afford capillary action for water distribution. In order to adapt to their different environments (such as sun or shade), plants had to adapt this structure to obtain optimal result. Sun leaves have a multi-layered palisade layer, while shade leaves or older leaves closer to the soil, are single-layered.
- Beneath the palisade layer is the **spongy layer**. The cells of the spongy layer are more rounded and not so tightly packed. There are large intercellular air spaces. These cells contain fewer chloroplasts than those of the palisade layer.

The pores or *stomata* of the epidermis open into substomatal chambers, connecting to air spaces between the spongy layer cells.

These two different layers of the mesophyll are absent in many aquatic and marsh plants. Even an epidermis and a mesophyll may be lacking. Instead for their gaseous exchanges they use a homogeneous **aerenchyma** (thin-walled cells separated by large gas-filled spaces). Their stomata are situated at the upper surface.

Leaves are normally green in color, which comes from chlorophyll found in plastids in the chlorenchyma cells. Plants that lack chlorophyll cannot photosynthesize

Leaves in temperate, boreal, and seasonally dry zones may be seasonally deciduous (falling off or dying for the inclement season). This mechanism to shed leaves is called abscission. After the leaf is shed, a leaf scar develops on the twig.

3.1.3 Veins

The **veins** are the vascular tissue of the leaf and are located in the spongy layer of the mesophyll. They are typical examples of pattern formation through ramification. The pattern of the veins is called venation.

Fig 6.8 Vein skeleton of a leaf (http://en.wikipedia.org/wiki/Leaf)

The veins are made up of:

- Xylem: tubes that brings water and minerals from the roots into the leaf.
- Phloem: tubes that usually move sap, with dissolved sucrose, produced by photosynthesis in the leaf, out of the leaf.

The xylem typically lies over the phloem. Both are embedded in a dense parenchyma tissue, called "pith", with usually some structural collenchyma tissue present.

SAE

- Name the different tissues found in leaves
- Mention the different layers found in a mesophyll

3.2 Leaf morphology

External leaf characteristics (such as shape, margin, hairs, etc.) are important for identifying plant species, and botanists have developed a rich terminology for describing leaf characteristics. These structures are a part of what makes leaves determinant; they grow and achieve a specific pattern and shape, then stop. Other plant parts like stems or roots are non-determinant, and will usually continue to grow as long as they have the resources to do so.

Classification of leaves can occur through many different designative schema, and the type of leaf is usually characteristic of a species, although some species produce more than one type of leaf. The longest type of leaf is a leaf from palm trees, measuring at nine feet long.

3.2.1 Basic leaf types

Fig 6.9 Leaves of the White Spruce (*Picea glauca*) are needle-shaped and their arrangement is spiral **(http://en.wikipedia.org/wiki/Leaf)**

- Conifer leaves are typically needle-, awl-, or scale-shaped
- Angiosperm (flowering plant) leaves: the standard form includes stipules, a petiole, and a lamina

3.2.2 Arrangement on the stem

Different terms are usually used to describe leaf placement (phyllotaxis):

Fig 6.10a The leaves on this plant are arranged in pairs opposite one another, with successive pairs at right angles to each other ("decussate") along the red stem **(http://en.wikipedia.org/wiki/Leaf)**

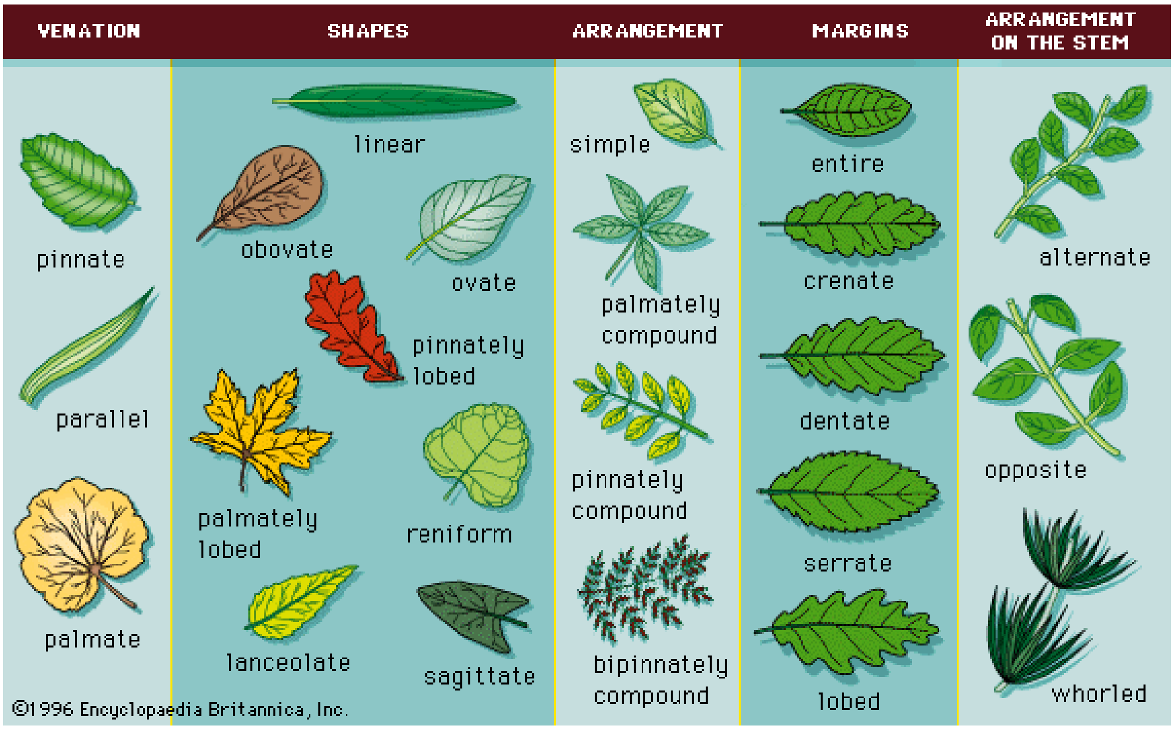

Fig 6.10b alternate leaf arrangement: angiosperm leaf morphology (http://www.britannica.com/EBchecked/media/374/Common-leaf-morphologies)

- **Alternate** — leaf attachments are singular at nodes, and leaves alternate direction, to a greater or lesser degree, along the stem.

- **Opposite** — leaf attachments are paired at each node; **decussate** if, as typical, each successive pair is rotated 90° progressing along the stem; or **distichous** if not rotated, but two-ranked (in the same geometric flat-plane).
- **Whorled** — three or more leaves attach at each point or node on the stem. As with opposite leaves, successive whorls may or may not be decussate, rotated by half the angle between the leaves in the whorl (i.e., successive whorls of three rotated 60°, whorls of four rotated 45°, etc). Opposite leaves may appear whorled near the tip of the stem.
- **Rosulate** — leaves form a rosette

- As a *stem* grows, leaves tend to appear arranged around the stem in a way that optimizes yield of light. In essence, leaves form a helix pattern centred around the stem, either clockwise or counterclockwise, with (depending upon the species) the same angle of divergence.

3.2.3 Divisions of the *lamina* (blade)

Two basic forms of leaves can be described considering the way the blade is divided. A simple leaf has an undivided blade. However, the leaf shape may be formed of lobes, but the gaps between lobes do not reach to the main vein. A compound leaf has a fully subdivided blade, each leaflet of the blade separated along a main or secondary vein. Because each leaflet can appear to be a simple leaf, it is important to recognize where the petiole occurs to identify a compound leaf. Compound leaves are a characteristic of some families of higher plants, such as the Fabaceae. The middle vein of a compound leaf or a frond, when it is present, is called a rachis.

Fig 6.11: A leaf with laminar structure and pinnate venation (http://en.wikipedia.org/wiki/Leaf)

- *Palmately compound* leaves have the leaflets radiating from the end of the petiole, like fingers off the palm of a hand, e.g. *Cannabis* (hemp) and *Aesculus* (buckeyes).

- *Pinnately compound* leaves have the leaflets arranged along the main or mid-vein.
  - odd pinnate: with a terminal leaflet, e.g. *Fraxinus* (ash).
  - even pinnate: lacking a terminal leaflet, e.g. *Swietenia* (mahogany).
- *Bipinnately compound* leaves are twice divided: the leaflets are arranged along a secondary vein that is one of several branching off the rachis. Each leaflet is called a "pinnule". The pinnules on one secondary vein are called "pinna"; e.g. *Albizia* (silk tree).
- *trifoliate*: a pinnate leaf with just three leaflets, e.g. *Trifolium* (clover), *Laburnum* (laburnum).
- *pinnatifid*: pinnately dissected to the midrib, but with the leaflets not entirely separate, e.g. *Polypodium*, some *Sorbus* (whitebeams).

3.2.4 Venation (arrangement of the veins)

There are two subtypes of venation, namely, *craspedodromous*, where the major veins stretch up to the margin of the leaf, and *camptodromous*, when major veins extend close to the margin, but bend before they intersect with the margin.

- Feather-veined, reticulate — the veins arise pinnately from a single mid-vein and subdivide into veinlets. These, in turn, form a complicated network. This type of venation is typical for (but by no means limited to) dicotyledons.
    - Pinnate-netted, penniribbed, penninerved, penniveined; the leaf has usually one main vein (called the mid-vein), with veinlets, smaller veins branching off laterally, usually somewhat parallel to each other; eg *Malus* (apples).
    - Three main veins branch at the base of the lamina and run essentially parallel subsequently, as in *Ceanothus*. A similar pattern (with 3-7 veins) is especially conspicuous in Melastomataceae.
    - Palmate-netted, palmate-veined, fan-veined; several main veins diverge from near the leaf base where the petiole attaches, and radiate toward the edge of the leaf; e.g. most *Acer* (maples).
- Parallel-veined, parallel-ribbed, parallel-nerved, penniparallel — veins run parallel for the length of the leaf, from the base to the apex. Commissural veins (small veins) connect the major parallel veins. Typical for most monocotyledons, such as grasses.
- Dichotomous — There are no dominant bundles, with the veins forking regularly by pairs; found in *Ginkgo* and some pteridophytes.

Fig 6.12a The lower epidermis of Tilia x europea

Fig 6.12b Palmate-veined leaf

Source: (**http://en.wikipedia.org/wiki/Leaf**)

3.2.5 Leaf morphology changes within a single plant

- Homoblasty - Characteristic in which a plant has small changes in leaf size, shape, and growth habit between juvenile and adult stages.
- Heteroblasty - Characteristic in which a plant has marked changes in leaf size, shape, and growth habit between juvenile and adult stages.

Extracted From: Raven, Peter H., Ray Franklin Evert, and Helena Curtis. 1981. *Biology of plants*. New York, N.Y.: Worth Publishers.ISBN 0-87901-132-7

Retrieved from "http://en.wikipedia.org/wiki/Leaf"

4.0 CONCLUSION

Leaves are the photosynthetic organ of a plant. They vary in shape and sizes depending on the species and are also arranged differently in the plant. Some leaves are modified. Some bear thorns or hairlike appendages

5.0 SUMMARY

At the end of this unit, you have learnt that:

- A leaf is an above-ground plant organ specialized for photosynthesis
- A structurally complete leaf of an angiosperm consists of a petiole(leaf stem), a lamina(leaf blade), and stipules.
- A leaf is considered a plant organ and typically consists of the epidermis, mesophyll and vascular tissues

6.0 TUTOR MARKED ASSIGNMENT

- With the aid of an annotated diagram, describe the structure of a leaf

7.0 REFERENCES/FURTHER READING

Raven, Peter H., Ray Franklin Evert, and Helena Curtis. 1981. *Biology of plants*. New York, N.Y.: Worth Publishers.ISBN 0-87901-132-7

Retrieved from "http://en.wikipedia.org/wiki/Leaf"

UNIT 7 VEGETATIVE STRUCTURE OF SEED PLANTS: THE ROOT

1.0 INTRODUCTION

In the last unit, we discussed about one of the vegetative structures of seed plants, which is the leaf. In this unit, we shall be looking at another important vegetative structure, the Root.

In vascular plants, the **root** is the organ of a plant that typically lies below the surface of the soil. This is not always the case, however, since a root can also be **aerial** (growing above the ground) or **aerating** (growing up above the ground or especially above water). Furthermore, a stem normally occurring below ground is not exceptional either (the rhizome). So, it is better to define *root* as a part of a plant body that bears no leaves, and therefore also lacks nodes. The first **root** that comes from a plant is called the radicle. The two major functions of roots are 1) absorption of water and inorganic nutrients and

2) anchoring of the plant body to the ground. In response to the concentration of nutrients, roots also synthesise cytokinin, which acts as a signal as to how fast the shoots can grow. Roots often function in storage of food and nutrients. The roots of most vascular plant species enter into symbiosis with certain fungi to form mycorrhizas, and a large range of other organisms including bacteria also closely associate with roots.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- Describe the growth of roots
- Explain the different types of roots, and the specialized roots
- Explain rooting depth and root architecture
- Outline the economic importance of roots

3.0 MAIN CONTENTS

3.1 Root Growth

Early root growth is one of the functions of the apical meristem located near the tip of the root. The meristem cells more or less continuously divide, producing more meristem, root cap cells (these are sacrificed to protect the meristem), and undifferentiated root cells. The latter become the primary tissues of the root, first undergoing elongation, a process that pushes the root tip forward in the growing medium. Gradually these cells differentiate and mature into specialized cells of the root tissues.Roots will generally grow in any direction where the correct environment of air, mineral nutrients and water exists to meet the plant's needs. Roots will not grow in dry soil. Over time, given the right conditions, roots can crack foundations, snap water lines, and lift sidewalks. At germination, roots grow downward due to gravitropism, the growth mechanism of plants that also causes the shoot to grow upward. In some plants (such as ivy), the "root" actually clings to walls and structures.

Growth from apical meristems is known as **primary growth**, which encompasses all elongation. **Secondary growth** encompasses all growth in diameter, a major component of woody plant tissues and many nonwoody plants. For example, storage roots of sweet potato have secondary growth but are not woody. Secondary growth occurs at the lateral meristems, namely the vascular cambium and cork cambium. The former forms secondary xylem and secondary phloem, while the latter forms the periderm.

In plants with secondary growth, the vascular cambium, originating between the xylem and the phloem, forms a cylinder of tissue along the stem and root. The cambium layer forms new cells on both the inside and outside of the cambium cylinder, with those on the inside forming secondary xylem cells, and those on the outside forming secondary phloem cells. As secondary xylem accumulates, the "girth" (lateral dimensions) of the stem and root increases. As a result, tissues beyond the secondary phloem (including the epidermis and cortex, in many cases) tend to be pushed outward and are eventually "sloughed off" (shed).

At this point, the cork cambium begins to form the periderm, consisting of protective cork cells containing suberin. In roots, the cork cambium originates in the pericycle, a component of the vascular cylinder.

The vascular cambium produces new layers of secondary xylem annually. The xylem vessels are dead at maturity but are responsible for most water transport through the vascular tissue in stems and roots.

3.2 Types of roots

A true root system consists of a **primary root** and **secondary roots** (or lateral roots).

- the diffuse root system: the primary root is not dominant; the whole root system is fibrous and branches in all directions. Most common in monocots. The main function of the fibrous root is to anchor the plant.

3.2.1 Specialized roots

The roots, or parts of roots, of many plant species have become specialized to serve adaptive purposes besides the two primary functions of the root:

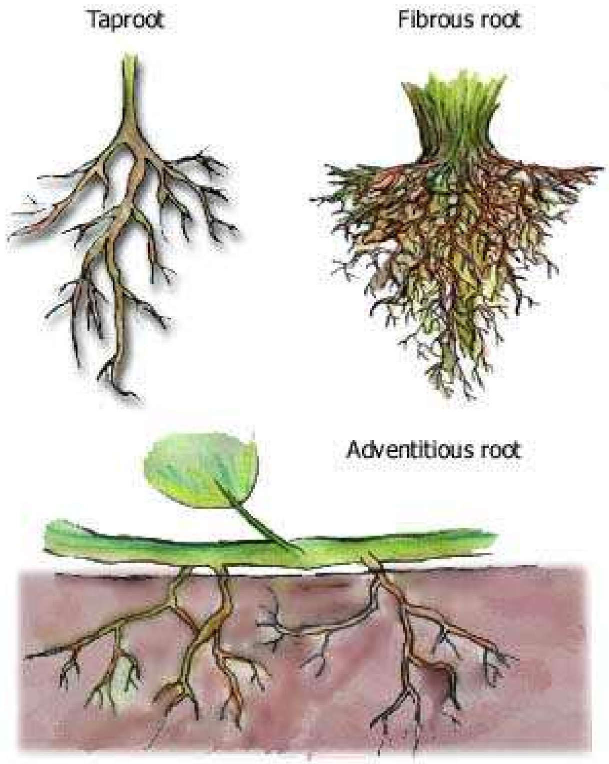

Fig 7.1 Different kinds of roots
(http://homepage.smc.edu/hodson_kent/plant_growth/Angiosperms/ID/basics.htm)

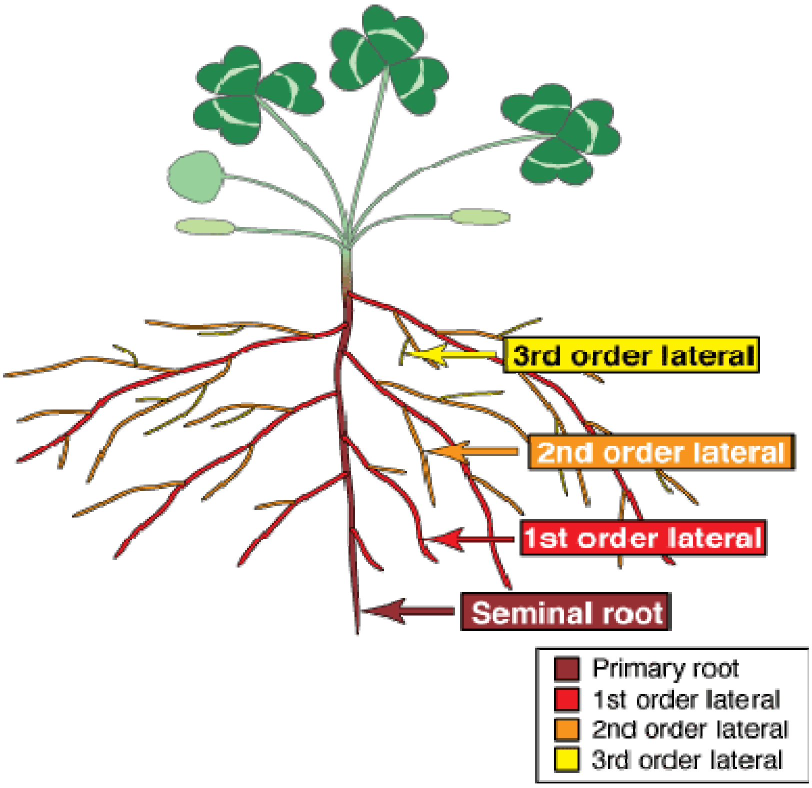

Fig 7.2 Root types (http://mycorrhizas.info/root.html)

- **Adventitious roots** arise out-of-sequence from the more usual root formation of branches of a primary root, and instead originate from the stem, branches, leaves, or old woody roots. They commonly occur in monocots and pteridophytes, but also in many dicots, such as clover (*Trifolium*), ivy (*Hedera*), strawberry (*Fragaria*) and willow (*Salix*). Most aerial roots and stilt roots are adventitious. In some conifers adventitious roots can form the largest part of the root system.

- **Aerating roots** (or **pneumatophores**): roots rising above the ground, especially above water such as in some mangrove genera (*Avicennia*, *Sonneratia*). In some plants like *Avicennia* the erect roots have a large number of breathing pores for exchange of gases.
- **Aerial roots**: roots entirely above the ground, such as in ivy (*Hedera*) or in epiphytic orchids. They function as prop roots, as in maize or anchor roots or as the trunk in strangler fig.
- **Contractile roots**: they pull bulbs or corms of monocots, such as hyacinth and lily, and some taproots, such as dandelion, deeper in the soil through expanding radially and contracting longitudinally. They have a wrinkled surface.
- **Coarse roots**: Roots that have undergone secondary thickening and have a woody structure. These roots have some ability to absorb water and nutrients, but their main function is transport and to provide a structure to connect the smaller diameter, fine roots to the rest of the plant.

- **Fine roots**: Primary roots usually <2 mm diameter that have the function of water and nutrient uptake. They are often heavily branched and support mycorrhizas. These roots may be short lived, but are replaced by the plant in an ongoing process of root 'turnover'.
- **Haustorial roots**: roots of parasitic plants that can absorb water and nutrients from another plant, such as in mistletoe (*Viscum album*) and dodder.
- **Propagative roots**: roots that form adventitious buds that develop into aboveground shoots, termed suckers, which form new plants, as in Canada thistle, cherry and many others.
- **Proteoid roots** or cluster roots: dense clusters of rootlets of limited growth that develop under low phosphate or low iron conditions in Proteaceae and some plants from the following families Betulaceae, Casuarinaceae, Elaeagnaceae, Moraceae, Fabaceae and Myricaceae.
- **Stilt roots**: these are adventitious support roots, common among mangroves. They grow down from lateral branches, branching in the soil.
- **Storage roots**: these roots are modified for storage of food or water, such as carrots and beets. They include some taproots and tuberous roots.
- **Structural roots**: large roots that have undergone considerable secondary thickening and provide mechanical support to woody plants and trees.
- **Surface roots**: These proliferate close below the soil surface, exploiting water and easily available nutrients. Where conditions are close to optimum in the surface layers of soil, the growth of surface roots is encouraged and they commonly become the dominant roots.
- **Tuberous roots**: A portion of a root swells for food or water storage, e.g. sweet potato. A type of storage root distinct from taproot.

3.3 Root Depth

The distribution of vascular plant roots within soil depends on plant form, the spatial and temporal availability of water and nutrients, and the physical properties of the soil. The deepest roots are generally found in deserts and temperate coniferous forests; the shallowest in tundra, boreal forest and temperate grasslands. Some roots can grow as deep as the tree is high. The majority of roots on most plants are however found relatively close to the surface where nutrient availability and aeration are more favourable for growth. Rooting depth may be physically restricted by rock or compacted soil close below the surface, or by anaerobic soil conditions.

3.4 Root architecture

The pattern of development of a root system is termed 'root architecture', and is important in providing a plant with a secure supply of nutrients and water as well as anchorage and support. The architecture of a root system can be considered in a similar way to above-ground architecture of a plant - i.e. in terms of the size, branching and distribution of the component parts. In roots, the architecture of fine roots and coarse roots can both be described by variation in topology and distribution of biomass within and between roots. Having a balanced architecture allows fine roots to exploit soil efficiently around a plant, but the 'plastic' nature of root growth allows the plant to then concentrate its resources where nutrients and water are more easily available. A balanced coarse root architecture, with roots distributed relatively evenly around the stem base, is necessary to provide support to larger plants and trees.

Tree roots normally grow outward to about three times the branch spread. Only half of a tree's root system occurs between the trunk and the circumference of its canopy. Roots on one side of a tree normally supply the foliage on that same side of the tree. So when roots on one side of a tree are injured the branches & leaves on that same side of the tree may die back and/or wilt. For some trees however, such as the maple family, the effect of a root injury may show itself anywhere in the tree canopy.

SAE

- Mention the different types of roots
- Define the followings: adventitious root; aerial roots

3.5 Economic Importance of Roots

The term root crops refers to any edible underground plant structure, but many root crops are actually stems, such as potato tubers. Edible roots include cassava, sweet potato, beet, carrot, rutabaga, turnip, parsnip, radish, yam and horseradish. Spices obtained from roots include sassafras, angelica, sarsaparilla and licorice.

Sugar beet is an important source of sugar. Yam roots are a source of estrogen compounds used in birth control pills. The fish poison and insecticide rotenone is obtained from roots of *Lonchocarpus* spp. Important medicines from roots are ginseng, aconite, ipecac, gentian and reserpine. Several legumes that have nitrogen-fixing root nodules are used as green manure crops, which provide nitrogen fertilizer for other crops when plowed under. Specialized bald cypress roots, termed knees, are sold as souvenirs, lamp bases and carved into folk art. Native Americans used the flexible roots of white spruce for basketry.

Tree roots can heave and destroy concrete sidewalks and crush or clog buried pipes. The aerial roots of strangler fig have damaged ancient Mayan temples in Central America and the temple of Angkor Wat in Cambodia.

Vegetative propagation of plants via cuttings depends on adventitious root formation. Hundreds of millions of plants are propagated via cuttings annually including chrysanthemum, poinsettia, carnation, ornamental shrubs and many houseplants.

Fig 7.3 Roots can protect the environment by holding the soil to prevent soil erosion..Retrieved from "http://en.wikipedia.org/wiki/Root"

4.0 CONCLUSION

The vegetative part of seed plants, especially the flowering plants consist mainly of the stem, the leaves, and the roots.

5.0 SUMMARY

At the end of this unit you have learnt that:

- Roots can be referred to as a part of a plant that bears no leaves, and no nodes
- The first root that comes from a plant is called the radicle
- The major functions of roots are for absorption and anchorage
- Early root growth is a function of the apical meristem
- Roots undergoes both primary and secondary growth
- A true root system consists of a primary root and secondary root
- Roots have also become specialized to serve adaptive purposes
- The pattern of development of a root system is termed root architecture
- Roots are of high economic importance

6.0 TUTOR MARKED ASSIGNMENT

- Explain what you understand by root depth and root architecture
- In what ways are roots specialized for adaptive purposes
- Differentiate between a root and a stem

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Retrieved from "http://en.wikipedia.org/wiki/Root"

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MODULE 4 VASCULAR ELEMENTS OF SEED PLANTS

UNIT 8 XYLEM AND PHLOEM

CONTENT

1.0 INTRODUCTION

In the last module, we generally looked at the morphology and anatomy of seed plants especially among the angiosperms since it is the most dominant. In this module we shall be looking at the vascular elements in seed plants. Vascular elements are basically made up of the Phloem, Xylem and the Cambium

These three components collectively make up the vascular elements of the plant or the strengthening tissues

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- Describe the anatomy of the xylem tissue
- Explain the meaning of primary and secondary xylem
- Describe the structure and the functions of the phloem tissue
- Explain the origin of Phloem

3.0MAIN CONTENT

3.1 Xylem

In vascular plants, **xylem** is one of the two types of transport tissue, phloem being the other. The word "xylem" is derived from classical Greek ξυλον (*xylon*), "wood", and indeed the best known xylem tissue is wood, though it is found throughout the plant. Its basic function is to absorb and distribute water throughout the body of plants

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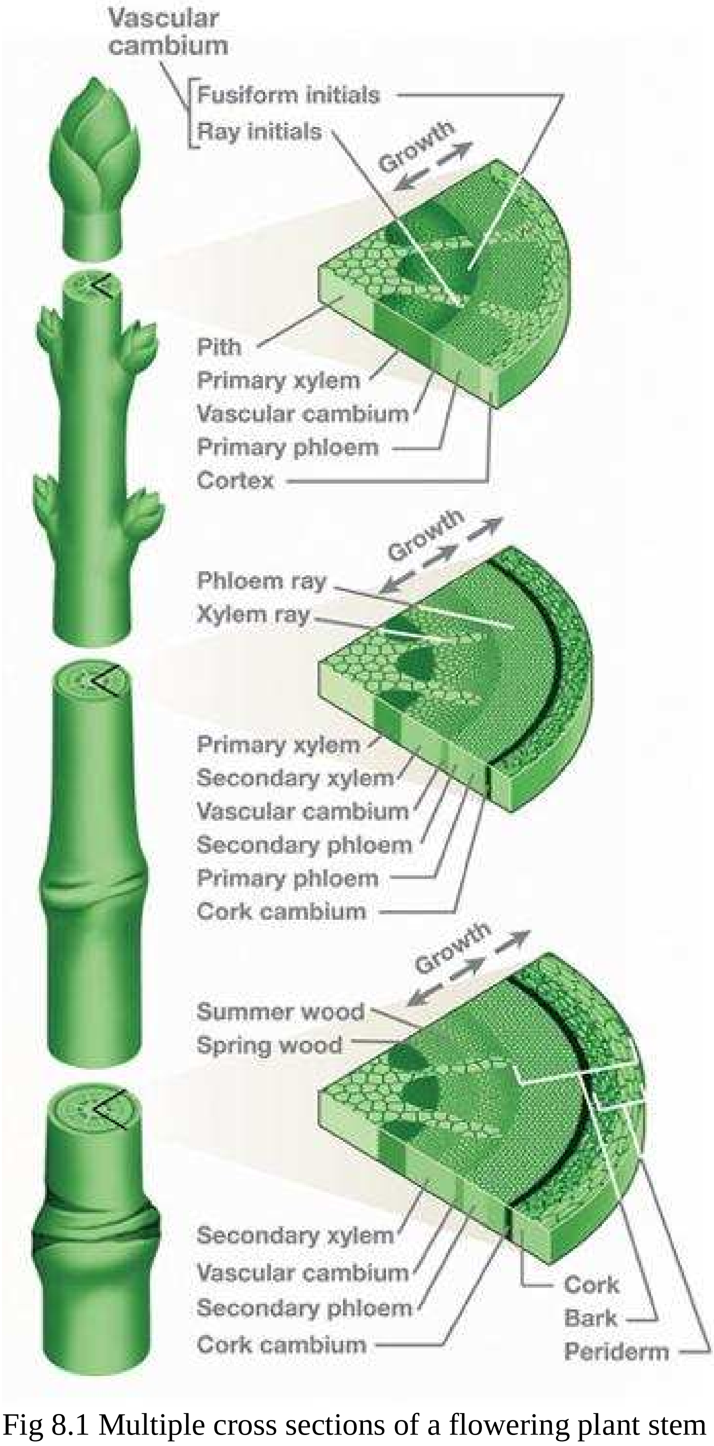

Fig 8.1 Multiple cross sections of a flowering plant stem showing primary and secondary **xylem** and phloem (Winterbone, 2005).

3.1.1 Anatomy of Xylem

Xylem can be found:

- in vascular bundles, present in non-woody plants and non-woody parts of plants with wood
- in **secondary xylem**, laid down by a meristem called the vascular cambium in woody plants
- as part of a stelar arrangement not divided into bundles, as in many ferns.

Note that, in transitional stages of plants with secondary growth, the first two categories are not mutually exclusive, although usually a vascular bundle will contain *primary xylem* only.

The moist distinctive cells found in xylem are the tracheary elements: tracheids and vessel elements. However, the xylem is a complex tissue of plants, which means that it includes more than one type of cell. In fact, xylem contains other kinds of cells, such as parenchyma, collenchyma, schlerenchyma in addition to those that serve to transport water. (McCulloh et al, 2003)

3.1.2 Primary and secondary xylem

Primary xylem is the xylem that is formed during primary growth from procambium. It includes protoxylem and metaxylem. Metaxylem develops after the protoxylem but before secondary xylem. It is distinguished by wider vessels and tracheids. Developmentally, xylem can be endarch or exarch i.e. grow internally or externally

Secondary xylem is the xylem that is formed during secondary growth from vascular cambium. Although secondary xylem is also found in members of the "gymnosperm" groups Gnetophyta and Ginkgophyta and to a lesser extent in members of the Cycadophyta, the two main groups in which secondary xylem can be found are:

1. Conifers (*Coniferae*): There are some six hundred species of conifers. All species have secondary xylem, which is relatively uniform in structure throughout this group. Many conifers become tall trees: the secondary xylem of such trees is marketed as **softwood**.
2. Angiosperms (*Angiospermae*): there are some quarters of a million to four hundred thousand species of angiosperms. Within this group secondary xylem has not been found in the monocots. In the remainder of the angiosperms this secondary xylem may or may not be present, this may vary even within a species, depending on growing circumstances. In view of the size of this group it will be no surprise that no absolutes apply to the structure of secondary xylem within the angiosperms. Many non-monocot angiosperms become trees, and the secondary xylem of these is marketed as **hardwood**. Nigeria examples are Mahogany, Obeche, Teak and the Iroko tree.

The xylem is responsible for the transport of water and soluble mineral nutrients from the roots throughout the plant. It is also used to replace water lost during transpiration and photosynthesis. Xylem sap consists mainly of water and inorganic ions, although it can contain a number of organic chemicals as well. This transport is not powered by energy spent by the tracheary elements themselves, which are dead at maturity and no longer have living contents.

SAE

- Mention three regions xylem can be found in vascular plants
- Where are the primary xylem and secondary xylem formed?

3.2 Phloem

In vascular plants, **phloem** is the living tissue that carries organic nutrients (known as photosynthate), particularly sucrose, a sugar, to all parts of the plant where needed. In trees, the phloem is the innermost layer of the bark, hence the name, derived from the Greek word φλόος (*phloos*) "bark". The phloem is mainly concerned with the transport of soluble organic material made during photosynthesis. This is called translocation.

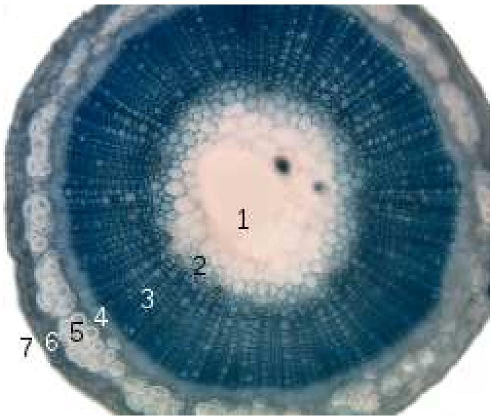

Fig 4.3 Cross-section of a flax plant stem:
1. Pith, 2. Protoxylem, 3. Xylem I, 4. **Phloem** I, 5. Sclerenchyma (bast fibre), 6. Cortex, 7. Epidermis (http://en.wikipedia.org/wiki/stem)

3.2.1 Phloem Structure

Phloem tissue consists of less specialized and nucleate *parenchyma* cells, ***sieve-tube cells***, and ***companion cells,*** fibres and sclereid

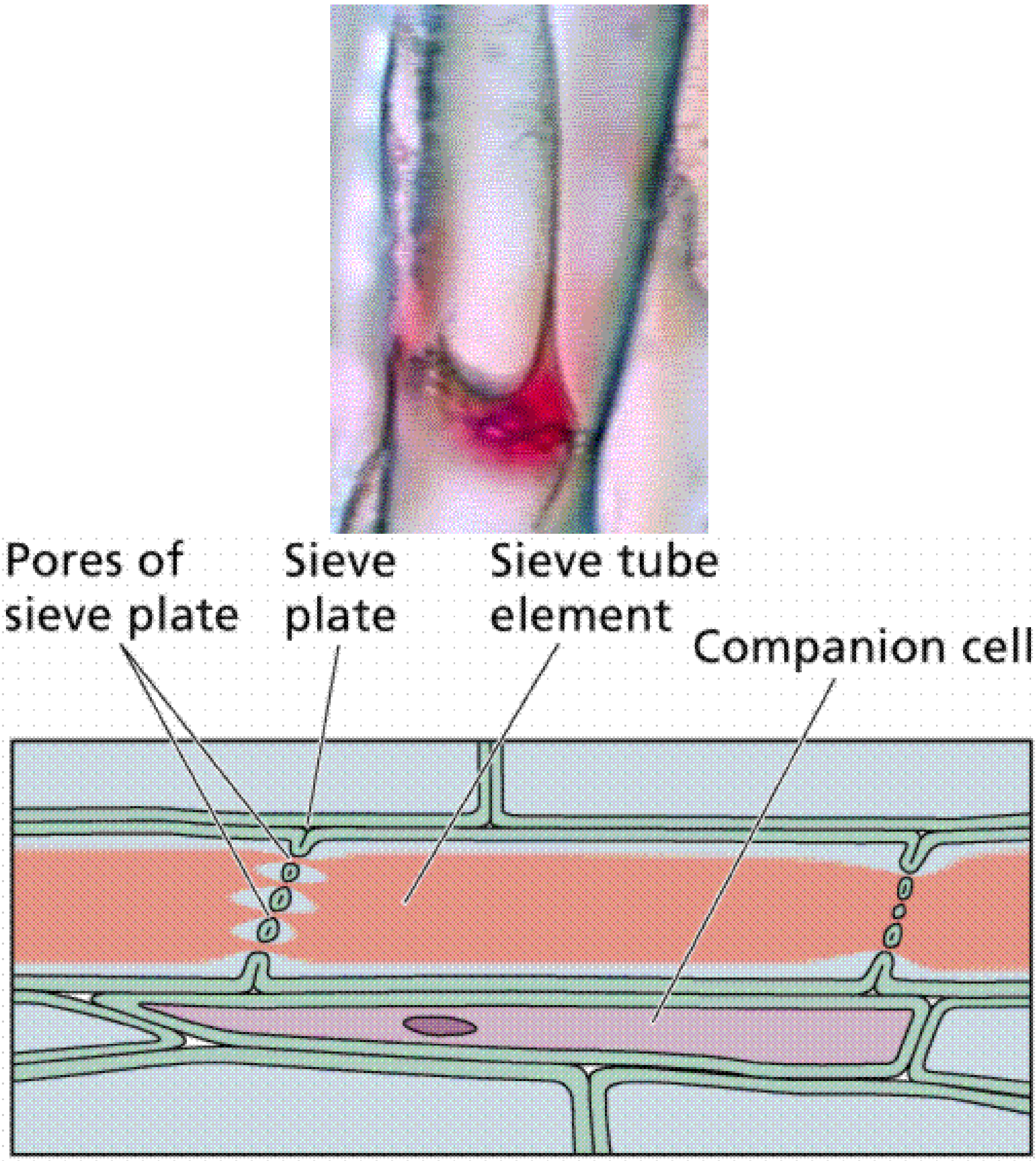

Fig 8.2 Structure of the phloem
(http://www.emc.maricopa.edu/faculty/farabee/biobk/biobookplantanat.html)

3.2.1.1 Sieve tubes

The sieve-tube cells lack a nucleus, have very few vacuoles, but contain other organelles such as ribosomes. The endoplasmic reticulum is concentrated at the lateral walls. Sieve-tube members are joined end to end to form a tube that conducts food materials throughout the plant. The end walls of these cells have many small pores and are called sieve plates and have enlarged plasmodesmata.

3.2.1.2 Companion cells

The survival of sieve-tube members depends on a close association with the *companion cells*. All of the cellular functions of a sieve-tube element are carried out by the (much smaller) companion cell, a typical plant cell, except the companion cell usually has a larger number of ribosome and mitochondria. This is because the companion cell is more metabolically active than a 'typical' plant cell. The cytoplasm of a companion cell is connected to the sieve-tube element by plasmodesmata.

There are three types of companion cell.

1. **Ordinary companions cells** - which have smooth walls and few or no plasmodesmata connections to cells other than the sieve tube.
2. **Transfer cells** - which have much folded walls that are adjacent to non-sieve cells, allowing for larger areas of transfer. They are specialized in scavenging solutes from those in the cell walls which are actively pumped requiring energy.
3. **Intermediary cells** - which have smooth walls and numerous plasmodesmata connecting them to other cells.

The first two types of cell collect solutes through apoplastic (cell wall) transfers, whilst the third type can collect solutes symplastically through the plasmodesmata connections.

3.2.2 Function of Phloem

Unlike xylem (which is composed primarily of dead cells), the phloem is composed of still-living cells that transport sap. The sap is a water-based solution, but rich in sugars made by the photosynthetic areas. These sugars are transported to non-photosynthetic parts of the plant, such as the roots, or into storage structures, such as tubers or bulbs.

The **Pressure flow hypothesis** was a hypothesis proposed by Ernst Munch in 1930 that explained the mechanism of phloem translocation. A high concentration of organic substance inside cells of the phloem at a source, such as a leaf, creates a diffusion gradient that draws water into the cells. Movement occurs by bulk flow; phloem sap moves from *sugar source*s to *sugar sinks* by means of turgor pressure. A sugar source is any part of the plant that is producing or releasing sugar. During the plant's growth period, usually during the spring, storage organs such as the roots are sugar sources, and the plant's many growing areas are sugar sinks. The movement in phloem is bidirectional, whereas, in xylem cells, it is unidirectional (upward).

After the growth period, when the meristems are dormant, the leaves are sources, and storage organs are sinks. Developing seed-bearing organs (such as fruit) are always sinks. Because of this multi-directional flow, coupled with the fact that sap cannot move with ease between adjacent sieve-tubes, it is not unusual for sap in adjacent sieve-tubes to be flowing in opposite directions.

While movement of water and minerals through the xylem is driven by negative pressures (tension) most of the time, movement through the phloem is driven by positive hydrostatic pressures. This process is termed *translocation*, and is accomplished by a process called *phloem loading* and *unloading*. Cells in a sugar source "load" a sieve-tube element by actively transporting solute molecules into it. This causes water to move into the sieve-tube element by osmosis, creating pressure that pushes the sap down the tube. In sugar sinks, cells actively transport solutes *out* of the sieve-tube elements, producing the exactly opposite effect.

Some plants however appear not to load phloem by active transport. In these cases a mechanism known as the polymer trap mechanism was proposed by Robert Turgeon in 1931. In this case small sugars such as sucrose move into intermediary cells through narrow plasmodesmata, where they are polymerised to raffinose and other larger oligosaccharides. Now they are unable to move back, but can proceed through wider plasmodesmata into the sieve tube element.

The symplastic phloem loading (polymer trap mechanism above) is confined mostly to plants in tropical rain forests and is seen as more primitive. The actively-transported apoplastic phloem loading is viewed as more advanced, as it is found in the later-evolved plants, and particularly in those in temperate and arid conditions. This mechanism may therefore have allowed plants to colonise the cooler locations.

Organic molecules such as sugars, amino acids, certain hormones, and even messenger RNAs are transported in the phloem through sieve tube elements.

3.2.3 Origin of the Phloem

The phloem originates, and grows outwards from, meristematic cells in the vascular cambium. Phloem is produced in phases. *Primary* phloem is laid down by the apical meristem. *Secondary* phloem is laid down by the vascular cambium to the inside of the established layer(s) of phloem.

SAE

- What are the constituents of the phloem?

4.0 CONCLUSION

You have learnt the structure of the stem. You have also learnt that the xylem carries water up the plant while the phloem carries manufactured food down the plant.you further learnt the structures found in the xylem and the phloem that facilitate these functions

5.0 SUMMARY

In a flowering plant, the following happens or takes place:

- the Xylem and Phloem are the transporting tissues in vascular plants
- the Xylem Sap consists mainly of water and inorganic ions
- the Transpirational Pull and Root Pressure causes xylem sap to flow
- the Xylem can be found in vascular bundles; secondary xylem, and as part of a stellar arrangement
- the Primary xylem is formed during primary growth from procambium, while secondary xylem is formed during secondary growth from vascular cambium
- the Phloem structure consist of parenchyma cells, sieve-tube cells and companion cells
- the Phloem originates from meristematic cells in the vascular cambium

6.0 TUTOR MARKED ASSIGNMENT

- Differentiate between xylem and phloem
- Describe the processes that leads to the movement of sap in vascular plants

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UNIT 9 THE VASCULAR CAMBIUM AND THE CORK CAMBIUM

CONTENT

1.0 INTRODUCTION

In the last unit, we looked at the vascular tissues- xylem and phloem. The xylem tissue is responsible for the transportation of water and mineral nutrients, while the phloem tissue is concerned with the translocation of foods (Organic Nutrients or Photosynthates) in plants. In this unit we shall be looking at the vascular cambium and the cork cambium.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- Explain the meaning of vascular cambium and cork cambium
- Mention the types of cells found in vascular cambium
- Describe the different layers of cork cambium
- Draw an annotated diagram showing the vascular cambium and cork cambium
- List the economic importance of cork cambium

3.0 **MAIN CONTENTS**

3.1 Vascular Cambium

The **vascular cambium** is a lateral meristem in the vascular tissue of plants. The vascular cambium is the source of both the secondary xylem (inwards, towards the pith) and the secondary phloem (outwards), and is located between these tissues in the stem and root. A few leaves even have a vascular cambium (Ewers, 1982)

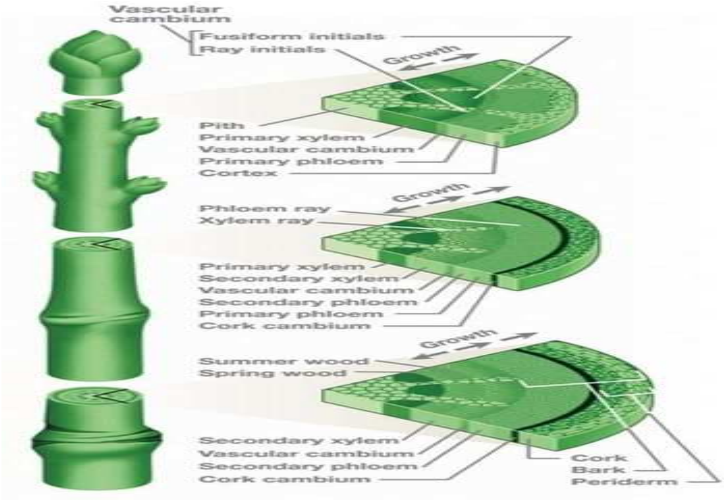


Fig 4.5a Multiple cross sections of a stem showing **vascular cambium** and companion cells (Winterborne, 2005)

The vascular cambium usually consists of two types of cells:

- Fusiform initials (tall cells, axially oriented)
- Ray initials (almost isodiametric cells - smaller and round to angular in shape)

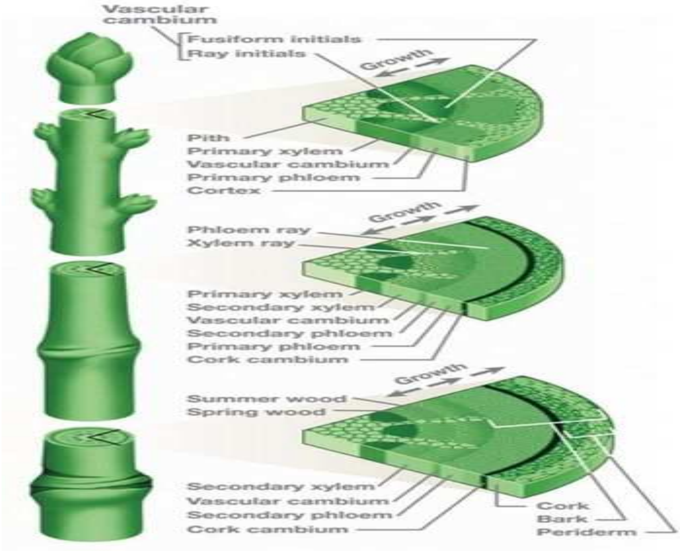
Vascular cambium is a type of meristem - a tissue consisting of embryonic (incompletely differentiated) cells from which other (and more differentiated) plant tissues originate. Primary meristems are the apical meristems on root tips and shoot tips. Another lateral meristem is the cork cambium, which produces cork, part of the bark.

Vascular cambia are found in dicots and gymnosperms but not monocots, which usually lack secondary growth.

For successful grafting, the vascular cambia of the stock and scion must be aligned so they can grow together.

3.2 Cork Cambium

Cork cambium is a tissue found in many vascular plants as part of the periderm. The cork cambium is a lateral meristem and is responsible for secondary growth that replaces the epidermis in roots and stems. It is found in woody and many herbaceous dicots, gymnosperms and some monocots, which usually lack secondary growth.



4.5b Multiple cross sections of a stem showing **cork cambium**

Cork cambium is one of the plant's meristems - the series of tissues consisting of embryonic (incompletely differentiated) cells from which the plant grows. It is one of the many layers of bark, between the cork and primary phloem. The function of cork cambium is to produce the cork, a tough protective material.

Synonyms for cork cambium are **bark cambium**, **pericambium** or **phellogen**. Phellogen is defined as the meristematic cell layer responsible for the development of the periderm. Cells that grow inwards from the phellogen are termed *phelloderm*, and cells that develop outwards are termed *phellem* or cork (note similarity with vascular cambium). The periderm thus consists of three different layers:

- Phelloderm,
- Phellogen (cork cambium) and
- Phellem.

Growth and development of cork cambium is very variable between different species, and also highly dependent on age, growth conditions etc. as can be observed from the different surfaces of bark; smooth, fissured, tessellated, scaly, flaking off, etc.

SAE

- Name the type of cells found in vascular cambium
- What are the other names for cork cambium?

3.3 Economic importance of Cork Cambium

- Commercial cork is derived from the bark of the cork oak *(Quercus suber).* Cork has many uses including wine bottle stoppers, bulletin boards, coasters, hot pads to protect tables from hot pans, insulation, sealing for lids, flooring, gaskets for engines, fishing bobbers, handles for fishing rods and tennis rackets, etc. It is also a high strength-to-weight/cost ablative material for aerodynamic prototypes in wind tunnels, as well as satellite launch vehicle payload fairings, reentry surfaces, and compression joints in thrust-vectored solid rocket motor nozzles.
- Many types of bark are used as mulch in the farm

4.0 CONCLUSION

The vascular cambium and cork cambium are both lateral meristem in the vascular tissues of plants.

5.0 SUMMARY

At the end of this unit, you have learnt that:

- The vascular cambium is a lateral meristem in the vascular tissue of plants
- The vascular cambium is the source of both the secondary xylem and the secondary phloem
- The vascular cambium consists of two types of cells which are Fusiform initials and Ray initials
- Vascular cambia are found in dicots and gymnosperms but not monocots
- Cork cambium is found in woody and many herbaceous dicots, gymnosperm and some monocots
- The function of the cork cambium is to produce the cork, a tough protective material

6.0 TUTOR MARKED ASSIGNMENT

- Differentiate between a vascular cambium and a cork cambium
- Outline the importance of cork cambium to the environment

7.0 REFERENCES/FURTHER READING

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