COURSE GUIDE

BIO 210
SEED PLANTS

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First Printed 2014, Reprint 2023

ISBN: 978-978-058-901-1

INTRODUCTION

BIO 210 is a fundamental course for undergraduate students of Botany and Biological sciences within the Faculty of Sciences and Biology Education within Faculty of Natural and Applied Sciences. It introduces the student to the world of different plant groups: Spermatophytes are otherwise referred to as Seed-bearing plants.

Course Competencies: For science students within the biological sciences and Biology Education.

Course Objectives

At the end of the course, students will be able to,

1. Differentiate the two groups of seed plants,
2. Classify the groups and their associated classes,
3. Recognize each group using morphological and anatomical differences.

Working Through this Course

To successfully complete this course, you are required to read each study unit, read the textbooks and other materials provided by the National Open University.

Reading the reference materials can also be of great assistance. Each unit has self –assessment exercise which you are advised to do.

There will be a final examination at the end of the course. The course should take you about 8 weeks to complete.

This course guide provides you with all the components of the course, how to go about studying and how you should allocate your time to each unit so as to finish on time and successfully.

Number of Study Units: The course is divided into 3 modules with 15 units

References and Further Readings: References are drawn from internet resources, peer-reviewed journals and articles and relevant books.

Presentation Schedule

There is a time-table prepared for the early and timely completion and submissions of your TMAs as well as attending the tutorial classes. You are required to submit all your assignments by the stipulated date and time. Avoid falling behind the schedule time

Assessment

At the end of each session, there are in-text questions for students' self-appraisal of their understanding of key terminologies typical of the area of focus. In addition, there are self-assessment exercises which should prepare students for continuous assessment tests and end of semester examinations.

The work submitted to your tutor for assessment will account for 30% of your total work. At the end of this course you will have to sit for a final or end of course examination of about a three hour duration and this will account for 70% of your total course mark.

How to get the Most from the Course

Seed plants abound within the immediate environment of the students. An avid nature-lover will easily pass this course, as they will easily identify some of the plants mentioned in the course around them. Importantly, students should be ready for field exercises which will help them through the course.

Online Facilitation

Eight weeks are provided for tutorials for this course. You will be notified of the dates, times and location for these tutorial classes.
As soon as you are allocated a tutorial group, the name and phone number of your facilitator will be given to you.
The duties of your facilitator are to monitor your progress and provide any necessary assistance you need.
Do not delay to contact your facilitator by telephone or e-mail for necessary assistance if

- You do not understand any part of the study in the course material.
- You have difficulty with the self-assessment activities.
- You have a problem or question with an assignment or with the grading of the assignment.

It is important and necessary you attend the tutorial classes because this is the only chance to have face to face contact with your facilitator and to ask questions which will be answered instantly. It is also a period where you can point out any problem encountered in the course of your study.

Ice Breaker

Dr**.** Ogbemudia, Felix Okpako is a Senior Lecturer in University of Uyo. Dr. Ogbemudia moderate and facilitate courses in the National Open University. He has supervised student projects and seminar review in the Department of Biological Sciences, Faculty of Science.

MAIN COURSE

CONTENTS

MODULE 1 ORIGIN AND EVOLUTION OF SEED PLANTS

Introduction

This module traces the origin and evolution of seed plants, otherwise known as Spermatophyte. It comprises three units that detail the different forms and classes of the Spermatophytes, their origin and evolution as shown below.

Unit 1 The Origin And Evolution Of Seed Plants

Contents

1.1 Introduction

In this unit, we shall be looking at the fossil records of seed plants, the late Devonian and the late Palaeozoic seed plants, fossil records of angiosperms and the Koonwarran Angiosperms.

1.2 Objectives

By the end of this unit, you will be able to:

- Outline the origin of seed plants
- Explain how seed plants evolved based on fossil records
- Explain the late Devonian and the late Palaeozoic seed plants
- Outline the fossil records of Angiosperms and the Koonwarran Angiosperms

1.3 Main Content

1.3.1 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.

1.3.2 The Late Devonian Seed Plants

The oldest known seed plant, Elkinsia polymorpha, dates back to the Late Devonian period in West Virginia. Although only small seed-bearing shoots have been found, these fragments provide valuable insights into the early evolution of seeds. Another fossil from the same period, Archaeosperma, is also known from fragments.

Early seed plants did not have specialized structures like cones or flowers. Instead, they produced seeds along their branches, either singly or in pairs, surrounded by loose cupules. These cupules had lobes and formed a sheltered chamber at one end of the seed. Within these cupules, the seed was enclosed by the integument, a tissue that would later become the seed coat. Over time, the integument evolved to enclose the seed more tightly, leaving an opening called the micropyle for pollen to enter and fertilize the egg cell. Both the integuments and cupules likely resulted from reduced and fused branches or leaves.

In later seed plants, a pollen chamber developed just inside the micropyle. Modern cycads and conifers have this chamber, which exudes sticky fluids to capture pollen. As the fluid dries, it pulls pollen inside the micropyle. Detailed preservation of this structure is seen in recently discovered permineralized Devonian seeds. Some Permian seeds even have preserved embryos. Here are some Carboniferous Trigonocarpus seeds.

Fig 3.1 Fossil Seeds*
(Source: http://www.ucmp.berkeley.edu/seedplants/seedplantsfr.html and

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

1.3.3 The Late Paleozoic Seed Plants

"In the Devonian period, early seed plants known as 'lyginopterids,' including Sphenopteris, emerged. Sphenopteris, which had fern-like leaves but also bore seeds and cupules, raises questions about whether it's a single group or several with similar leaves.

During the Carboniferous age, there was a surge in seed plant diversity. In North American coal swamps, pteridosperms like Medullosa, resembling modern tree-ferns but bearing seeds, thrived. Cordaites also grew in these swamps and other habitats, possibly closer relatives of modern conifers. However, towering scale-trees overshadowed these early seed plants.

By the Late Carboniferous (Westphalian), Voltziales, believed to be the closest relatives of modern conifers, appeared. Some classify them as conifers. In the Permian, seed plants began to grow into large trees, and by the Triassic, all major seed plant groups had emerged, except for flowering plants.

Now, shifting focus from gymnosperm evolution, let's explore the evolution of angiosperms." What is the essence of the fossil seeds?

1.3.4 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 palaeobotanist 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. Palaeobotanists 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)

1.3.5 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)

SELF ASSESSMENT EXERCISE

• What are the characteristics of the Koonwarran Angiosperms?

1.4 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

1.5 References/Further Readings/Web Sources

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1.6: Possible Answers to Self-Assessment Exercises

Unit 2 The Origin of Angiosperms

Contents

2.1 Introduction

In unit 1, we looked at the origin and evolution of seed plants which are also known as spermatophytes or phanerogams. We look at the fossil records of seed plants. in this unit we will consider the origin and evolution of angiosperms; when, where and how did the angiosperms evolve?

2.2 Objectives

By the end of this unit, you will be able to:

- Explain when, where and how the angiosperms evolved
- Outline the factors that may have been responsible for the success in the evolution of angiosperms.

2.3 Main Content

2.3.1 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.

2.3.2 When Did Angiosperm Evolve?

The sudden appearance of diverse angiosperms in the Cretaceous period suggests that flowering plants may have originated much earlier, potentially up to 100 million years before the oldest known angiosperm fossil. The ancestors of angiosperms might have shared commonalities with extinct groups like cycadeoids.

The emergence of the carpel is crucial in understanding the evolution of angiosperms. One theory proposes that the carpel evolved from the cupule of seed ferns like caytonia. This suggests that the carpel may have appeared as early as 200 million years ago, during the Carboniferous period. However, other hypotheses exist.

Cycadeoids were once considered possible ancestors of angiosperms because they had microsporangia and ovules in proximity, resembling the structure of perfect flowers common in angiosperms. More recent research using cladistics suggests that angiosperms may have descended directly from seed-fern ancestors, potentially originating in the Triassic period, coinciding with the appearance of cycadeoids in the fossil record.

2.3.3 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.

2.3.4 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 they searched for food. In turn, plants evolved floral nectar and odours 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)

2.3.5 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.

SELF ASSESSMENT EXERCISE

• What are the characteristics of the Koonwarran Angiosperms? What is the fossil evidence that angiosperms originated at least about 200 million years ago

2.4 Summary

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

- The angiosperms are the most dominant plants on earth
- The angiosperms have flowers that include seeds in a Carpel
- The main force behind the 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.

2.5 References/Further Readings/Web Sources

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https://www.youtube.com/watch?v=ijdLYAWVPHc

Unit 3 Classification of Spermatophytes

Contents

3.1 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. Seed plants comprises, non-flowering and flowering groups of plants. Examples of seed plants are, Conifers, which 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 Spermatophytes, let’s examine in the next section the course specific objectives and expected learning outcomes for this unit.

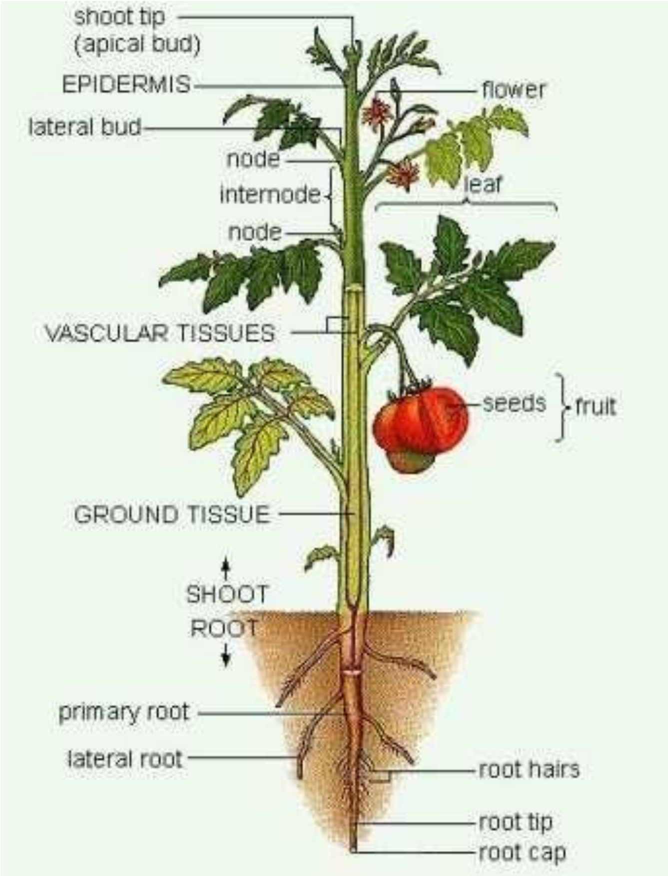

Fig. 1.1b: Basic Anatomy of a Seed Plant
(Source: http://universe-review.ca/R10-34-anatomy2.html)

3.2 Intended Learning Outcomes (ILOs)

At the end of this unit, students 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

3.3 Main Content

3.3.1 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 the five groups mentioned above:

- Division **Spermatophyta**
- **Cycadopsida**,the cycads
- **Ginkgoopsida**, theginkgo
- **Pinopsida** or Coniferopsida, the conifers
- **Gnetopsida**, the gnetophytes
- **Magnoliopsida or Angiospermopsida** the flowering plants

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 look at the individual classes of gymnosperm and the flowering plants. What are seed plants?

3.3.2 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.

What are Gymnosperms?

3.3.2.1. Division: Pinophyta-The Conifers

Case studies: The Conifers are pine trees and are regarded as evergreen trees to the layman. There are about 550 conifer species; because they are well adapted to harsh climates, they often form the tree line on mountains and in sub polar regions.

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 softwood, while the wood of broadleaf trees is hardwood. The xylem rings in conifers are often wide because 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.

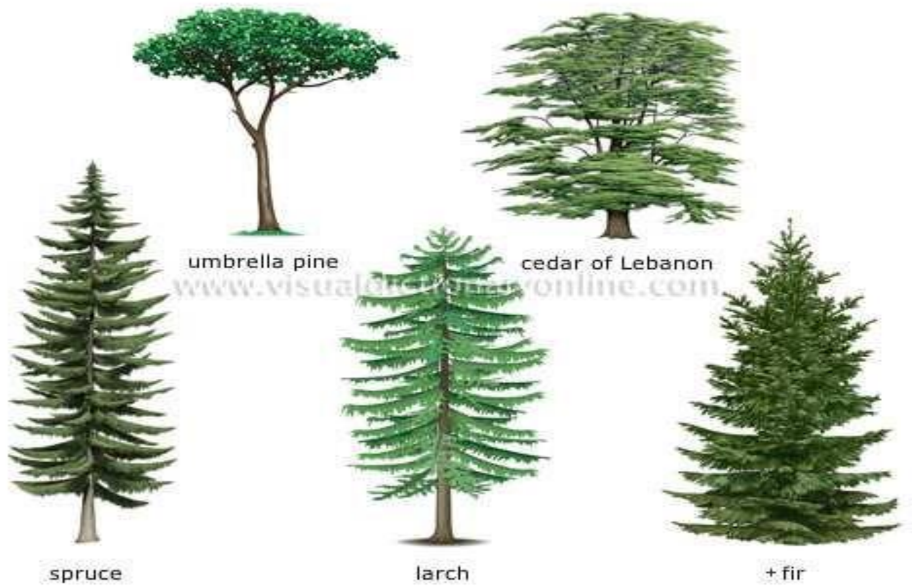

Fig 3.2 Diagram of Conifers

(Source:http://visual.merriam-webster.com/plantsgardening/plants/conifer/examples-conifers.php)

Fig 3.3 Cross section of a dicot leaf (showing cuticle and epidermis)

3.3.2.2 Division: Ginkgophyta- the Ginkgo

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.

3.3.2.3 Division: Cycadophyta- the Cycads

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.

3.3.2.4 Division: Gnetophyta- the Gnetophytes

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. What are Pinophyta?

3.3.3 Relevance of Seed Plants to Humans

Discussion: 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 resin 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

SELF-ASSESSMENT EXERCISE(S)

Of what relevance are the seed plants to humans?

3.4 Summary

In this unit, you have learnt that:

- Seed plants is composed of the gymnosperm 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.

3.5 References/Further Readings/Web Sources

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3.6 Possible Answers to Self-Assessment Exercises

Answers:

- 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 resin 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

Unit 4 Classification of Angiosperms

Contents

4.1 Introduction

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

4.3 Main Content

4.3.1 Angiosperms

Angiosperms are also commonly referred to as flowering plants. They are easily identified/differentiated from other groups of plants by the following characteristics:

- They have a reproductive device called **flower** which consists of structures such as the pistil, stamen, sepals and petals.
- They produce ovules that is inside or enclosed in a carpel. The ovules develop into a seed while the carpel develops into the fruit.
- Most angiosperm exhibit double fertilization
- Xylem has vessels, phloem contains companion cells

4.3.2 Classification of Angiosperms

Angiosperms are classified into two main groups

a) **Monocotyledons:** is one of the divisions of Angiosperms in which embryo has one cotyledon and leaves are usually parallel-veined, with about 40, 000 species E.g. Grasses, Sugarcane, banana tree, daffodils, palm trees, ginger, grains which include wheat, rice, corn, millets, bamboo, onion, and garlic.

b) **Dicotyledons**: (otherwise called Dicotyledonae) is one of the divisions of Angiosperms in which embryo has two cotyledons and leaves are usually net - veined with about 160, 000 species) E.g., Mango, pea, tomato, lettuce etc.

These two groups are differentiated based on the following characters:

Monocots	**Dicots**
Produce one cotyledon	Produce two cotyledons
Produce flowers in threes or multiple of threes	Produce flowers in fours or fives or their multiple
They possess parallel venation	The possess net or reticulate venation
Their stem usually has scattered vascular bundles	Here, the vascular bundles are well arranged in a ring-like pattern
They have adventitious or fibrous root system	They have tap roots
Cambium is absent, hence, no secondary growth	Cambium is present, hence, there is secondary growth
Monocots are herbaceous.	Dicots are both woody as well herbaceous.

The above characters have been used in distinguishing most monocots and dicots, however many exceptions to them have been found.

*N/B The palm tree is an exception to the rule when it comes to monocot plants. Most monocots cannot grow as large and tall as palm trees do because they lack secondary growth—the growth of wood and bark—limiting most monocots to be herbaceous. However, palm trees have circumvented this issue by utilizing their vascular bundles and the lignin within them to create a firmer stem. Palm stems are also thickened by parenchymal cells that surround the vascular bundles, providing even more support for a tall tree-form

4.3.2.1. Classification According to Habit

Angiosperms are also classified on the basis of the plant habits as, herbs, shrubs and trees. Herbs are plants that do not produce permanent shoot system aerially. They die off, usually in the cold season. Such a shoot system is generally of a soft, green in nature.

Shrubs have a hard woody permanent shoot system. They are not usually tall plants, with branches that are usually branched from the base Trees and shrubs also have hardwood permanent shoot system but are greater in size than shrubs. Trees are characterized by single main trunk.

Trees and shrubs do not retain their aerial parts throughout the growing season, they shed their leaves.

The life span of plant is determined by the number of seasons through which it persist. On the bases of these, plants are classified as annuals, biennials or perennials. Annual plants complete their life cycle (from seed germination to seed production in one year and then die off e.g., Maize). Biennials require two growing seasons to complete their life cycle. In the first season, they grow vegetatively storing food in certain organs of their body. In the second season, they utilize the stored food to develop vegetatively and develop flowers and fruits before dying off e.g. carrot, ginger. The perennials continue to grow indefinitely, storing food for winter and making new growth in spring. The perennials most often have a long lifespan, during which they reproductive parts in successive seasons

4.3.2.2. Organization of Angiosperms

- Angiosperms are differentiated into an underground **root system** and an aerial **shoot system.**
- The root system consists of **root** and its **lateral branches**.
- The shoot system has a **stem, branches** and **leaves**.
- Root, stem and leaves together constitute the **vegetative organs** of the plant body and they do not take part in the process of reproduction.
- The flowering plants on attaining maturity produce **flowers**, **fruits** and **seeds**. These are called the **reproductive organs** of the plant.

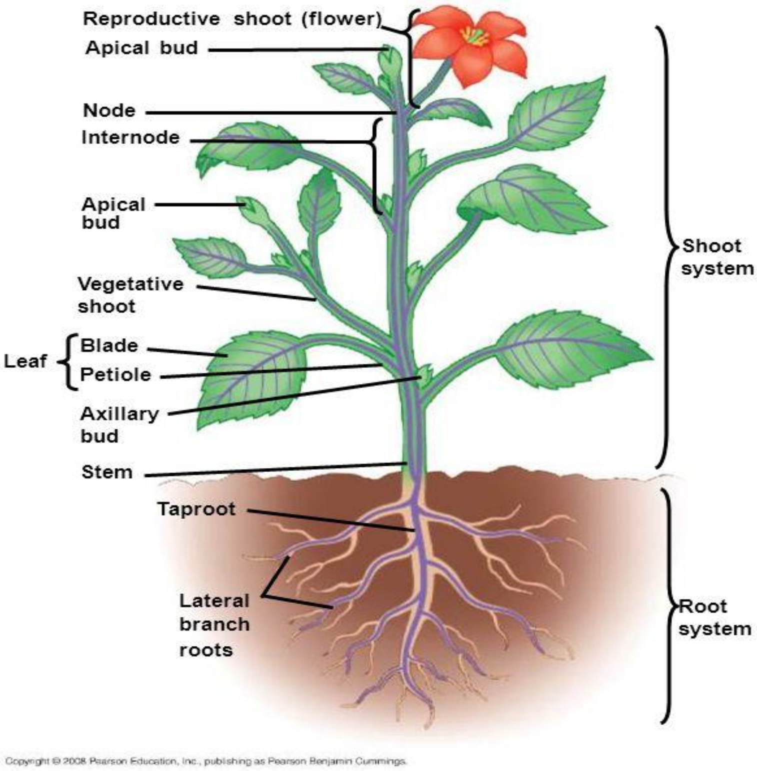
Root System

- The roots consist of a main root also called the taproot. Branch roots arise from the taproot and these are called secondary roots.
- Most monocot do not have tap root rather they usually produce fibrous and adventitious roots

Shoot System

- The shoot consists of a main axis called the stem. This may be branched.
- The stem usually has an apical bud which is responsible for growth in length in the upward direction.
- Arising from the stem/branches are leaves. They are usually green in colour and flat. They are responsible for food production and photosynthesis.
- The leaves have veins which are parallel in monocots and reticulate in dicots
- Each leaf may have a stalk called **petiole**

- ❖ The point of attachment of a leaf to the stem is called **node**
- ❖ The angle between the leaf stalk and the stem is referred to as the **axil**
- ❖ **Buds** are sometimes found in the axils. Such buds are referred to as **Axillary buds**
- ❖ Another feature of the shoot is the **flower** which is usually formed towards the apex of the shoot/branches. The flowers give rise **fruits** which contain **seed**
- ❖ Apical buds sometimes give rise to flowers. In such cases, growth in the upward direction ceases.



4.3.2.3. The Angiosperm Roots

- ❖ The root system is typically a non-green underground descending portion of the plant axis.
- ❖ It gives rise to many lateral roots.
- ❖ The roots do not have nodes and internodes.

General Characteristic features of the root

- ❖ Root is positively geotropic and negatively phototropic.
- ❖ Roots are generally non-green in colour since they do not have chlorophyll pigments and hence they cannot perform photosynthesis.
- ❖ Roots do not have nodes and internodes; these do not bear leaves and buds.

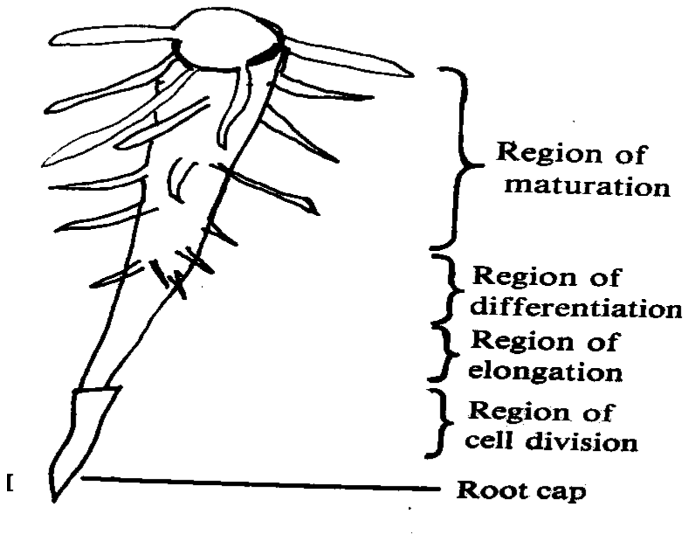
- The lateral branches of the roots are **endogenous** in origin i.e they arise from the inner tissue called **pericycle** of the primary root.
- Roots have unicellular hairs

There is presence of root cap at the root tip.

Regions of A Typical Root

The following 5 regions are distinguished in a root from apex upwards.

1. **Root Cap:** It is a cap like structure that covers the apex of the root. The main function of the root cap is to protect the root apex.
2. **Meristematic Zone or Region of Cell Division:** This is the growing tip of the root. It lies a little beyond the root cap. The cells of this region are actively dividing and continuously increase in number.
3. **Region of Differentiation:** Here the elongated cells become differentiated into various functional types such as xylem, phloem, epidermis and cambium
4. **Zone of Elongation**: It is a region that lies just above the meristematic zone. The cells of this zone increase in size. This zone helps in the growth in length of the plant root.
5. **Zone of Cell Maturation**: This is a zone that lies above the zone of elongation. In this zone the cells differentiate into different types. They form the tissues like the epidermis, cortex and vascular bundles. In this region a number of **root hairs**are also present. The root hairs are responsible for absorbing water and minerals from the soil.



Regions of a root

4.3.2.4 Functions of Roots

Roots perform two kinds of function namely **primary and secondary function**.

The primary functions are performed by all the roots in general. In some plants, the roots perform certain additional functions in order to meet some special needs. These are called secondary functions of the roots. In order to perform these special functions, the roots show modification in their structure accordingly.

Primary functions

- **Absorption**: The main function of any root system is absorption of water and minerals from the soil with the help of root hairs.
- **Anchorage**: The roots help to fix the plant firmly in the soil.

Secondary functions

The following are some of the secondary functions performed by the roots in addition to the primary functions mentioned above.
(1) Storage of food (2) Additional support (3) Haustoria function (**4) Assimilation (5) Respiration (6**) **Symbiosis.**

4.3.2.5Types of Root System

There are two types of root system

- **Tap root system**
- **Adventitious root system**

Tap Root System

It develops from the radicle of the embryo. The radicle grows in to the **primary or tap root**. It produces branches called **secondary roots**. These branch to produce what are called **tertiary roots**. This may further branch to produce fine **rootlets**. The tap root with all its branches constitutes the tap root system. Tap root system is the characteristic feature of most of the dicot plants.

Adventitious Root System

Root developing from any part of the plant other than the radicle is called **adventitious root**. It may develop from the base of the stem or nodes or internodes. The adventitious roots of a plant along with their branches constitute the adventitious root system.

In most of the monocots the primary root of the seedling is short lived and lateral roots arise from various regions of the plant body. They are thread like and are of equal size and length. These are collectively called

fibrous root system. It is commonly found in monocot plants like **maize, sugarcane and wheat**.

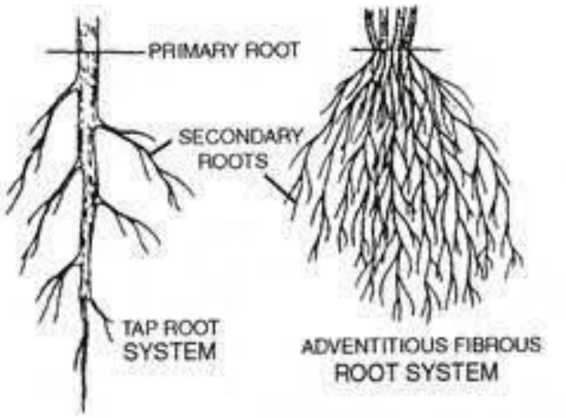


Fig. 5.24. Tap and adventitious root systems.

Modification of Roots

Besides primary functions like absorption and anchorage some roots also perform certain additional functions in order to meet some specific needs. These roots are modified in their structure to perform these special functions. Modification of roots occurs either in the tap roots or adventitious roots. Define Angiosperms. What distinguishes a gymnosperm from an angiosperm?

4.4 Summary

In this unit, you have learnt that:

- Seed plants is composed of angiosperms
- 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.

4.5 References/Further Readings/Web Sources

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Unit5 Classification and Distribution Of Gymnosperms

Contents

5.1 Introduction

In the vast world of plants, one group stands out for its unique characteristics and evolutionary history: the Gymnosperms. These remarkable plants, often referred to as 'naked seeds,' have intrigued botanists and nature enthusiasts for centuries. In this lecture, we will delve into the captivating world of Gymnosperms, exploring their classification, distribution, and significance in the plant kingdom.

5.2 Intended Learning Outcomes (ILOs)

By the end of this lecture, you should be able to:

Understand the fundamental characteristics that define Gymnosperms.
Recognize the major taxa within the Gymnosperm group.
Comprehend the geographical distribution of Gymnosperms worldwide.
Appreciate the ecological and economic importance of Gymnosperms.
Identify key examples of Gymnosperms and their unique adaptations.

5.3 Main Content

5.3.1 Characteristics of Gymnosperms

Gymnosperms are a group of seed-producing plants that differ from angiosperms (flowering plants) in several key ways. These differences include:
Naked Seeds: Gymnosperms produce seeds that are not enclosed within fruits. This fundamental distinction sets them apart from angiosperms, where seeds are protected within a fruit.
Cones: Gymnosperms typically produce cones as their reproductive structures. These cones can be male (pollen cones) or female (seed cones).

Vascular Tissue: Gymnosperms possess well-developed vascular tissue, including xylem and phloem, which enables them to transport water and nutrients efficiently.

5.3.2 Classification of Gymnosperms

Gymnosperms are classified into four main orders:

a. Coniferophyta (Conifers)
Conifers are the largest and most well-known group of Gymnosperms. They include familiar trees like pines, spruces, and firs. These plants are predominantly found in temperate regions and are characterized by needle-like leaves and the production of cones.
Example: Pinus sylvestris (Scots Pine)

b. Cycadophyta (Cycads)
Cycads are often referred to as "living fossils" because they resemble plants that existed during the age of dinosaurs. They have palm-like fronds and are typically found in tropical and subtropical regions.
Example: Cycas revoluta (Sago Palm)

c. Ginkgophyta (Ginkgo)
Ginkgo biloba is the only living species in this group. It's known for its distinctive fan-shaped leaves and is often used in traditional medicine.
Example: Ginkgo biloba (Maidenhair Tree)

d. Gnetophyta (Gnetophytes)
Gnetophytes are a diverse group that includes three genera: Gnetum, Ephedra, and Welwitschia. They exhibit a range of morphological diversity and inhabit various environments.
Example: Ephedra sinica (Mormon Tea)

5.3.3 Distribution of Gymnosperms

Gymnosperms have a global presence, but their distribution is not uniform. They thrive in a variety of ecosystems, from alpine forests to arid deserts. Here are some distribution patterns:

Conifers: Conifers are widespread and dominant in northern temperate regions, such as the boreal forests of North America and Eurasia.
Cycads: Cycads are primarily found in tropical and subtropical regions, with a significant presence in Africa, Central America, and Asia.
Ginkgo: Ginkgo biloba is native to China but is cultivated worldwide for its medicinal and ornamental value.
Gnetophytes: Gnetophytes are scattered across different continents, with species found in Africa, Asia, and the Americas.

Self-Assessment Exercise(s)

True or False: Gymnosperms produce seeds enclosed within fruits.

Match the Gymnosperm order with its example:

a. Coniferophyta (Conifers)
b. Cycadophyta (Cycads)
c. Ginkgophyta (Ginkgo)
d. Gnetophyta (Gnetophytes)

Examples: Pinus sylvestris, Ginkgo biloba, Cycas revoluta, Ephedra sinica

5.3 4 Ecological and Economic Importance

Gymnosperms play crucial ecological roles. They provide habitat and food for various wildlife species. Additionally, they have economic significance:

Timber Production: Conifers are a major source of timber for construction and paper production.

Medicinal Uses: Ginkgo biloba is used in traditional medicine for various ailments.

Ornamental Plants: Several Gymnosperms are prized for their ornamental value in landscaping.

5.4 Summary

Gymnosperms are seed-producing plants with naked seeds and cones. They are classified into four main orders: Coniferophyta, Cycadophyta, Ginkgophyta, and Gnetophyta.

Gymnosperms have diverse global distributions, with each order adapted to specific environments.

They play essential ecological and economic roles in various ecosystems.

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MODULE 2 MORPHOLOGY OF SEED PLNTS

Module Introduction

Module 2 deals with the morphology (the visible structure of seed plants which are used in the identification of different seed plants. The module is presented in three units as shown below.

Unit 1 Vegetative Structure of Seed Plants: The Root

Contents

1.1 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.

1.2 Intended Learning Outcomes (ILOs)

At the end of this unit, you will 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

1.3 Main Content

1.3.1 Root Growth

Early root growth is one of the functions of the apical meristem located near the tip of the root. The meristem cells 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.

1.3.2 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.

1.3.2.1. 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:

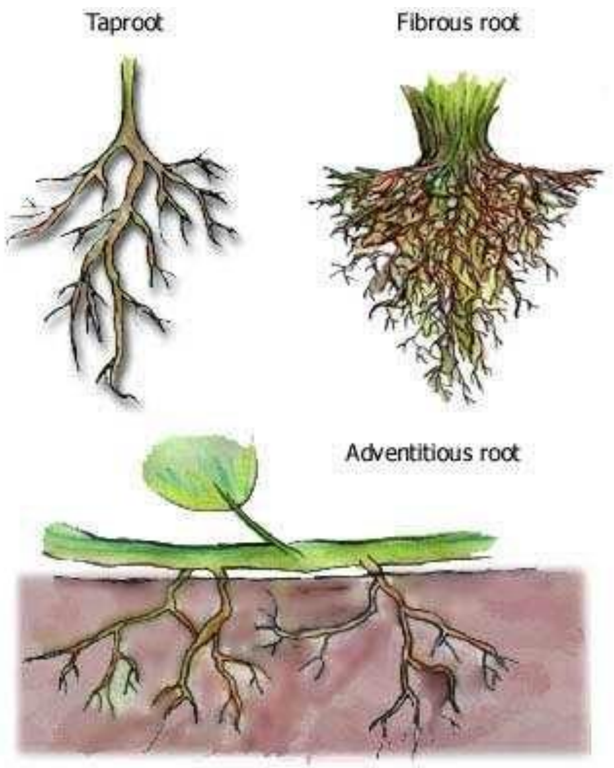

Fig 7.1 Different kinds of roots
(Source: http://homepage.smc.edu/hodson_kent/plant_growth/Angiosperms/ID/basics.htm)

Fig 7.2 Root types (Source: 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.

1.3.3. 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.

1.3.4 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 aboveground architecture of a plant - ie. 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.

1.3.4.1Tap Root System

Taproots have a main central root upon which, small, lateral roots called root hairs are attached. Mustard, carrot, beetroot, parsley, China rose and all dicotyledons are examples of taproot systems.

1.3.4.2Fibrous Root System

Fibrous roots, on the other hand, are bushy roots in which thin, moderately branching roots grow from the stem. Rice, wheat, maize, marigold, banana and all monocotyledons are some examples of the fibrous root system.

Also Read: Anatomy of Monocot and Dicot Plants

1.3.5 Functions of Root

Following are the important functions of root:
Roots perform various functions that are necessary for the survival of the plants. They are an integral or integrated system that helps the plant in:
Anchoring: Roots are the reason plants remain attached to the ground. They support the plant body, ensuring that it stands erect.

Absorption: Primary function of the roots is to absorb water and dissolved minerals from the soil. This is crucial as it helps in the process of **photosynthesis**.

Storage: Plants prepare food and store in the form of starch in the leaves, shoots and roots. Prominent examples include carrots, radish, beetroot, etc.

Reproduction: Even though roots are not the reproductive part of plants, they are vegetative parts. In some plants, the roots are a means of reproduction. For instance, new plants arise from creeping horizontal stems called runners (stolons) in jasmine, grass, etc. This type of reproduction is called vegetative propagation.

Ecological Function: They check soil erosion, provide sustenance and also habitat to various organisms.

Explore More: Morphology of Flowering Plants
Learn more about root system, types of roots, the function of the root, and other related topics @ BYJU'S Biology. What are the different types of root systems?

The different types of root systems are:
- Taproots
- Fibrous roots
- Adventitious roots

What are the functions of roots?
Roots perform the following functions:
- Roots absorb water and nutrients from the soil.
- They anchor the plant firmly.
- They help in storing food and nutrients.
- Roots transport water and minerals to the plant.

What are the differences between monocot and dicot roots?
The main difference between monocot and dicot root is that the dicot root contains xylem in the middle and phloem surrounding the xylem. Whereas in monocot root, xylem and phloem are arranged circularly.
What are the primary and secondary roots?

Primary roots are the early roots in young plants that consist of taproots, basal roots, and lateral roots. Secondary roots are the side branches of the primary roots.
Name the plants with taproots.
The plants with taproots are:

- Beetroot
- Carrot
- Parsley
- Dandelion

Mention some edible roots.
Some edible roots include:

- Ginger
- Turnip
- Yam tubers
- Cassava tubers

What are fibrous roots?
Fibrous roots are the roots formed by thin, moderately branching roots emerging from the stem. Wheat, rice and corn are some of the examples of fibrous roots.

SELF-ASSESSMENT EXERCISE(S)
1. **Define the following: adventitious root and Aerial roots**

Answers:
Answer A: Adventitious roots are **plant roots that form from any nonroot tissue** and are produced both during normal development (crown roots on cereals and nodal roots on strawberry [Fragaria spp.]) and in response to stress conditions, such as flooding, nutrient deprivation, and wounding.

What are aerial roots?
Aerial root is **a type of root wherein it grows from the stem of the plant, i.e. above the ground**. This type of root absorbs water directly from the air. This is exemplified by the roots of the epiphytes (eg. orchids). Aerial roots are adventitious roots.

1.3.6 Economic Importance of Roots

The term root crops refer to any edible underground plant structure, but many root crops are actually stemming, 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 licoricey.

Sugar beet is an important source of sugar. Yam roots are a source of oestrogen compounds used in birth control pills. The fish poison and insecticide rotenone are 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 ploughed 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.

Self-Assessment Exercise(s)
Explain what you understand by root depth and root architecture

What is root depth?
We define rooting depth (D_i) of an individual plant i as **the deepest soil depth reached by the roots of an individual plant** (i.e. maximum rooting depth) and lateral root spread (L_i) as the maximum linear distance (one-sided) from the stem of an individual plant reached by its roots. WHILE What is root system architecture?
Root architecture is composed of a collection of root phones, which determine the temporal and spatial distribution of roots in the heterogeneous matrix of the soil and thus the ability of plant roots to obtain mobile and immobile resources.

2. In what ways are roots specialized for adaptive purposes
How are root hairs an adaptive advantage?
What are three root adaptations?
What is a specialized root, give examples of specialized roots and their functions?

Answer: Storage roots, such as **carrots, beets, and sweet potatoes**, are examples of roots that are specially modified for storage of starch and water. They usually grow underground as protection from plant-eating animals.

Self-Assessment question. Differentiate between a root and a stem

Answer: Comparison Table between Root and Stem

Parameters of Comparison	Root	Stem
Definition	Rots are the part of a plant that provides support and are under the soil.	Stems are the upper part that usually provides support from the plant above the ground.
Geotropism	Roots grow along the direction of gravity, and hence they are positively geotropic.	Stems grow away from gravity towards the sky, and hence they are negatively geotropic.
Phototropism	Roots are negatively phototropic as they grow in the direction opposite of that light.	The stem is positively phototropic as they grow upwards towards the sun.
Function	Provides support, holds it firmly with the soil and provides water, moisture, and nutrients from the soil.	Transports the substances and also provides support for leaves, fruits, and flowers.
Above or below the ground	They are mostly under the ground, whereas they can also be above the soil in aerial plants.	The stem is always present above the ground and very rarely under the s

Mention the different types of roots.

1.4 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

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www.youtube.com › watch

Unit 2 Vegetative Structure of Seed Plants: Stem

Contents

2.1 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 Phyto morphology 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.

2.2 Intended Learning Outcomes (ILOs)

At the end the end of this unit, you will 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

2.3 Main Content

2.3.1 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.

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

- 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.

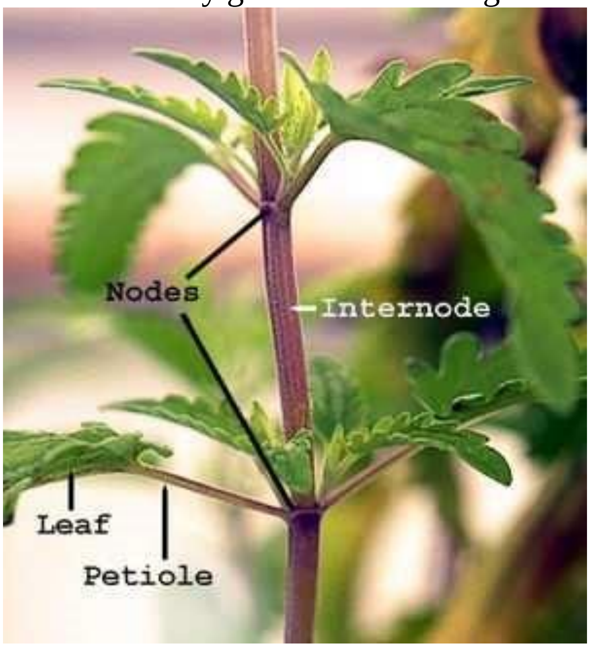

Fig 5.2 Stem showing internode and nodes plus leaf petioles
(Source: http://en.wikipedia.org/wiki/stem) and Evolution of Seed Plants – Biology 2e - BC Open Textbooks *https://opentextbc.ca* › chapter › evolution-of-seed-plants and

Seed Plants | Biology | Botany - YouTube
https://www.youtube.com › watch

2.3.1.1 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.

2.3.1.2 Specialized Terms for Stems

Discussions: 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.

2.3.1.3 Dicot Stems

Dicot stems with primary growth have pith in the centre, 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
(Source: http://en.wikipedia.org/wiki/Flower)

2.3.1.4 Monocot Stems

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.

2.3.1.5 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. What are the tissues that constitute the stem structure?

2.3.1.6 Economic Importance of Stems

Case Studies: 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, eg. 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).

Self-Assessment Exercise(s)

1. Mention and define ten specialized functions of the stem

Answer: Functions of Stem

- It supports and holds leaves, flowers, and fruits.
- The stem allows the leaves to arrange in a way that they are able to receive direct sunlight in order to efficiently perform photosynthesis. The arrangement and position of leaves also allow for gas exchange.
- The xylem and phloem present in the vascular bundles of stems conduct water and minerals across the plant.
- Stems bear flowers and fruits in a position that facilitates the processes of pollination, fertilization, and dispersion of seeds.
- Some stems undergo modification to store food and water. Example: succulents.
- Few green stems contain chloroplasts and are capable of carrying out photosynthesis as well.
- Some stems are modified to carry out vegetative propagation which is a form of asexual reproduction seen in plants.

2. **Differentiate between a dicotyledonous stem and a monocotyledonous stem**

Answer: key differences between monocot and dicot stem

Character	Monocot Stem	Dicot Stem
Definition	Monocot stems are a circular-shaped stem with lateral branches and are bounded with a layer of the dermis.	Dicot stems have a well-defined epidermis with cuticle, a layer of dermis along with multicellular stem hair.
Epidermal hair	In this multicellular epidermal hair are present over the epidermis.	In this the epidermal hair is absent.
Silica	No silica	Usually, silica occurs

	occurs over the epidermis in Monocot.	over the epidermis in Dicot.
Ground Tissue	The ground tissue is differentiated into stelar and extra stelar tissues.	The ground tissue is not differentiated into stelar and extra stelar tissues.
Endodermis	The endodermis is present in the Monocot Stem.	The endodermis is absent in the Dicot Stem.
	The monocot stem is usually hollow at the center.	The dicot stem is solid in most of the cases.
Vascular Bundles	Vascular bundles are present in a limited number, usually 4 to 8.	Vascular bundles are numerous in Dicot.
Vascular bundles arrangement	Vascular bundles are arranged in the form of one or two broken rings. They are conjoint, collateral, and open.	Vascular bundles are arranged scattered in the ground tissue. They are conjoint, collateral, and closed.
Elements	The vascular bundle consists	The vascular bundle consists of only two

	of many protoxylem and metaxylem elements.	metaxylem elements.
Xylem element	The xylem elements are polygonal.	The xylem elements are circular.
Bundle cap	The bundle cap is present.	The bundle cap is absent.
Pericycle	The pericycle is present.	The pericycle is absent.
Phloem parenchyma	Phloem parenchyma is present.	Phloem parenchyma is absent.
Phloem fiber	Phloem fiber is present.	Phloem fiber is absent.
Pith	Pith is present. Pith is well-developed.	Pith is absent. Pith is not as well-developed in monocots (usually absent in most)
Medullary rays	Medullary rays are present.	Medullary rays are absent.
Secondary thickness	It undergoes secondary thickness.	there is no secondary thickness.
Hypodermis	The hypodermis is made of sclerenchyma	The hypodermis is formed of collenchyma fibers which are often green in color.

	fibers, and they are not green.	
Trichomes	The monocot stems do not have trichomes.	The dicot stems have trichomes.
Vascular tissues	Vascular tissues remain the same throughout the plant's life cycle.	Usually, vascular tissues stop functioning when they get old. New vascular tissues replace the old ones.
Vessels	Vessels are rounded or oval and are arranged in a Y-shaped formation.	Vessels are of a polygonal shape and are arranged in rows or chains.

3.Why is a stem referred to as climbing, and another as herbaceous?

Answer: What is called a stem?
stem, in botany, **the plant axis that bears buds and shoots with leaves and, at its basal end, roots**. The stem conducts water, minerals, and food to other parts of the plant; it may also store food, and green stems themselves produce food and secondly What is an herbaceous stem?
Herbaceous plants are plants that, by definition, have **non-woody stems**. Their above-ground growth largely or totally dies back in winter in the temperate zone, but they may have underground plant parts (roots, bulbs, etc.) that survive
Definitions of "herb" and "herbaceous"
"A plant whose stem does not become woody and persistent (as in a tree or shrub) but remains soft and succulent, and dies (completely or down to the root) after flowering"; "A (freq. aromatic) plant used for flavouring or scent, in medicine, etc."

2.4 Summary

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

- A stem is a structural axis 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

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Unit 3 Vegetative Structure of Seed Plants: Leaf

Contents

3.1 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 morelight 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.

3.2 Intended Learning Outcomes (ILOs)

By the end of this unit, you will be able to:

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

3.3 Main Contents

3.3.1 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 schemata, 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.

3.3.1.1 Basic Leaf Types

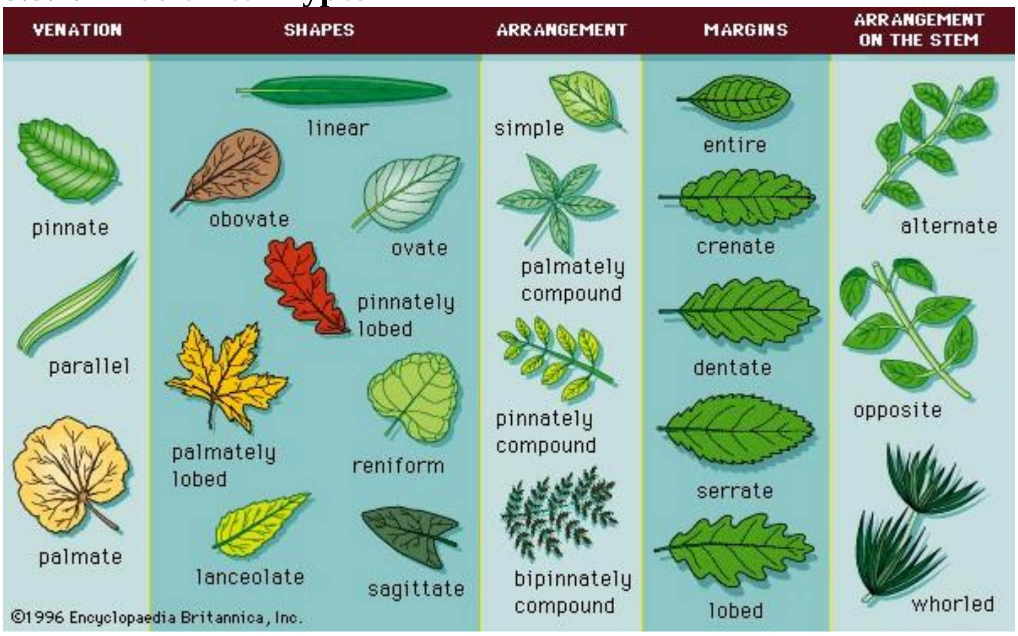

Fig 6.6b Basic diagram of a leaf
(Source: http://masterman535.hubpages.com/hub/Labeled-Diagram-Of-A-Leaf

3.3.1.2. Leaf Arrangements

- **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 counter clockwise, with (depending upon the species) the same angle of divergence.

3.3.1.3. Leaf 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; e.g., *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, Penni parallel — 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.

3.3.1.4. 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. What are the layers of the mesophyll?
Most flowering plants and ferns have a mesophyll layer divided into two sublayers: **(1) palisade layer and (2) spongy layer**. The palisade layer is the upper part of the mesophyll. It is comprised of vertically elongated cells. The spongy layer is located beneath the palisade layer.

Self-Assessment Exercise(s)
With the aid of an annotated diagram, describe the structure of a leaf

Explain the structure of a leaf with the help of a labelled diagram.
Solution: Leaves are vital to the survival of plants. They help plants in a variety of ways, including producing food and oxygen through photosynthesis, balancing water loss, regulating gas exchange, and transporting the products of photosynthesis.
A leaf has two main parts:
(1) Petiole- the stalk that supports a leaf in a plant and attaches the leaf blade to the stem.
(2) Lamina- the green flat part of a leaf that is specialized for photosynthesis. The lamina contains the following parts:
(i) Veins- the lines on the green flat part in a leaf that provide support for the leaf and transport both water and food.
(ii) Midrib- The central, thick, linear vein that runs along the length of a leaf is called midrib.

3.4 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

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Unit 4 Xylem and Phloem Structure of Seed Plants

4.1 Introduction
4.2 Intended Learning Outcomes (ILOs)
4.3 Main Content
    4.3.1. Xylem Structure
    4.3.2. Phloem Structure
4.4 Summary
4.5 References/Further Readings/Web Sources

4.1 Introduction

Understanding the intricate structures and functions of xylem and phloem in seed plants is pivotal to comprehending the complexities of plant physiology. In this lecture, we will embark on an exploratory journey into the world of these vascular tissues, uncovering their vital roles in plant life. From water transport to nutrient distribution, the significance of xylem and phloem cannot be overstated**.**

4.2 Intended Learning Outcomes (ILOs):

By the end of this lecture, you should be able to:
Describe the anatomical features of xylem and phloem.
Explain the functions of xylem and phloem in seed plants.
Understand how xylem and phloem work together to facilitate plant growth and development.

4.3 Main Contents

4.3.1. Xylem structure

The xylem is a complex tissue responsible for transporting water and minerals from the roots to the rest of the plant. It's composed of various cell types, including vessel elements, tracheids, and fibers, each with unique features and functions.

Vessel elements are shorter and wider cells that facilitate rapid water flow. Their wide diameter allows for efficient water transport. Think of them as the express highways of the plant's water transport system.

In contrast, tracheids are narrower, elongated cells. They are efficient at preventing air bubbles from blocking the flow of water. Tracheids are often found in plants that need to transport water against gravity, like tall trees.

For example, in conifers like pine trees, tracheids dominate the xylem structure. This adaptation ensures effective water transport even in cold conditions when air bubbles could be more of a problem. The xylem's intricate design allows it to transport water and minerals efficiently over long distances within the plant. Explain the anatomy of xylem in seed plants, including the types of cells involved (vessel elements, tracheids, etc.). With the help of diagrams or illustrations discuss the functions of xylem, such as water and mineral transport.

4.3.2. Phloem structure

The phloem, on the other hand, transports organic nutrients, primarily sugars, from source to sink. It's composed of specialized cells, including sieve tube members and companion cells.

Sieve tube members are the main transport cells in the phloem. They are elongated and lack many cellular components to facilitate the rapid movement of nutrients. These cells form interconnected tubes that span the entire plant.

Companion cells are closely associated with sieve tube members and play a crucial role in supporting their function. They provide metabolic support and help load sugars into the sieve tube members.

Take the classic example of sugar transport in sugar maple trees. During spring, sugar maple trees draw water from the xylem and transport it to the leaves. Photosynthesis in the leaves produces sugars that are then transported via the phloem to the roots for storage. This process ensures the plant's energy needs are met and that excess sugars are stored for future use. Describe the components of phloem, such as sieve elements, companion cells, and phloem fibers. Explain the role of phloem in transporting organic nutrients (sugars) throughout the plant, utilize visual aids if possible.

Self-Assessment Exercise(s):

To assess your understanding, let's delve into some exercises:
Describe the differences between vessel elements and tracheids in xylem. How do these differences relate to their functions?
Explain the role of sieve tube members and companion cells in phloem transport.

Imagine you're a botanist studying a new plant species. What structural features would you look for in its xylem and phloem to understand its ecological niche?

4.5 Summary

To summarize, xylem and phloem are two critical vascular tissues in seed plants. While xylem specializes in water and mineral transport, phloem excels in moving organic nutrients like sugars. Their structures, vessel elements, tracheid's, sieve tube members, and companion cells, are intricately designed to fulfil these functions efficiently.

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Unit 5 Vascular Cambium and Cork Cambium

Contents

5.1 Introduction

Botany, the study of plants, is a field that encompasses the vast diversity of plant life on Earth. Understanding plant anatomy and growth mechanisms is fundamental to botany. In this lecture, we will explore two essential components of plant growth: vascular cambium and cork cambium.

Vascular cambium is responsible for secondary growth in plants, allowing them to increase in girth over time. This process is vital for the development of trees and shrubs, enabling them to produce wood for support and water-conducting tissues. We will delve into the intricacies of vascular cambium, examining its location, functions, and the types of cells it produces.

On the other hand, cork cambium plays a pivotal role in the protective layers of plant stems and roots. It forms cork, a substance known for its permeability and insulation properties. We will explore the formation of cork, its significance in plants, and how different species have adapted to use cork cambium effectively.

5.2. Intended Learning Outcomes (ILOs):

By the end of this lecture, you should be able to:

- Understand the role of vascular cambium in secondary growth and tissue differentiation.
- Explain the significance of cork cambium in plant development and protection.
- Differentiate between vascular cambium and cork cambium in terms of function and location.

5.3 Main Contents

5.3.1 Vascular Cambium:

a. What is vascular cambium?
Vascular cambium is a meristematic tissue located in the stems and roots of plants. It's responsible for secondary growth, allowing plants to increase in diameter over time.

b. Location:
Vascular cambium is found in a layer known as the cambium ring, which lies between the xylem and phloem tissues.

c. Functions:
Secondary Growth: Vascular cambium is crucial for secondary growth in plants. Unlike primary growth, which increases plant length, secondary growth increases girth.

d. Types of Cells Produced:
Xylem: This type of cell conducts water and minerals from the roots to the rest of the plant. It's essential for structural support.
Phloem: Phloem cells transport organic nutrients, such as sugars, throughout the plant.

e. Factors influencing activity:
Vascular cambium activity is influenced by several factors, including environmental conditions, hormones, and genetic factors. For instance, increased sunlight and warmth can stimulate cambium activity.

f. Examples:
Tree Rings: Tree rings are a visible representation of vascular cambium activity. Each ring corresponds to a year of growth, with lighter rings indicating rapid growth and darker rings slower growth due to adverse conditions.
Woody Plants: Trees, shrubs, and woody vines depend heavily on vascular cambium for their structural integrity and growth.

5.3.2 Cork cambium

A. Process of cork formation:
Cork cambium produces cork cells, which are characterized by their thick walls and waxy substance called suberin. Suberin makes cork cells impermeable to gases and water, providing protection against environmental stressors.

b. Significance of cork in plants:
Protection: The cork layer acts as a protective barrier, shielding the plant from physical damage, pathogens, and extreme weather conditions.

Insulation: Cork's insulating properties help regulate temperature and prevent excessive water loss.

c. Adaptations in different plant species:
Various plant species have adapted cork cambium to suit their unique needs. For example, cork oaks (Quercus suber) produce exceptionally thick cork layers, making them a valuable source of cork for commercial use.

d. Examples:
Cork Oak: The cork oak tree is renowned for its cork production. The bark is carefully harvested, allowing for cork regeneration and sustainable use.

Cacti: Cacti, especially those in arid regions, have cork cambium that assists in water storage and protection from the harsh desert environment.

Self-Assessment Exercise(s)
Now that we've explored vascular cambium and cork cambium in detail, it's time to test your knowledge. Please answer the following questions to assess your understanding of the material.

What is the primary function of vascular cambium in plants, and where is it located?

Describe the significance of cork cambium in protecting plants. Give an example of a plant species that heavily relies on cork cambium for protection.

Differentiate between xylem and phloem in terms of their functions in plant physiology.

How do environmental factors influence vascular cambium activity? Provide an example.

5.4 Summary

To summarize, vascular cambium and cork cambium are two critical components of plant anatomy, each with its unique functions and adaptations.

Vascular cambium is essential for secondary growth in plants, enabling them to increase in diameter. It produces xylem and phloem, vital tissues for water and nutrient transport. The activity of vascular cambium is influenced by environmental factors, hormonal signals, and genetic factors. Tree rings are a visible representation of vascular cambium activity, and woody plants heavily rely on this tissue for structural support and growth.

Cork cambium, on the other hand, is responsible for the formation of cork, a protective layer in the bark of woody plants. Cork cells produced by cork cambium contain suberin, which makes them impermeable to gases and water. This impermeability provides plants with protection against physical damage and extreme environmental conditions. Furthermore, cork's insulating properties help regulate temperature and prevent excessive water loss.

In different plant species, cork cambium has adapted to meet specific needs. For instance, cork oaks (*Quercus suber*) produce exceptionally thick cork layers, making them a valuable source of cork for commercial use. Cacti, which inhabit arid regions, have cork cambium that assists in water storage and protection from the harsh desert environment.

Understanding these structures is vital for botanists and ecologists as it sheds light on plant growth, adaptation, and ecological interactions. It also has practical applications, such as in the sustainable harvesting of cork from cork oak trees for various industrial purposes.

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MODULE 3 LIFE CYCLE OF SEED PLANTS

Module Introduction

Module 3 outlines the life cycle of seed plants, it discusses Reproduction in Gymnosperms, Angiosperms, development of Gametophyte and fruits in Angiosperms. The module consists of four units as shown below.

Unit 1 Generalized Life Cycle of Seed Plants

Contents

1.1 Introduction

We have generally learnt about the Spermatophytes: their classification, divisions, origin, and evolution in module 1. In this unit, we shall be considering the life cycle of seed plants particularly the mode of reproduction in gymnosperms, Micro and megasporangia, pollination and fertilization in Gymnosperms.

1.2 Intended Learning Outcomes (ILOs)

At the end of this unit, you would 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

1.3 Main Contents

1.3.1. 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 as modified (Fig 2.1) illustrate plants which have separate male and female gametophytes (***megagametophyte*** and ***microgametophyte***) produced by different sized spores (***megaspores*** and ***microspores***).

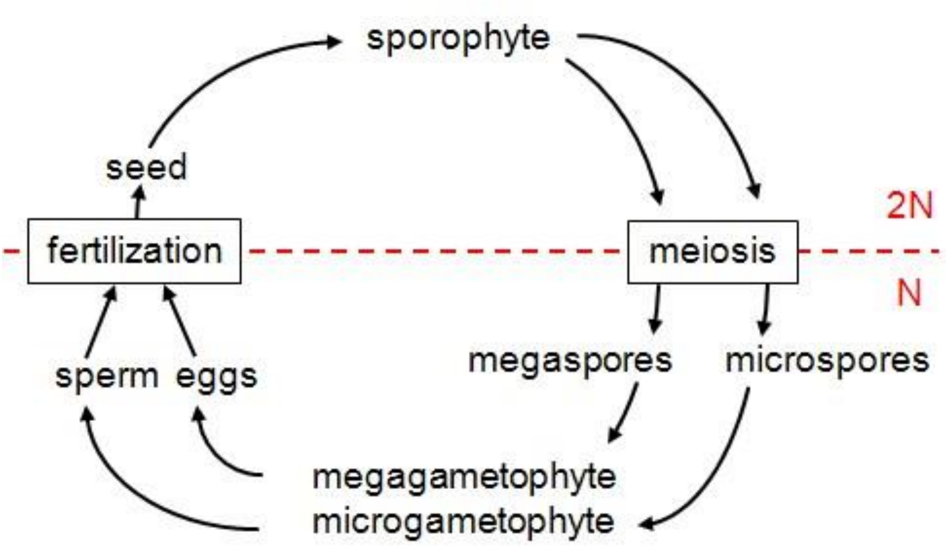

Fig 3.1 Generalised life cycle of a seed plant
(Source:http://en.wikipedia.org/wiki/seedplant) and
https://www.youtube.com/watch?v=752YhVLYWro
Seeds and the Life Cycle of Plants - YouTube
https://www.youtube.com › watch

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.

1.3.2 Reproduction in Gymnosperm (PINE)

Gymnosperm is one of the two classes of seed plants that produces cones. They produce naked seeds on their microsporophyll.

MICROSPORANGIA AND MEGASPORANGIA

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

Case studies: In Fig 3.2 below, in pine, microsporangium is found within pollen cones. Why are seed plants heterosporous?

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

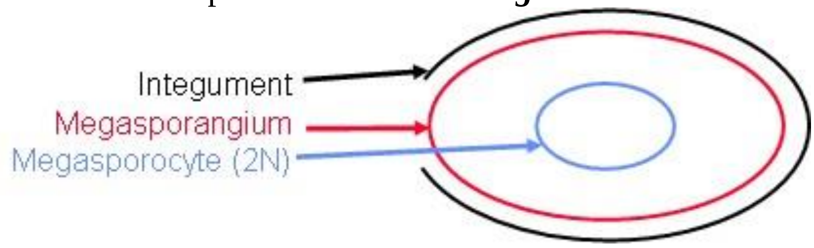

Fig 3.3a Diagrammatic structure of an ovule

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

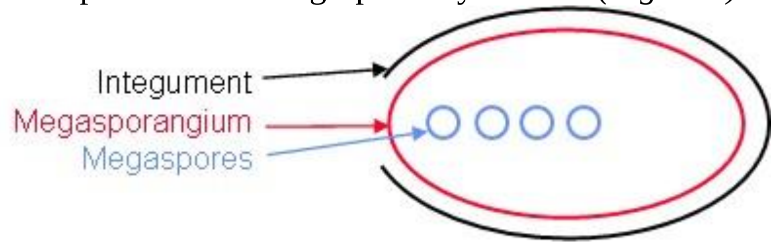

Fig 3.3b Megasporocyte containing four megaspore

Three of the megaspores die (fig 3.3c)

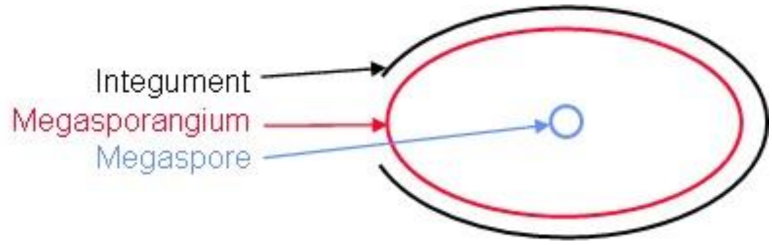

Fig 3.3c Megasporocyte containing only one megaspore

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

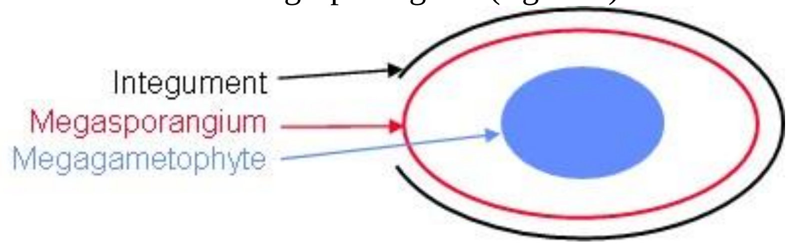

Fig 3.3d Megasporangium containing the gametophyte

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

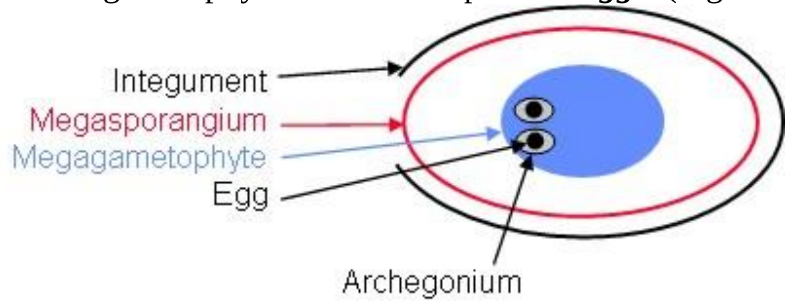

Fig 3.3e Eggs formation by the gametophyte

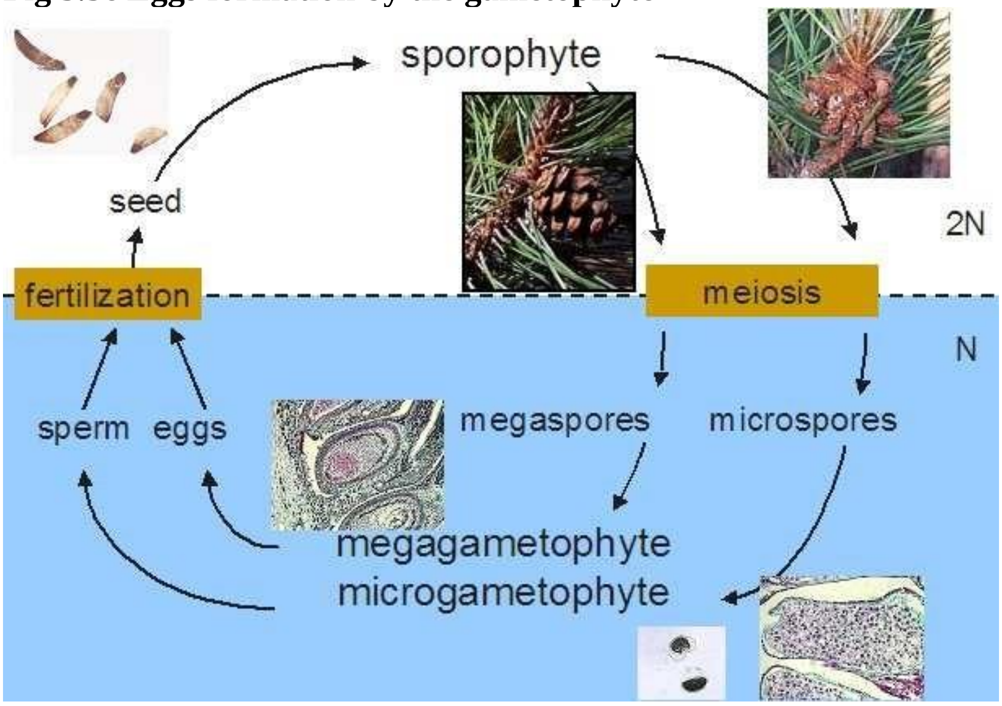

Fig 3.4. Diagrammatic illustration of Pine life cycle

(Source: http://en.wikipedia.org/wiki/seedplant) and

Seeds and the Life Cycle of Plants - YouTube
https://www.youtube.com › watch

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

1.3.3 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). **Describe Pollination and Fertilization in Gymnosperms**
produced by the generative cell enter the pollen tube and move toward the egg.

Self-Assessment Exercise(s)
With the aid of a diagram, describe the life cycle of a named gymnosperm

Answer:
Life Cycle of a Conifer
Pine trees are monoecious conifers, bearing both male and female sporophylls on the same plant. They are heterosporous, producing male microspores and female megaspores. Male cones release pollen, which, when reaching female cones, initiates pollen tube growth. Fertilization occurs as one sperm nucleus unites with the egg nucleus.
Female cones contain two ovules, each with a micropyle for pollen tube growth. One surviving megaspore develops into a female gametophyte, trapping pollen grains with a sticky drop. Fertilization results in a diploid embryo encased in a seed coat. This process can take up to two years.

The conifer life cycle involves a lengthy sporophyte phase (2n), with reduced-sized gametophytes (1n) produced from microspores and megaspores. Pollen tube growth allows female gametophyte development, leading to egg production.

1.4 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

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Unit 2 Reproduction in Angiosperms

Contents

2.1 Introduction

In the last unit we studied General life cycle of seed plant and reproduction in Gymnosperms. 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.

2.2 Intended Learning Outcomes (ILOs)

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

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

2.3 Main Content

2.3.1 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

2.3.2. 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***.

2.3.2.1. 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:

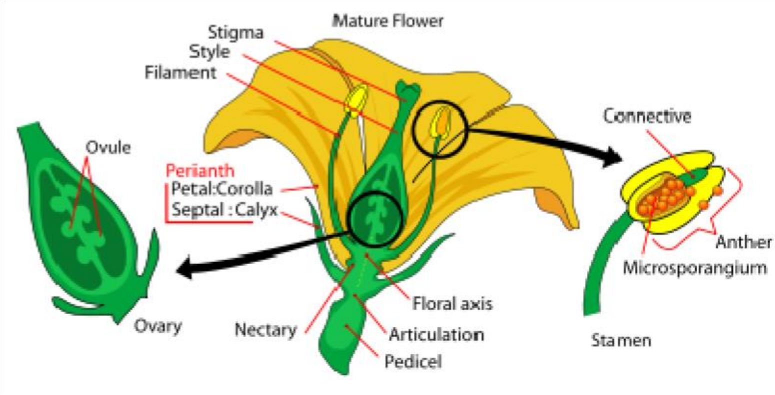

Fig 4.1 Diagram showing the main parts of a mature flower
(Source: http://en.wikipedia.org/wiki/Flower)
Question: what is a flower?

2.3.2.2 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.

"Floral structures in plants vary significantly from the typical plan described above, which has implications for the evolution of flowering plants and botanical classification. For instance, dicotyledons typically have 4 or 5 floral organs in each whorl, while monocotyledons have three or multiples of three. Some plants may have only two carpels in a compound pistil, deviating from this generalization.

Flowers are often classified as perfect (having both pistils and stamens), imperfect (having only male or female parts), or unisexual. If a plant has exclusively male or female flowers, it's dioecious, whereas monoecious plants have both male and female flowers on the same plant. Composite flowers with multiple flowers on an axis are called inflorescences.

In botanical terms, a single daisy or sunflower is not a flower but a flower head composed of numerous tiny florets, each with the described anatomy. Flowers can be regular (symmetrical when bisected) like roses or trillium, or irregular (zygomorphic) like snapdragons or most orchids."

2.3.2.3. 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)
C2o = 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: **Ca5Co5A10 - ∞G1**
Question: what is a floral formula?

2.3.2.4. 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*.

a. Pollination Attraction Methods

Plants cannot 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 attarcted 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.

b. 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.

2.3.2.5 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 colour and flavour 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 is infused into tea both for their fragrance and medical properties. Sometimes, they are also mixed with tea leaves for the added fragrance.

2.3.3 Asexual Reproduction in Angiosperms

- **Stems**
  New plants can grow from horizontal stems.
  Aboveground horizontal stems are called stolons (runners).

Fig 4.10b Stolon of a bermudagrass (stolons located above the soil surface)

(Source: http://www.pssc.ttu.edu/pss1321/Web%20topics/cpa1.htm)
Underground horizontal stems are called rhizomes.

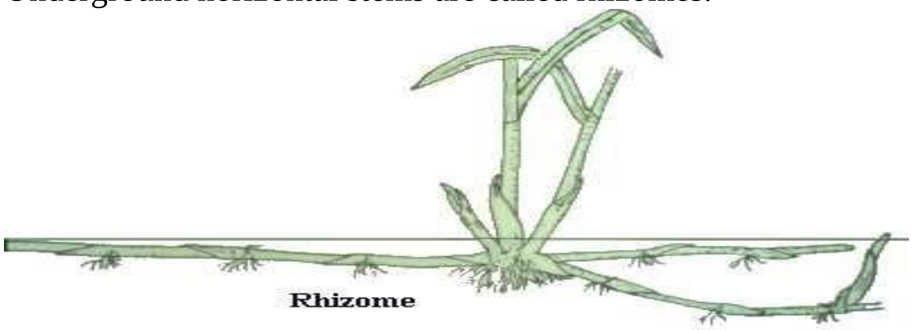

Fig 4.10c Rhizome of a bermudagrass (horizontal underground stem)
(Source: http://www.pssc.ttu.edu/pss1321/Web%20topics/cpa1.htm)
White potatoes are underground stems. The eyes are buds and can be used to produce new plants.

- **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.

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.

2.3.4 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.

2.3.4.1.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.

Self-Assessment Exercise(s)
Outline the importance of flowers to seed plants

Answer: The Functions of Flowers
One of the most critical functions of flowers is pollination. The pollen of the flower comes from the stamen and contains the gamete, the male reproductive organ. Once pollination has taken place, the male pollen is transferred to the female structures called the pistil and stigma.

Some plants have flowers with stigma and pollen. This allows them to pollinate themselves. Others, on the other hand, have only pistils, or even stamens. Pollen can pass from flower to flower through insects such as bees, and through the air. Generally, brightly colored and highly fragrant flowers depend on insects for pollination. Their appearance also attracts them.

Flowers constitute the most attractive part of the plant, without which we would only see green leaves. When birds and insects come near the flower, they extract their nectar. In this way, they pollinate the plants, moving sperm from the male stamens to the female pistils

2.What structure of the flower is involved in reproduction?

Answer: What part of the flower is involved in reproduction?

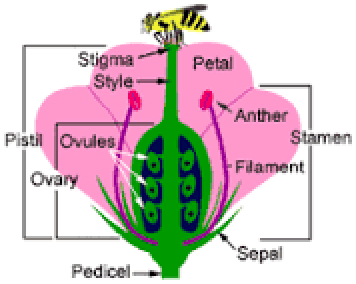

Figure 19. Complete flower structure

As a plant's reproductive part, a flower contains a **stamen (male flower part) or pistil (female flower part)**, or both, plus accessory parts such as sepals, petals, and nectar glands (Figure 19). The stamen is the male reproductive organ. It consists of a pollen sac (anther) and a long supporting filament

3.Define the followings: parthenocarpy; inflorescence

Answer : Parthenocarpy is the development of fruit without the formation of seeds due to lack of pollination, fertilization and embryo development.
The condition can be artificially induced by the application of hormones.
Such fruits are seedless.
Example: Grapes, Banana, Oranges
While
Answer : An inflorescence is **a group or cluster of flowers arranged on a stem that is composed of a main branch or a complicated arrangement of branches**. Morphologically, it is the modified part of the shoot of seed plants where flowers are formed on the axis of a plant.

2.4 Summary

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

- Angiosperms are classified into monocot and dicot
- The life cycle of flowering plants involves 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 contains the microsporangium which produces the microspores
- Ovules are structures that will become the seeds
- All 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 what is a cleistogamous flower?

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https://www.britannica.com/plant/angiosperm/Reproduction

Unit 3 Development of Gametophytes

Contents

3.1 Introduction

In the last unit we studied General life cycle of seed plant and reproduction in Gymnosperms. 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.

3.2 Intended Learning Outcomes (ILOs)

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

- Explain how Gametophyte developed in angiosperms
- Explain embryonic development
- Describe mega and microsporangium
- Describe pollen grain
- Explain pollination and fertilization in angiosperms

3.3 Main Content

3.3.1 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.

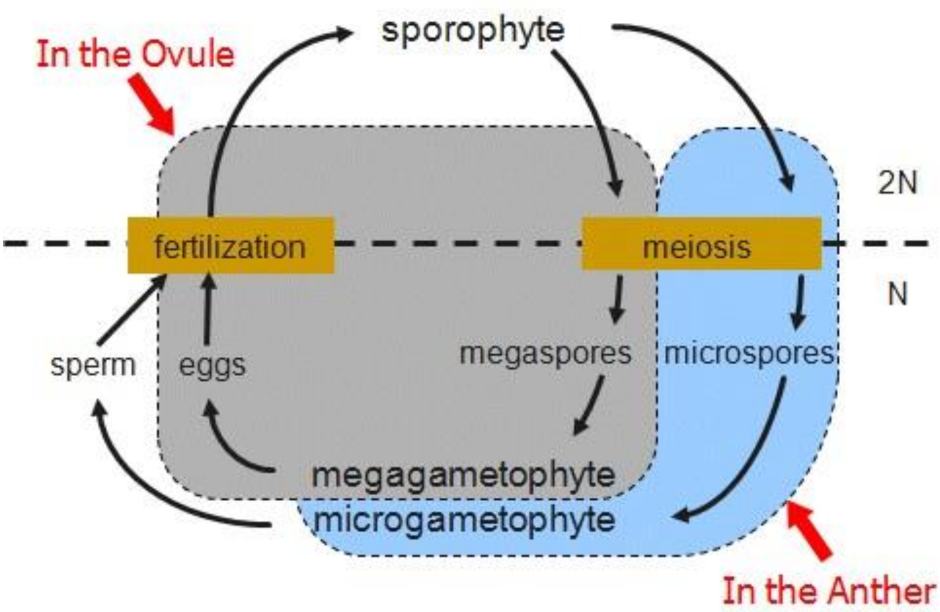


Fig 4.6 Diagrammatic Illustration of the Life Cycle of an Angiosperm
(Source: http://wikipedia.org/wiki/seedplant) and

a. 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.

b. 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 the seed coat.

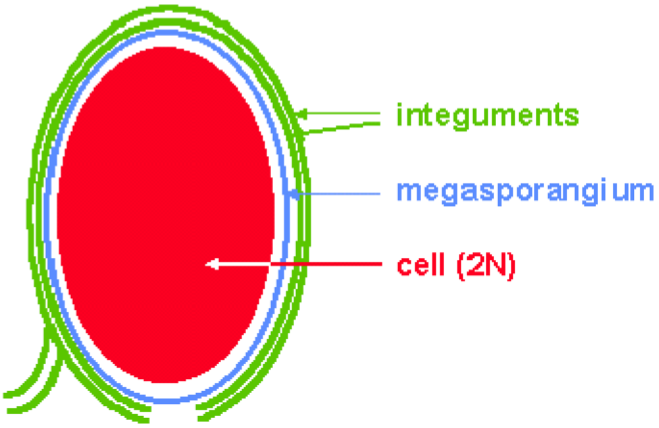


Fig 4.7a Ovule of an angiosperm plant (http://wikipedia.org/wiki/seedplant)

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

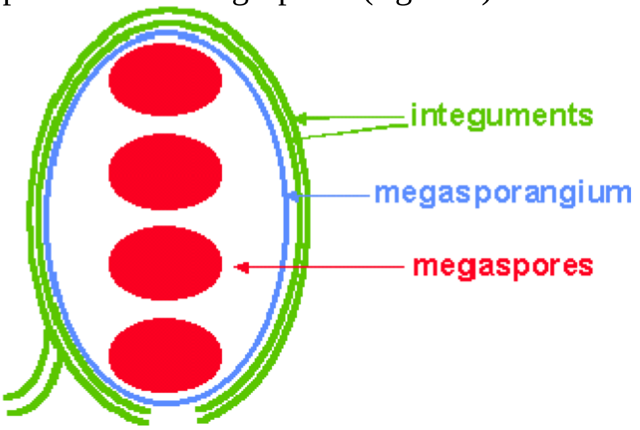


Fig 4.7b Ovule

Three of the megaspores disintegrate.(fig 4.7c)

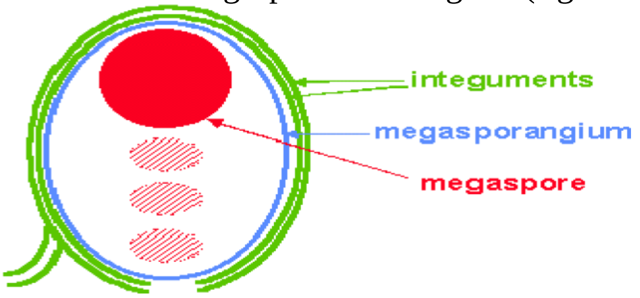
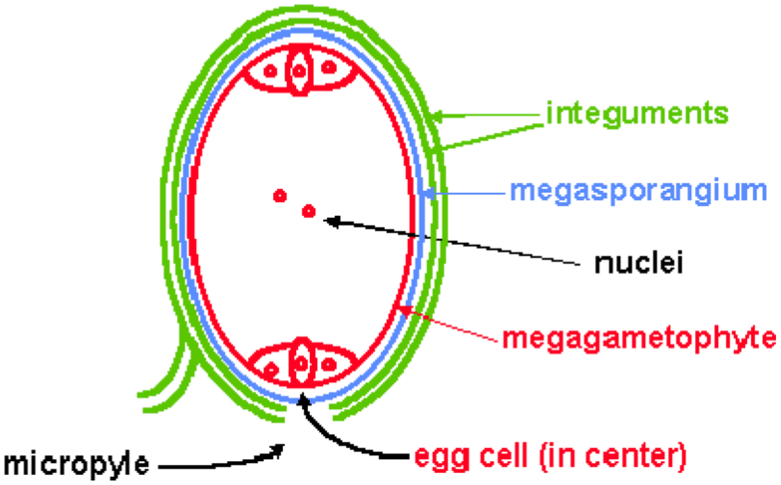


Fig 4.7c Ovule

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.



c. **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.

d. **Pollen**

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***.

In-Text Questions (ITQs)

Question: using diagram where necessary, describe the formation of a megasporangium

Answers: 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 the seed coat.

3.3.2 Pollination and Fertilization in Angiosperms

a. **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.

b. Fertilization

Double fertilization in angiosperms

After pollen is deposited on the stigma, it must germinate and grow through the style to reach the ovule. The microspores, or the pollen, contain two cells: the pollen tube cell and the generative cell. The pollen tube cell grows into a pollen tube through which the generative cell travels. The germination of the pollen tube requires water, oxygen, and certain chemical signals. As it travels through the style to reach the embryo sac, the pollen tube's growth is supported by the tissues of the style. During this process, if the generative cell has not already split into two cells, it now divides to form two sperm cells. The pollen tube is guided by the chemicals secreted by the synergids present in the embryo sac; it enters the ovule sac through the micropyle. Of the two sperm cells, one sperm fertilizes the egg cell, forming a diploid zygote; the other sperm fuses with the two polar nuclei, forming a triploid cell that develops into the endosperm. Together, these two fertilization events in angiosperms are known as double fertilization. After fertilization is complete, no other sperm can enter. The fertilized ovule forms the seed, whereas the tissues of the ovary become the fruit, usually enveloping the seed.

Figure 32.2D.132.2D.1: Double fertilization: In angiosperms, one sperm fertilizes the egg to form the 2n zygote, while the other sperm fuses with two polar nuclei to form the 3n endosperm. This is called a double fertilization.

Self-Assessment Exercise(s)

1. Describe Double Fertilization in Angiosperms

Answer: Double Fertilization in Angiosperms

After pollen is deposited on the stigma, it must germinate and grow through the style to reach the ovule. The microspores, or the pollen, contain two cells: the pollen tube cell and the generative cell. The pollen tube cell grows into a pollen tube through which the generative cell travels. The germination of the pollen tube requires water, oxygen, and certain chemical signals. As it travels through the style to reach the embryo sac, the pollen tube's growth is supported by the tissues of the style. During this process, if the generative cell has not already split into two cells, it now divides to form two sperm cells. The pollen tube is guided by the chemicals secreted by the synergids present in the embryo sac; it enters the ovule sac through the micropyle. Of the two sperm cells, one sperm fertilizes the egg cell, forming a diploid zygote; the other sperm fuses with the two polar nuclei, forming a triploid cell that develops into the endosperm. Together, these two fertilization events in angiosperms are known as double fertilization. After fertilization is complete, no other sperm can enter. The fertilized ovule forms the seed, whereas the tissues of the ovary become the fruit, usually enveloping the seed.

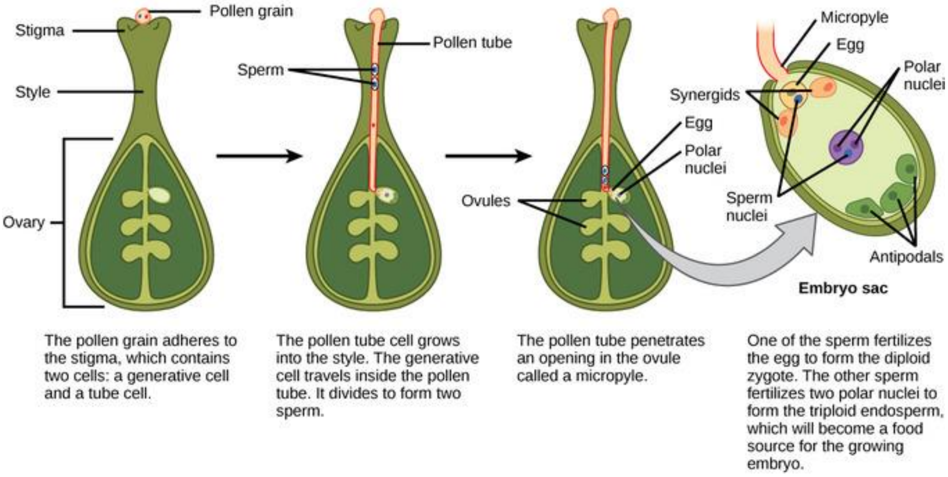
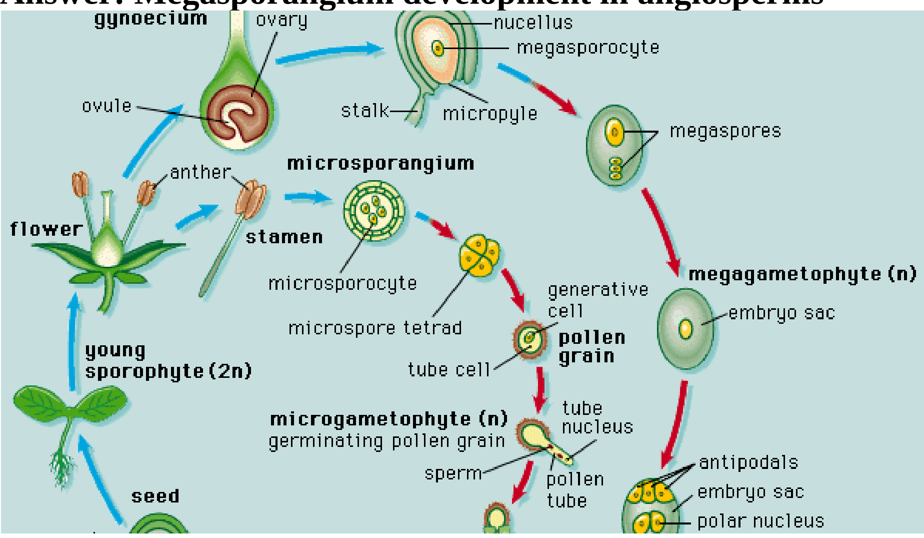


Figure 32.2D.132.2D.1: Double fertilization: In angiosperms, one sperm fertilizes the egg to form the 2n zygote, while the other sperm fuses with two polar nuclei to form the 3n endosperm. This is called a double fertilization.

2.In the development of gametophytes in angiosperms, describe the events that happens in the megasporangium

Answer: Megasporangium development in angiosperms



angiosperm life cycle

Figure 16: Typical angiosperm life cycle (see text).
Encyclopædia Britannica, Inc.

3.4 Summary

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

- The ovary and the anther represent the female and the male reproductive structures, respectively.
- A ***sporangium*** is a structure that produces spores
- An anther has 4 microsporangia (pollen sacs) and each contains many ***microsporocytes*** that will divide by meiosis to produce 4 ***microspores*** each.
- Pollen contains two nuclei, a generative nucleus and a tube nucleus
- ***Pollination*** is the transfer of pollen to the stigma
- Angiosperms carry out double fertilization
- Stamens are composed of an anther and a filament which are the male reproductive parts
- The anther contains the microsporangium which produces the microspores
- Ovules are structures that will become the seeds

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Unit 4 Fruits Development in Angiosperms

Contents

4.1 Introduction

Angiosperm Fruit

The fruit may be defined as a fertilized, ripened or developed ovary. Inside the ovary is one or more ovules where the megagametophyte contains the mega gamete or egg cell. Fruits and seeds develop from flowers after completion of two processes namely pollination and fertilization. After fertilization, the ovary develops into fruit. The ovary wall develops into the **fruit wall called pericarp** and the ovules inside the ovary develop into **seeds**. The branch of horticulture that deals with study of fruits and their cultivation is called ***pomology***.

Fertilization acts as a stimulus for the development of ovary into fruit. But there are several cases where ovary may develop into fruit without fertilization. This phenomenon of development of fruit without fertilization is called **parthenocarpy** and such fruits are called parthenocarpy fruits. These fruits are necessarily seedless. eg. ***Banana, grapes, pineapple*** and ***guava*** etc.

Fruits are classified into two main categories, **- true and false fruits. True Fruit**: A fruit is termed as being true when it develops from the ovary alone. eg. ***Tomato, Brinjal, Pea, Mango, Banana*** etc. **False Fruit**: **(Pseudocarp):** When a fruit develops from the receptacle and other floral parts it is termed false fruit. eg. ***Apple*** (edible part of the fruit is the fleshy receptacle), cashew.

4.2 Intended Learning Outcomes (ILOs)

At the end of this unit, you would be able to

- Explain development of fruit in angiosperms
- Discuss the structure of fruits
- Analyse the different types of fruits
- Give the classification of fruits
- Explain dissemination and dispersal of fruits

4.3 Main Content

4.3.1 Fruit Development

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. In some multisided fruits, the extent to which the flesh develops is proportional to the number of fertilized ovules.

4.3.2. Structure of Fruit

A fruit consists of two main parts **- the seeds and the pericarp or fruit wall**. The structure and thickness of pericarp varies from fruit to fruit. The **pericarp** consists of three layers - outer **epicarp**, middle **mesocarp** and inner **endocarp**. The sweet juicy and edible flesh is the mesocarp, the inner most hard covering is the endocarp. These three layers are not easily distinguishable in dry fruits.

4.3.3. 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 fruits**
2) **Aggregate fruits**
3) **Multiple or composite fruits**.

1. Simple fruits

When a single fruit develops from a single ovary of a single flower, it is called **simple fruit**. The ovary may be monocarpellary or multicarpellary syncarpous. On the nature of pericarp, simple fruits are divisible into two types;

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).

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)
- nut – (hazelnut, beech, oak acorn)
- samara – (elm, ash, maple key)
- schizocarp – (carrot seed)
- silique – (radish seed)
- silicle – (shepherd's purse)
- utricle – (beet)
- 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)

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2. Simple Fleshy Fruits

In these fruits either the entire pericarp or part of the pericarp is succulent and juicy when fully ripe. Normally the fruit wall may be differentiated into three layers **-** an outer **epicarp**, a middle **mesocarp** and an inner **endocarp**. As a general rule, the fleshy fruits are indehiscent. Fleshy fruits are broadly divided into berry, drupe, hesperidium, pepo and pome,

a) **BERRY**: It is a many seeded fruits. These are formed from a single or syncarpous pistil. They usually have axile or parietal placentation. The pericarp can be differentiated into the epi, meso, and fleshy endocarp. e.g Tomatoes, garden eggs etc.

b) **DRUPE**: This is normally a one-seeded fruit. In these fruits the pericarp is differentiated into an outer skinny epicarp, a middle fleshy and juicy mesocarp and an inner hard and stony endocarp. Drupes are called **stone fruits** because of the stony hard endocarp. The endocarp encloses a single seed. The edible portion, of the fruit is the fleshy mesocarp eg. ***mango***. In coconut, the mesocarp is fibrous, the edible part is the endosperm.

c) **HESPERIDIUM**: It is a kind of baccate fruit that develops from a superior multi-carpellary and syncarpous ovary. The fruit wall is differentiated into three layers **- an outer glandular skin** or **epicarp**, a **middle fibrous mesocarp**, and an **inner membranous endocarp**. The latter divides the fruit chamber into a number of compartments. The seeds arise on axial placentae and are covered by juicy hairs or outgrowths from the placentae that are edible. It is characteristic fruit of the genus ***Citrus***

d) **PEPO**: A large fleshy fruit developing from a tricarpellary, syncarpous, unilocular and inferior ovary with parietal placentation. The fruit is many seeded with pulpy interior; eg. **Cucumber, Melon, Bottle gourd** etc.

e) **POME**: It is a fleshy and a false fruit or Pseudocarp. It develops from a multicarpellary syncarpous inferior ovary in which the receptacle also develops along with the ovary to become fleshy and enclosing the true fruit. The true fruit containing seeds remains inside. The edible part is fleshy thalamus. eg. **Apple, Pear** etc

3. Simple Dry Fruits

These fruits have dry pericarp, which is not distinguished into three layers. The dry simple fruits are further divided into three types;

(A) **Dehiscent**
(b) **Schizocarpic**
(c) **Indehiscent**

4. Dry Dehiscent Fruits

These are fruits that the pericarp breaks open when mature to release their seeds. They include the following;

1. **legume**: A dehiscent dry fruit produced from a monocarpellary, superior ovary, which dehisces from both the sutures into two valves. e.g. **Pea**
2. **follicle**: A dehiscent dry fruit produced from a monocarpellary, superior ovary, which dehisces from one suture only. e.g. ***Calotropis***.
3. **siliqua**: A dehiscent dry fruit produced from a bicarpellary, syncarpous, superior, ovary, which is unilocular but appears bilocular due to false septum. Fruits dehisce along both the sutures from base to apex and large number of seeds remain attached to the false septum called **replum**. e.g. ***Brassica***
4. **Capsule**: A dehiscent dry fruit produced from syncarpous, superior or inferior ovary which dehisces along two or more lines of suture in various ways

Schizocarpic Dry Fruits

Here, the pericarp splits into one seeded part. They include the following; **Lomentum**, **Cremocarp** and **Regma**

a. **Lomentum**: Fruit is similar to a legume but constricted between the seeds. Dehiscing sutures are transverse. The fruit splits into one-seeded indehiscent compartments at maturity; eg. ***Tamarindus, Cassia fistula***

b **Cremocarp**: Fruit is produced from a bicarpellary, syncarpous, bilocular and inferior ovary. It is a two-seeded fruit which splits longitudinally into two indehiscent mericarps which remain attached to a thread-like carpophore. eg. **Coriandrum**

c. **Regma**: The fruit is produced from a bi- or multicarpellary, syncarpous and superior ovary, it breaks up into as many segments or cocci as there are carpels; eg. ***Ricinus***.

5. Dry Indehiscent Fruits

These are fruits that do not split open to release their seeds. They include the Achne, Caryopsis, nut, cypsela and samara.

a. **Achene**: A small, indehiscent one seeded fruit developing from a monocarpellary ovary and in which the pericarp is hard, leathery and remains free from seed coat; e.g. ***Mirabilis, Clematis***.

b. **Caryopsis**: A small, indehiscent and one seeded fruit developing from a monocarpellary ovary and in which the pericarp is fused with the seed coat. The seed completely fills the chamber; eg. **Paddy, Maize**

c. **Cypsela**: The fruit is produced from bicarpellary, syncarpous and inferior ovary with persistent calyx forming the ‘pappus’. It contains only one seed. The pericarp and seed coat remain free; eg. ***Tridax, Helianthus***.

d **Nut**: A large, indehiscent, one-seeded fruit that develops from a bi- or multicarpellary ovary. The fruit wall becomes hard, stony or woody at maturity; etc. **Cashew nut**

e. **Samara**: A dry indehiscent, one-seeded winged fruit developing from bicarpellary, syncarpous ovary. The wing is a modified outgrowth of pericarp; e.g. **Acer**

6. 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 *aggregateaccessory* 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.

3.7. 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.

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). What is the difference between a fruit and a seed?

4.3.4 CLASSIFICATION OF FRUITS – A SUMMARY

- **Simple fruit** (formed from a monocarpous or syncarpous pistil)
  - **Fleshy fruits** (have succulent parts)
    - Drupe e.g Mango
    - Berry e.g Tomatoes
    - Pepo e.g Melon
    - Pome e.g Avocado pear
  - **Dry fruits** (Lack succulent parts, have dry pericarp
    - **Dry Indehiscent fruits** (One seeded, no splitting of pericarp)
      - Caryopsis e.g Maize
      - Achene e.g Sunflower
      - Nut e.g Cashew
      - Cypsela e.g *Tridax*
      - Samara e.g *Combretum*
    - **Dry Dehiscent fruits** (The pericarp splits)
      - Follicle e.g *Calotropis*
      - Legume e.g Bean pod
      - Capsule e.g Okro
      - Siliqua e.g *Tecoma*
      - Scizocarp e.g *Desmodium*
- **Aggregate fruit** (formed from any apocarpous pistil)
- **Multiple fruit** (formed from an inflorescence)

What is the difference between a fruit and a seed?

4.3.5. Seed Dissemination/Dispersal

Fruit structures vary depending on seed dispersal methods: animals, wind, water, or explosive dehiscence (Capon, 2005). Some fruits have protective features like spikes or burrs to deter animals or hitch rides on them, e.g., cocklebur and unicorn plant (Heiser, 2003).

Many fruits appeal to animals for seed dispersal, allowing seeds to be carried away. Nuts are favored by rodents like squirrels, which bury them for winter (McGee, 2004).

Wind disperses fruits naturally, like maple and dandelion seeds. Coconut fruits can float long distances in water, spreading seeds (Capon, 2005).

Certain fruits use explosive mechanisms for dispersal, e.g., sandbox tree and squirting cucumber (Feldkamp, 2002).

4.3.6. 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.

Self-Assessment Exercise(s)
Explain Simple Fleshy fruits in angiosperms

Answer: Simple Fleshy Fruits
In these fruits either the entire pericarp or part of the pericarp is succulent and juicy when fully ripe. Normally the fruit wall may be differentiated into three layers - an outer **epicarp**, a middle **mesocarp** and an inner **endocarp**. As a general rule, the fleshy fruits are indehiscent. Fleshy fruits are broadly divided into berry, drupe, hesperidium, pepo and pome,

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4.4 Summary

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

- 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
- A fruit consists of two main parts **- the seeds and the pericarp or fruit wall**. The structure and thickness of pericarp varies from fruit to fruit
- There are three basic types of fruits **Simple fruits, Aggregate fruits, Multiple or composite fruits**.
- Fruits are classified in to simple, aggregate and multiple fruits
- 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

- Dispersal of fruits are based on their structures and their the type

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UNIT 5 ANATOMY OF THE DIFFERENT ORGANS OF SEED PLANTS

CONTENTS

5.1 Introduction

You have studied secondary growth, tissues and tissue systems, xylem and phloem, vascular cambium and cork cambium in the previous units. In this unit, you will learn the anatomy of the different organs of seed plants, the root, the stem and the leaf

5.2 Intended Learning Outcomes (ILOs)

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

- Explain the internal structure of root, stem and leaf
- Discuss the epidermis tissue
- Explain the role of mesophyll in leaf

5.3 Main Content

5.3.1 Anatomy of root

a. Dicotyledonous Root

Look at Figure 6.6 (a) below, it shows the transverse section of the sunflower root. The internal tissue organization is as follows:
The outermost layer is epiblema. Many of the cells of epiblema protrude in the form of unicellular root hairs. The cortex consists of several layers of thin-walled parenchyma cells with intercellular spaces. The innermost layer of the cortex is called endodermis. It comprises a single layer of barrel-shaped cells without any intercellular spaces. The tangential as well as radial walls of the endodermal cells have a deposition of water-impermeable, waxy material suberin in the form of casparian strips. Next to endodermis lies a few layers of thick-walled

parenchymatous cells referred to as pericycle. Initiation of lateral roots and vascular cambium during the secondary growth takes place in these cells. The pith is small or inconspicuous. The parenchymatous cells which lie between the xylem and the phloem are called conjunctive tissue. There are usually two to four xylem and phloem patches. Later, a cambium ring develops between the xylem and phloem. All tissues on the inner side of the endodermis such as pericycle, vascular bundles and pith constitute the stele.

b. Monocotyledonous Root

The anatomy of the monocot root is similar to the dicot root in many respects (Figure 6.6 b). It has epidermis, cortex, endodermis, pericycle, vascular bundles and pith. As compared to the dicot root which have fewer xylem bundles, there are usually more than six (polyarch) xylem bundles in the monocot root. Pith is large and well developed. Monocotyledonous roots do not undergo any secondary growth.

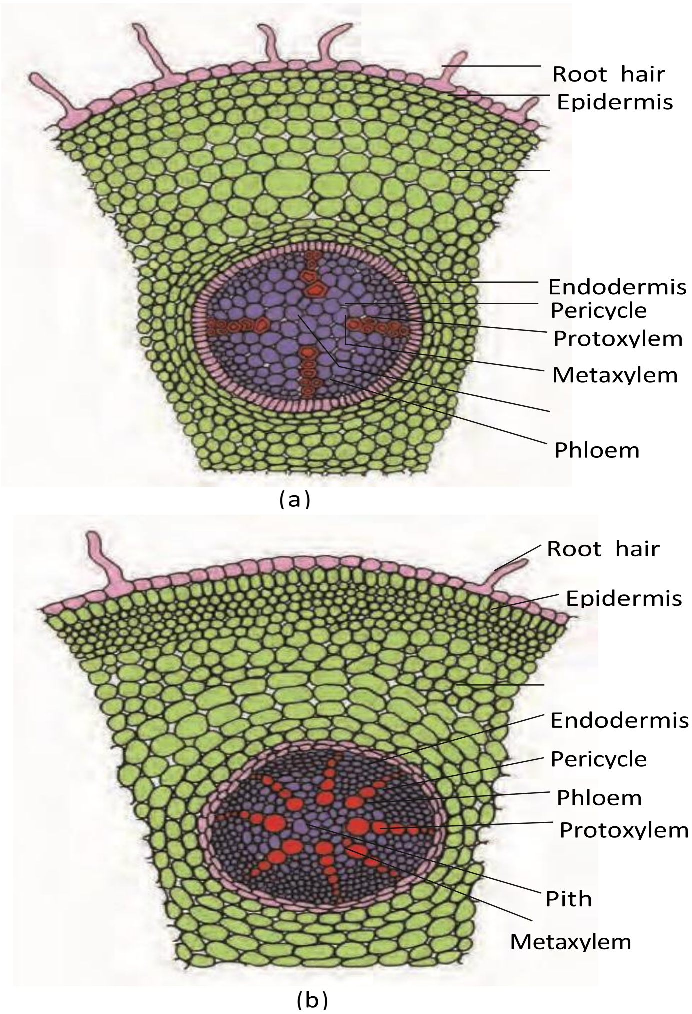

Figure 6.6T.S. : (a) Dicot root (Primary) (b) Monocot root

5.3.2 Anatomy of stem

The anatomy of stem consists of vascular tissues and the vascular cambium.

1 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.

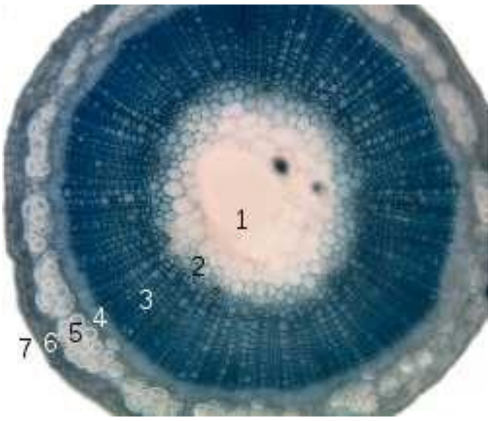

Fig 4.3 Cross-section of a flax plant stem:
1. Pith, 2. Protoxylem, 3. Xylem I, 4. **Phloem** I, 5. Sclerenchyma (bast fibre), 6. Cortex,
7. Epidermis
(Source: http://en.wikipedia.org/wiki/stem)

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.

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.

Phloem Structure

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

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.
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.

Functions of Phloem

The phloem, unlike xylem, consists of living cells that transport sugar-rich sap created in photosynthetic areas. This sap moves from sugar sources (e.g., leaves) to sugar sinks (e.g., roots or storage organs) through turgor pressure.

Ernst Munch's Pressure Flow Hypothesis (1930) explains phloem translocation. It involves a diffusion gradient created by a high concentration of organic substances in source cells, drawing water in for bulk flow. Movement in the phloem is bidirectional.

During growth, storage organs like roots are sources, while growing areas are sinks. After growth, leaves become sources, and storage organs are sinks. The movement can be multi-directional, with sap in adjacent tubes flowing in opposite directions.

Unlike xylem driven by negative pressure, phloem relies on positive hydrostatic pressure for translocation. It involves phloem loading (sugar source cells actively transport solutes into sieve tubes) and unloading (sugar sinks remove solutes), creating pressure for sap movement.
Some plants use the polymer trap mechanism, where sugars are polymerized before entering sieve tubes. Symplastic phloem loading is primitive, found in tropical rainforest plants. Apoplastic phloem loading is advanced, seen in temperate and arid conditions, possibly aiding colonization in cooler locations.

Phloem transports organic molecules like sugars, amino acids, hormones, and messenger RNAs.

2. **Vascular Cambium**

The vascular cambium is a lateral meristem in plant vascular tissue, responsible for secondary growth of secondary xylem (inwards) and secondary phloem (outwards). It's located between these tissues in stems and roots. Some leaves also have a vascular cambium (Ewers, 1982).

The vascular cambium consists of two cell types: fusiform initials (tall, axially oriented cells) and ray initials (smaller, round to angular cells).

Vascular cambium is a meristem tissue, where embryonic cells give rise to differentiated plant tissues. Apical meristems are primary meristems on root and shoot tips. Another lateral meristem is cork cambium, producing cork as part of the bark.

Vascular cambia exist in dicots and gymnosperms but not monocots, which usually lack secondary growth.
For successful grafting, align the vascular cambia of stock and scion for growth together.

Cork cambium is part of the periderm in many vascular plants, replacing epidermis in roots and stems. It's a lateral meristem found in woody and some herbaceous dicots, gymnosperms, and some monocots lacking secondary growth.

Cork cambium is one of the plant's meristems, producing cork for protection. Synonyms include bark cambium, pericambium, or phellogen, which develops the periderm, including phelloderm and phellem (cork).

Cork cambium's growth varies by species and age, influenced by conditions, resulting in different bark textures.

5.3.3. Anatomy of 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)

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.

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**.** Name the different tissues found in leaves

5.3.3.1Leave 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.

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.

5.3.3.2 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.

Self-assessment question:
Explain the structures of leaf epidermis

Answer:

The epidermis is a multi-layered cell group on a leaf's surface, serving various roles. It forms a protective boundary separating inner plant cells from the external environment. Key functions include preventing water loss, regulating gas exchange, secreting metabolic compounds, and, in some species, absorbing water.

The epidermis is typically transparent and has a waxy cuticle on its outer side to prevent water loss. In drier climates, the cuticle is thicker on the leaves' upper epidermis. Differentiated cell types within the epidermis include epidermal cells, guard cells, subsidiary cells, and epidermal hairs (trichomes). Among these, epidermal cells are the most common and least specialized. Stomata, small pores surrounded by chloroplast-containing guard cells and subsidiary cells without chloroplasts, are found on the epidermis. They regulate gas and water vapor exchange between the leaf interior and the outside air, with more stomata typically located on the lower epidermis."

a. The Tissues

A tissue is a group of cells having a common origin and usually performing a common function. A plant is made up of different kinds of tissues. Tissues are classified into two main groups, namely, meristematic and permanent tissues based on whether the cells being formed are capable of dividing or not.

b. The Tissue System

We were discussing types of tissues based on the types of cells present. Let us now consider how tissues vary depending on their location in the plant body. Their structure and function would also be dependent on location. On the basis of their structure and location, there are three types of tissue systems. These are the epidermal tissue system, the ground or fundamental tissue system and the vascular or conducting tissue system.

c. Epidermal Tissue System

The epidermal tissue system forms the outer-most covering of the whole plant body and comprises epidermal cells, stomata and the epidermal appendages – the trichomes and hairs. The epidermis is the outermost layer of the primary plant body. It is made up of elongated, compactly arranged cells, which form a continuous layer. Epidermis is usually single layered. Epidermal cells are parenchymatous with a small amount of cytoplasm lining the cell wall and a large vacuole. The outside of the epidermis is often covered with a waxy thick layer called the cuticle which prevents the loss of water. Cuticle is absent in roots. Stomata are structures present in the epidermis of leaves. Stomata regulate the process of transpiration and gaseous exchange. Each stoma is composed of two bean shaped cells known as guard cells which enclose stomatal pore. In grasses, the guard cells are dumb-bell shaped. The outer walls of guard cells (away from the stomatal pore) are thin and the inner walls (towards the stomatal pore) are highly thickened. The guard cells possess chloroplasts and regulate the opening and closing of stomata. Sometimes, a few epidermal cells, in the vicinity of the guard cells become specialised in their shape and size and are known as subsidiary cells. The stomatal aperture, guard cells and the surrounding subsidiary cells are together called stomatal apparatus (Figure 6.4)

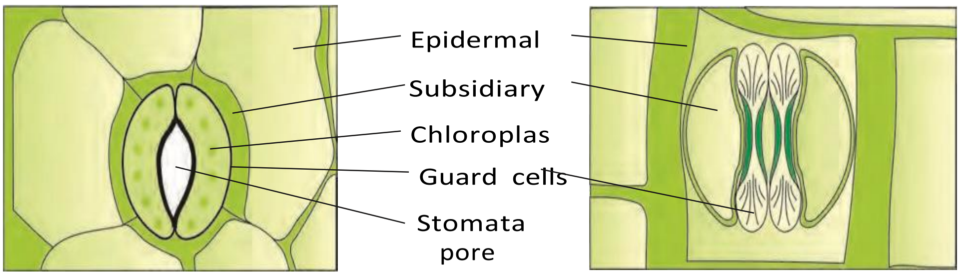

Figure 6.4 Diagrammatic representation: (a) stomata with bean-shaped guard cells
(b) stomata with dumb-bell shaped guard cell

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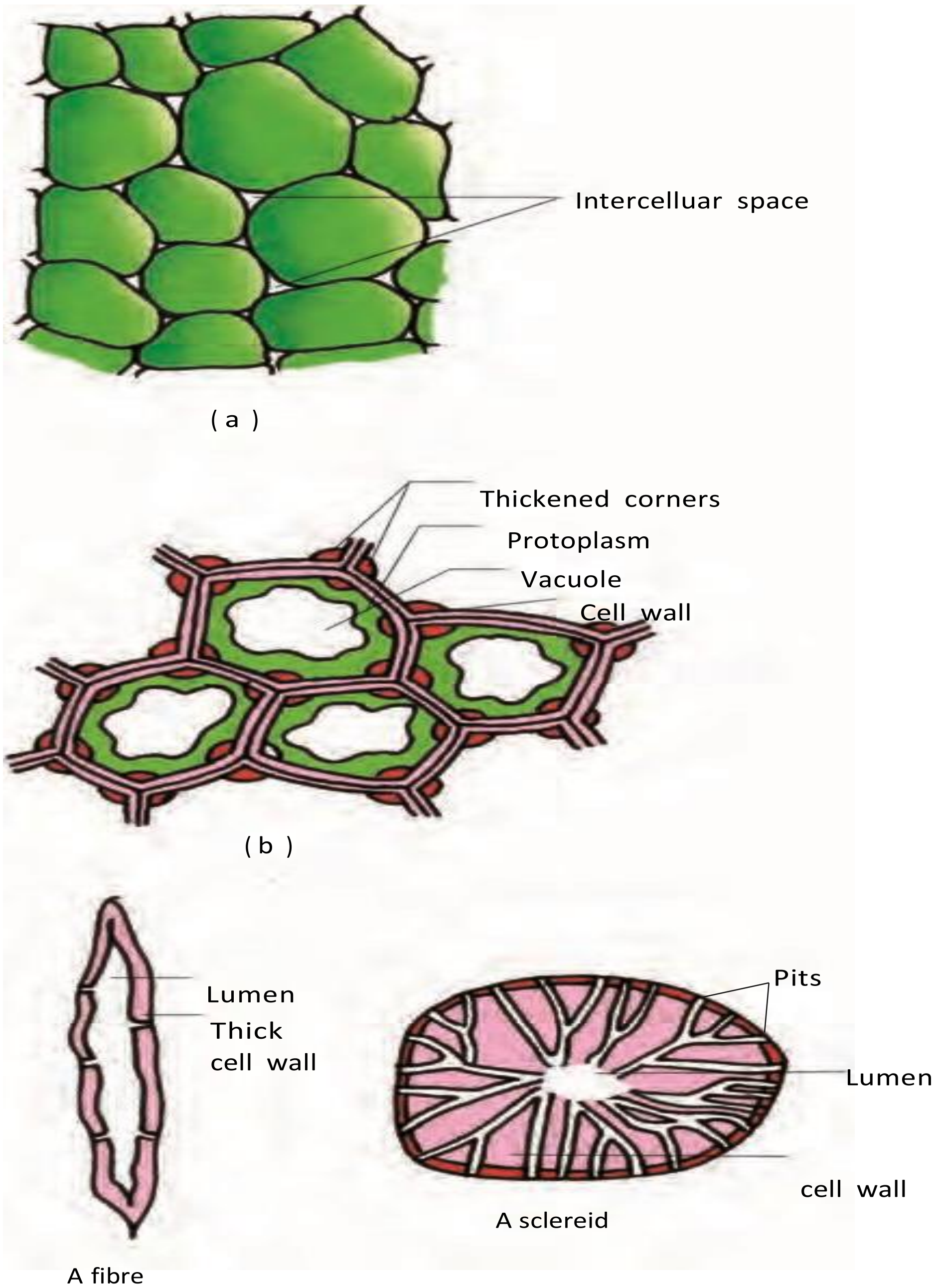


Figure 6.2 Simple tissues:
(a) **Parenchyma**
(b) **Collenchyma**
(c) Sclerenchyma

d. Heartwood and sapwood

In old trees, the greater part of secondary xylem is dark brown due to deposition of organic compounds like tannins, resins, oils, gums, aromatic substances and essential oils in the central or innermost layers of the stem. These substances make it hard, durable and resistant to the attacks of microorganisms and insects. This region comprises dead elements with highly lignified walls and is called heartwood. The heartwood does not conduct water but it gives mechanical support to the stem. The peripheral region of the secondary xylem, is lighter in colour and is known as the sapwood. It is involved in the conduction of water and minerals from root to leaf.

Self-Assessment Exercise(s)
Discuss the activity of cambial ring

ANSWER: The cambial ring becomes active and begins to cut off new cells, both towards the inner and the outer sides. The cells cut off towards pith, mature into secondary xylem and the cells cut off towards periphery mature into secondary phloem. The cambium is generally more active on the inner side than on the outer. As a result, the amount of secondary xylem produced is more than secondary phloem and soon forms a compact mass. The primary and secondary phloem get gradually crushed due to the continued formation and accumulation of secondary xylem. The primary xylem however remains more or less intact, in or around the center. At some places, the cambium forms a narrow band of parenchyma, which passes through the secondary xylem and the secondary phloem in the radial directions. These are the secondary medullary rays (Figure 6.9).

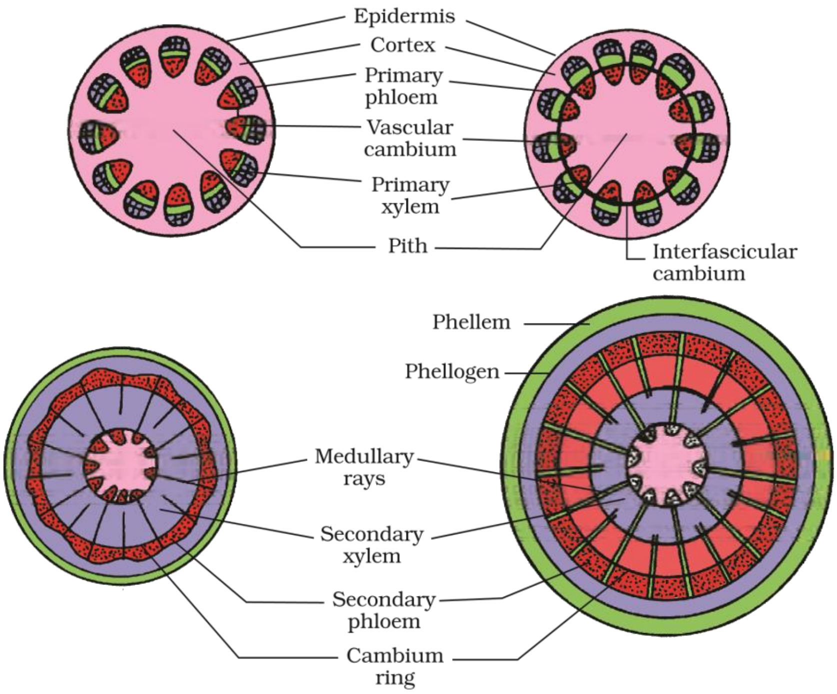


Figure 6.9 Secondary growth in a dicot stem (diagrammatic) – stages in transverse views

The activity of cambium is under the control of many physiological and environmental factors. In temperate regions, the climatic conditions are not uniform through the year. In the spring season, cambium is very active and produces a large number of xylary elements having vessels with wider cavities. The wood formed during this season is called spring wood or early wood. In winter, the cambium is less active and forms fewer xylary elements that have narrow vessels, and this wood is called autumn wood or late wood.

The spring wood is lighter in colour and has a lower density whereas the autumn wood is darker and has a higher density. The two kinds of woods that appear as alternate concentric rings, constitute an annual ring. Annual rings seen in a cut stem give an estimate of the age of the tree.

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

5.3.4. 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)

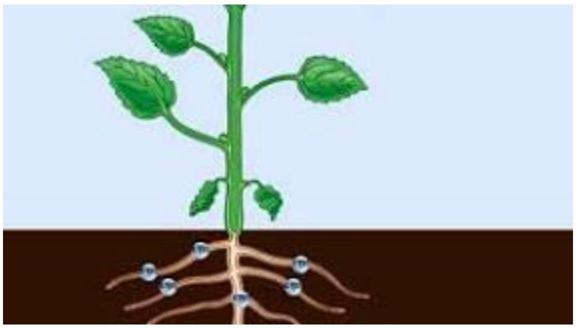
1. **Primary and secondary xylem**
   Primary xylem is the xylem that is formed during primary growth from procambium. It includes protoxylem and metaxylem. Metaxylem develops after the protoxylem but before secondary xylem. It is distinguished by wider vessels and

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. Mention three regions xylem can be found in vascular plants



Xylem cells constitute **the major part of a mature woody stem or root**. They are stacked end to end in the center of the plant, forming a vertical column that conducts water and minerals absorbed by the roots upward through the stem to the leaves. Where are the primary xylem and secondary xylem formed?

5.3.5 Anatomy of 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.

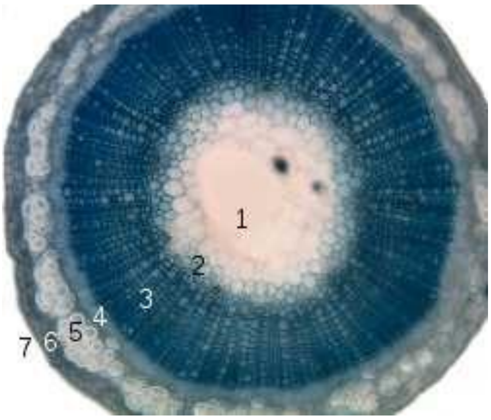


Fig 4.3 Cross-section of a flax plant stem:
1. Pith, 2. Protoxylem, 3. Xylem I, 4. **Phloem** I, 5. Sclerenchyma (bast fibre), 6. Cortex,
7. Epidermis

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
(Source: http://www.emc.maricopa.edu/faculty/farabee/biobk/biobookplantanat.html)

a. 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.

b. 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.

4.7.3. 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.

4.7.4. 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.

Self-Assessment Exercise(s)
Differentiate between xylem and phloem

1. **Answer**: Important difference between xylem and phloem

Parameter	**Xylem**	**Phloem**
Meaning	Complex tissue of plants that transports water and	Living tissue that transports food and organic materials within the plant

	nutrients within the plant	
Type of Cell	Contains dead cells with the exception of parenchyma	Contains of mostly living cells
Materials	It comprises of fibre, tracheids, and xylem vessels	It comprises of sieve cells, sieve tubes, phloem fibres, phloem parenchyma, and companion cells
Location	The location of xylem is deep in the plant, in the centre of vascular bundle	The location of phloem is on the outer side of the plant's vascular bundle
Mechanical Support	It provides mechanical support	Provides no mechanical support
Type of Movement	Undirectional	Bidirectional
Xylem and Phloem functioning	Transports only waters and minerals from roots	Transports food materials whose preparation takes place by the green parts of the plant
Proportion of Plant	Xylem constitutes mostly the bulk of the body of the	Phloem constitutes a small part of the body of the plant

	plant	
Conducting Cells	In xylem, the conducting cells are dead	In phloem, the conducting cells are certainly living

Describe the processes that leads to the movement of sap in vascular plants

Answer: Mechanism Driving Water Movement in Plants
Unlike animals, plants lack a metabolically active pump like the heart to move fluid in their vascular system. Instead, water movement is passively driven by pressure and chemical potential gradients. The bulk of water absorbed and transported through plants is moved by negative pressure generated by the evaporation of water from the leaves (i.e., transpiration) — this process is commonly referred to as the Cohesion-Tension (C-T) mechanism. This system is able to function because water is "cohesive" — it sticks to itself through forces generated by hydrogen bonding. These hydrogen bonds allow water columns in the plant to sustain substantial tension (up to 30 MPa when water is contained in the minute capillaries found in plants), and helps explain how water can be transported to tree canopies 100 m above the soil surface. The tension part of the C-T mechanism is generated by transpiration. Evaporation inside the leaves occurs predominantly from damp cell wall surfaces surrounded by a network of air spaces. Menisci form at this air-water interface (Figure 4), where apoplastic water contained in the cell wall capillaries is exposed to the air of the sub-stomatal cavity.Water evaporation is driven by solar energy, breaking hydrogen bonds, leading to surface tension. This force travels through the plant's water transport system called the Soil Plant Atmosphere Continuum (SPAC).

Stephen Hales, in 1727, proposed the C-T mechanism for plant water flow, emphasizing the role of perspiration. Recently, a lab-produced 'synthetic tree' replicated evaporative flow based on negative pressure.
Osmosis, the diffusion of water, plays a key role in water movement within plants, especially across cell membranes. Root pressure, driven by osmotic forces, occurs when solutes accumulate in root xylem. It's essential in some plants for refilling non-functional xylem conduits.

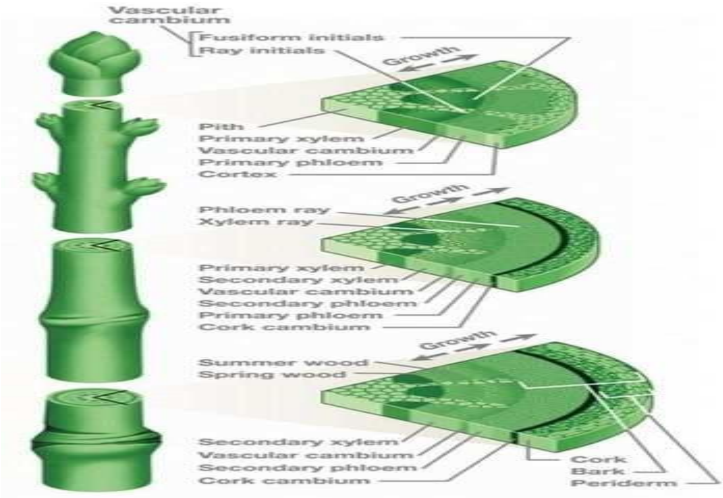


Fig 4.5a Multiple cross sections of a stem showing vascular cambium and companion cells (Source: Winterborne, 2005)

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.

4.8. 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.

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.

In-Text Question(s)

Questions:

1. Name the type of cells found in vascular cambium

Answer: The vascular cambium is located between the xylem and the phloem in the stem and root of a vascular plant and is the source of both the secondary xylem growth and the secondary phloem growth.

It is a cylinder of unspecialized meristem cells that divide to give new cells which then specialize to form secondary vascular tissues. Vascular cambia are found in dicots and gymnosperms but not monocots, which usually lack secondary growth. A few leaf types also have a vascular cambium. The vascular cambium usually consists of two types of cells - fusiform initials (tall cells, axially oriented) and ray initials (almost isodiametric cells - smaller and round to angular in shape)

2. **What are the other names for cork cambium?**

Answer: What is other name of cork cambium?

cambium, called **the phellogen** or cork cambium, is the source of the periderm, a protective tissue that replaces the epidermis when the secondary growth displaces, and ultimately destroys, the epidermis of the primary plant body

4.8.1. 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

4.8.2.Self-Assessment Exercise(s)

Differentiate between a vascular cambium and a cork cambium

Answer: What is the difference between Vascular Cambium and Cork Cambium?

There are some similarities and differences between Vascular Cambium and Cork Cambium.

• Cork cambium and vascular cambium both are responsible for the secondary growth of the plants. Therefore, these are found only in dicotyledonous plants.

• Cork cambium and vascular cambium arise from the lateral meristematic tissue.

• Both cambia increase the girth to stems and roots.

• Both comprises of a single cell layer that adds new cells to the in terior and exterior of the plant body.

• Cork cambium is secondary in origin while vascualar cambium has both primary origin and secondary origin (intrafasicular cambium of the vascular cambium is primary in origin and interfasicular cambium is secondary in origin)

• Cork cambium is located outer part of the cortex while vascular cambium is located basically in-between primary xylem and primary phloem.

• Cork cambium produces cells to its exterior while vascular cambium produces secondary phloem to its exterior.• Cork cambium produces phelloderm to its interior, but vascular cambium produces secondary xylem to its interior.

• Cork cambium produces lenticels that allow gas exchange between wood and outside air, while vascular rays produced by the vascularcambium allows water and nutrient transformation between secondary xylem and secondary phloem.

Self-Assessment Exercise(s)

Outline the importance of cork cambium to the environment

Answer: Cork produced by the cork cambium functions as a thick layer of cells that **protects the delicate vascular cambium and secondary phloem from mechanical damage, predation, and desiccation**

5.4 Summary

Anatomically, a plant is made of different kinds of tissues. The plant tissues are broadly classified into meristematic (apical, lateral and intercalary) and permanent (simple and complex). Assimilation of food and its storage, transportation of water, minerals and photosynthates, and mechanical support are the main functions of tissues. There are three types of tissue systems – epidermal, ground and vascular. The epidermal tissue systems are made of epidermal cells, stomata and the epidermal appendages. The ground tissue system forms the main bulk of the plant. It is divided into three zones – cortex, pericycle and pith. The vascular tissue system is formed by the xylem and phloem

- . Dicotyledonous and monocotyledonous roots
- The anatomy of stem which consists mostly vascular cambium and cork cambium
- A leaf is considered a plant organ and typically consists of the epidermis, mesophyll and vascular tissues

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 Transpiration 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
- 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

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