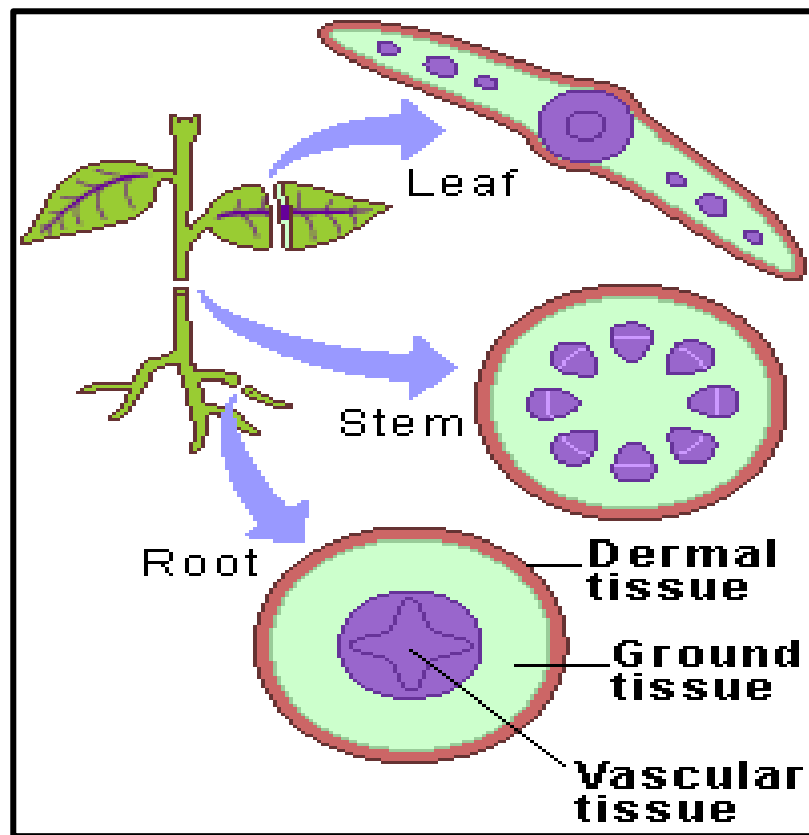


MORPHOLOGY & ANATOMY

First Year Biology Code: B.101



Prof. Ragab Teama

2025-2026

Course Specification

(2025)

1. Basic Information

Course Title (according to the bylaw)	Morphology & Anatomy			
Course Code (according to the bylaw)	Bot, 101			
Department/s participating in delivery of the course	Botany and Microbiology Depart.			
Number of credit hours/points of the course (according to the bylaw)	Theoretical	Practical	Other (specify)	Total
	2	3	--	3
Course Type	اجباري			
Academic level at which the course is taught	الفرقة/المستوي الاول			
Academic Program	Biology			
Faculty/Institute	Fac. Science			
University/Academy	Zagazig University			
Name of Course Coordinator	Prof. Ragab Teama			
Course Specification Approval Date	6/9/2025			
Course Specification Approval (Attach the decision/minutes of the department /committee/council)	26/8/2025			

2. Course Overview (Brief summary of scientific content)

Plant morphology is the study of a plant's external features and form, including its roots, stems, leaves, flowers, and fruits, while plant anatomy is the study of its internal structure at the cellular and tissue level, often requiring microscopy. Morphology helps in plant identification and classification by describing observable external

characteristics, whereas anatomy reveals the microscopic details of how these structures function.

3. Course Learning Outcomes CLOs

Matrix of course learning outcomes CLOs with program outcomes POs (NARS/ARS)

Program Outcomes (NARS/ARS) (according to the matrix in the program specs)		Course Learning Outcomes Upon completion of the course, the student will be able to:	
Code	Text	Code	Text
A1	Student can identify, formulate, and solve fundamental problems	A1-a	Biologists investigate the processes that sustain life, such as energy transformation, reproduction, and homeostasis.
		A1-b	Formulate basic concepts life process through morphology and anatomy
		A1-c	Fundamental themes, such as the cell as the basic unit of life and the concept of evolution driving biological diversity
A2	Student can Design and Analysis data and interpret results	A2-a	Design biological experiments using proper computational platforms, measuring instruments
		A2-b	Use relevant laboratory equipment and analyze the results correctly.
		A2-c	Interpret results to identifying patterns, and forming conclusions that provide insights and contribute to broader knowledge in a field.
A3	Student can use the techniques, skills, and appropriate biological tools for their practice.	A3-a	The field examines the vast array of plants including their unique characteristics and how they interact
		A3-b	Skills to organize tasks into structured form to be able to support activities.
A4	Student can work effectively in multi-disciplinary teams and communicate their ideas clear	A4-a	Work effectively in multi-disciplinary teams
		A4-b	Communicate effectively orally and in written form
A5	Understanding Scientific language and report writing	A5-a	Be aware of terms of technical language and rules of writing reports in the biological science
		A5-b	Compile proper technical reports and present them orally or in written forms.
		A5-c	Discusses to examining or presenting a topic in detail, either through speech or writing.

4. Teaching and Learning Methods

- 1- Traditional lecture-based, interactive, student-centered, and technology.
2. Inquiry-based learning.
3. Project-based learning
4. Collaborative learning.

Course Schedule

Number of the Week	Scientific content of the course (Course Topics)	Total Weekly Hours	Expected number of the Learning Hours			
			Theoretical teaching (lectures/discussion groups/.....)	Training (Practical/Clinical/.....)	Self-learning (Tasks/Assignments/Projects/...)	Other (to be determined)
1	Introduction	1	1	x	x	x
2	Life cycle of the angiosperm	2	2	x	x	x
3	Seed structure and germination	2	1	2	x	x
4	Morphology of roots	3	2	3	x	x
5	Morphology of normal and modified stems	3	2	3	x	x
6	Morphology of normal and modified plant leaves	3	2	3	x	x
7	Morphology of flowers and fruits	3	2	3	x	x
8	Plant cell, structure and shape	3	2	3	x	x
9	Types of plant cells	3	2	3	x	x
10	Plant tissues, simple and complex	3	2	3	x	x
11	Anatomy of plant roots	3	2	3	x	x
12	Anatomy of plant stems	3	2	3	x	x
13	Anatomy of plant leaves	3	2	3	x	x
14	Ecological anatomy	3	2	3	x	x

5. Methods of students' assessment

No.	Assessment Methods *	Assessment Timing (Week Number)	Marks/ Scores	Percentage of total course Marks
1	Exam 1 written (Semester work)	7	10	10%
2	Exam 2 (Semester work)	x	x	x
3	Final Written Exam	16	60	60%
4	Final Practical/Clinical/... Exam	15	10	10%
5	Final Oral Exam	15	10	10%
6	Assignments / Project /Portfolio/ Logbook	10	10	10%
7	Field training	x	x	x
8	Other (Mention)	x	x	x

6. Learning Resources and Supportive Facilities *

Learning resources (books, scientific references, etc.) *	The main (essential) reference for the course (must be written in full according to the scientific documentation method)	Raven, P. H., R. F. Evert, & S. E. Eichhorn. Biology of Plants, 7th ed., page 9. (New York: W. H. Freeman, 2005). ISBN 0-7167-1007-2. Evert, Ray Franklin and Esau, Katherine (2006) Esau's Plant anatomy: meristems, cells, and tissues of the plant body - their structure, function and development Wiley, Hoboken, New Jersey, page xv, ISBN 0-471-73843-3 Bäurle, I; Laux, T (2003). "Apical meristems: The plant's fountain of youth". <i>BioEssays</i>. 25 (10): 961–70. doi:10.1002/bies.10341. PMID 14505363. Review. Brand, U; Hobe, M; Simon, R (2001). "Functional domains in plant shoot meristems". <i>BioEssays</i>. 23 (2): 134–41. doi:10.1002/1521-1878(200102)23:2<134::AID-BIES1020>3.0.CO;2-3. PMID 11169586. S2CID 5833219. Review. Barlow, P (2005). "Patterned cell determination in a plant tissue: The secondary phloem of trees". <i>BioEssays</i>. 27 (5): 533–41. doi:10.1002/bies.20214. PMID 15832381. Michael A Dirr; Charles W Heuser, jr. (2006). "2". <i>The Reference Manual of Woody Plant Propagation</i> (Second ed.). Varsity Press Inc. pp. 26, 28, 29. ISBN 0942375092. Kirchoff, B K; Pfeifer, E; Rutishauser, R (2008). "Plant structure ontology: How should we label plant structures with doubtful or mixed identities?". <i>Zootaxa</i>. 1950: 103–122. doi:10.11646/zootaxa.1950.1.10. Rutishauser, R.; Isler, B. (2001). "Developmental Genetics and Morphological Evolution of Flowering Plants, Especially Bladderworts (Utricularia): Fuzzy Arberian Morphology Complements Classical Morphology" (PDF). <i>Annals of Botany</i>. 88 (6): 1173–
	Other References	x
	Electronic Sources (Links must be added)	Websites, journal articles, e-books, online news articles, blogs, videos
	Learning Platforms (Links must be added)	Udemy LinkedIn Learning Khan Academy for foundational education Skillshare for creative skills
	Other (to be mentioned)	x
Supportive facilities & equipment for teaching	Devices/Instruments	classrooms, laboratories, libraries, and sports fields
	Supplies	whiteboards and projectors to computers, learning management systems

and learning *		(LMS), and even virtual reality (VR) headsets
	Electronic Programs	software programs used in the design, simulation, and control of electronic systems
	Skill Labs/ Simulators	environments and technologies used for hands-on, risk-free training in various professions, particularly healthcare
	Virtual Labs	To enthuse students to conduct experiments by arousing
	Other (to be mentioned)	Workshops

Name and Signature
Course Coordinator
Prof. Ragab Teama

Name and Signature
Program Coordinator
Prof. Ragab Teama

Introduction

Biology is the branch of science that studies **living organisms**, derived from the Greek words "bios" (life) and "logos" (study or science). It is a broad natural science encompassing the structure, function, growth, origin, evolution, and distribution of life **in all its forms**, from single-celled bacteria to complex plants.

Aspects of biology include:

- **Study of life:**

Biologists investigate the processes that sustain life, such as energy transformation, reproduction, and homeostasis.

- **Diversity of organisms:**

The field examines the vast array of living things, including their unique characteristics and how they interact.

- **Unifying principles:**

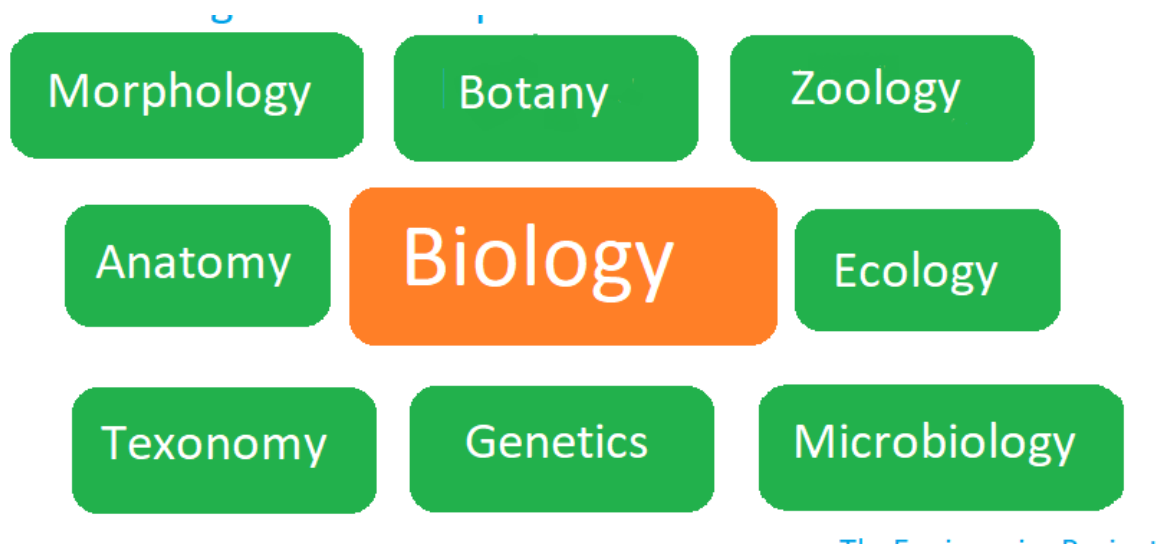
Biology is built upon fundamental themes, such as the cell as the basic unit of life and the concept of evolution driving biological diversity.

- **Interdisciplinary nature:**

Biology often intersects with other sciences like chemistry (biochemistry), physics (biophysics), and even social sciences (evolutionary psychology).

Importance of biology:

- **Medicine and health:** Advances in biology lead to new medicines and treatments for diseases.
- **Environmental understanding:** It helps us comprehend how environmental changes affect plants and animals.
- **Food production:** Biological principles are applied to ensure sufficient food for a growing human population



Living things share common characteristics as: -

1. Organization

Living organisms are organized hierarchically from **simple to complex**, starting with cells, the basic unit of life. Multiple cells form tissues, which combine to create organs. Groups of organs working together constitute organ systems, and the entire **functioning unit is the organism**.

Cells are the **basic unit** of all living things. Cells, like all living things, have an inside and an outside, separating of the inside from the outside by **cell membrane**. Within some cells, another structure called the **nucleus** is also surrounded by a membrane.

Level of organization



2. Growth

Living things **increase in size**. But all living things need to **get energy**. All living things also need to **obtain materials to build new structures** inside cells or replace

worn-out cell parts. As a result, individual cells grow **larger over time**.

3. Reproduction

Living things reproduce, **forming other organisms**. Every organism contains genetic material, which is a code contained a special **molecule called DNA**, characteristics of the individual organism. In order to reproduce, an organism must make a copy of this material, which is passed on to its offspring. Single-celled organisms reproduce by a process called binary fission, material from one cell separates into two cells. The **genetic material** of the original cell first **doubles** so that each daughter cell has an exact. copy of the DNA of the original cell. **In some cells, binary fission can take place as often as every 20 minutes.**

4. Response

Organisms respond to **changes in the environment**. Even microscopic organisms respond to conditions such as light, temperature, and touch. The ability to respond **allows organisms to find food, avoid being eaten**, or perform other tasks necessary to survive.

5. Living things need energy

All living things need **energy and materials**. For most organisms, water and air are materials necessary for life. Food supplies you with energy. You—like all living things—need energy to move, grow, and develop. **All animals have systems for breaking down food into usable forms of energy and materials.** Plants have structures that enable them to transform sunlight into usable energy.

.All living things must have **living material protoplasm**, that able to **produce energy or transformed it from one form to another**.

All living things **require energy** to do the work necessary for **survival and reproduction**. But what is energy? **Energy** is simply the ability to do work, where **work** is done when a force moves an object.

So where does energy come from and how do we use it? **On Earth, energy ultimately comes from the sun**. Plants use the sun's energy to make sugar. **Organisms**, in turn, use sugar as a source of energy to do work.

Botany, also called **plant science(s), plant biology or phytology**, is the science of plant life and a branch of biology. The term "botany" comes from the Ancient Greek word *botanē* meaning "pasture", "grass", or "fodder".

General botany includes many branches as:

Plant Morphology (External morphology) deals with the external forms of the plant and their peculiarities.

Plant Anatomy (Internal morphology or Micromorphology) deals with the internal structure or tissues of the plants.

Plant Systematic deals with the classification of the plant Kingdom into groups according certain systems of classification.

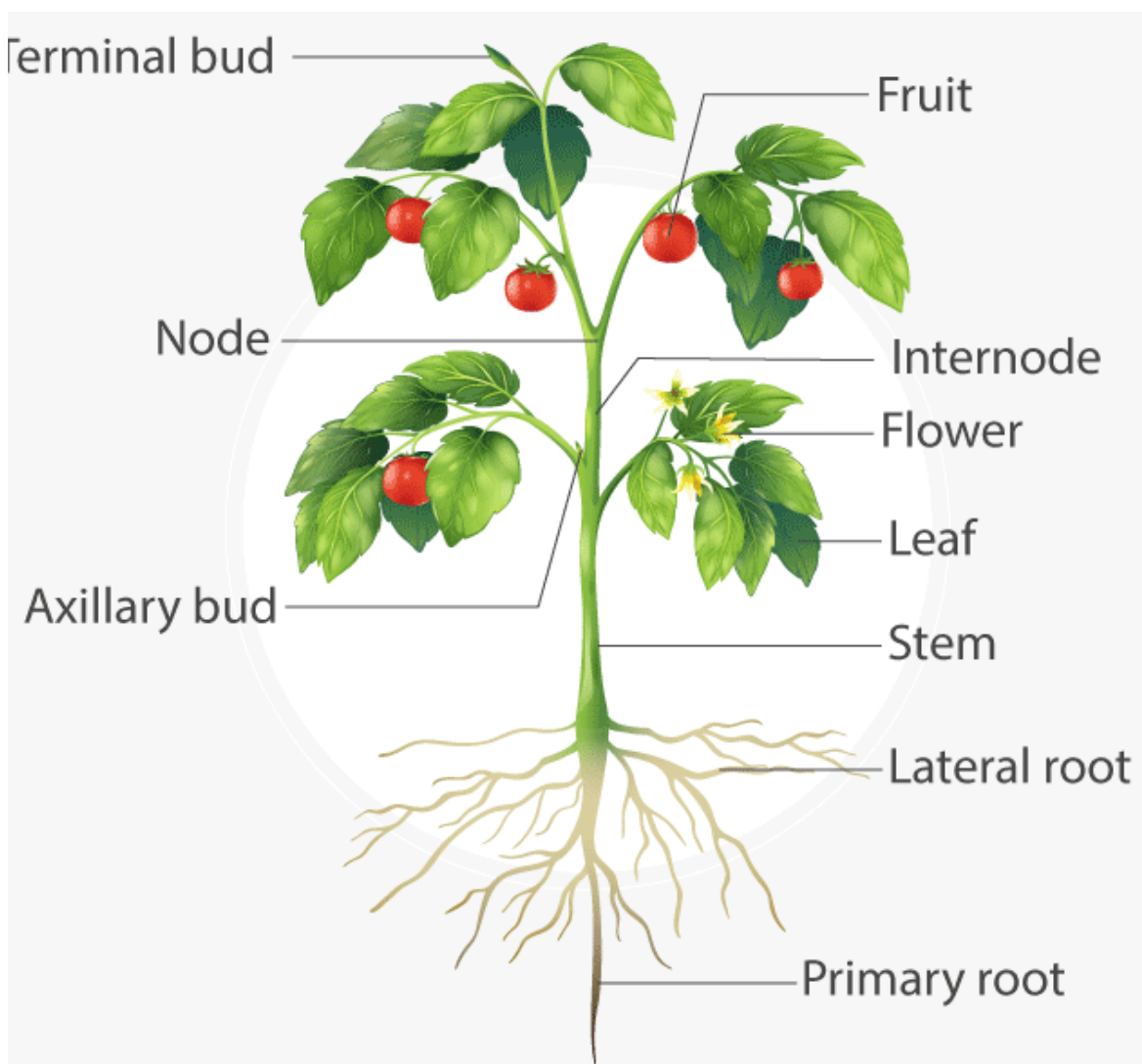
Plant Physiology discusses the various life processes within the plant such as growth, photosynthesis, respiration, transpiration, etc.

Paleobotany concerns with the study of the fossil plants which become extinct a long time ago. It tries to connect the past with the present through discovering the ancestral forms.

Plant Microbiology is dealing with the study of the lower plant organisms such as bacteria, fungi and algae.

PART 1

Morphology of Plants



Prof. Ragab Teama

2025-2026

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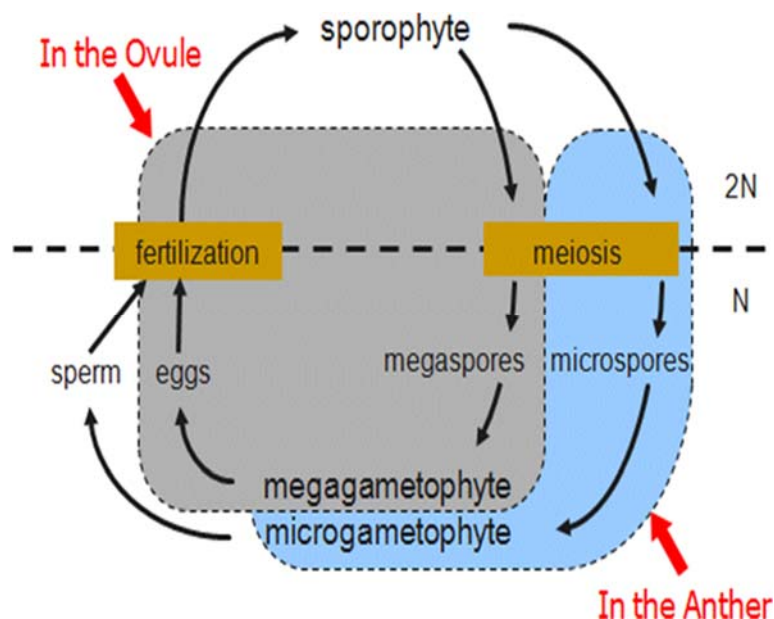
Plant Morphology is the study of the form, structure, and external appearance of plants, encompassing their roots, stems, leaves, flowers, and fruits, to understand their development, diversity, and evolutionary relationships. It is a fundamental branch of botany that aids in plant identification, classification, and understanding their adaptations to different environments.

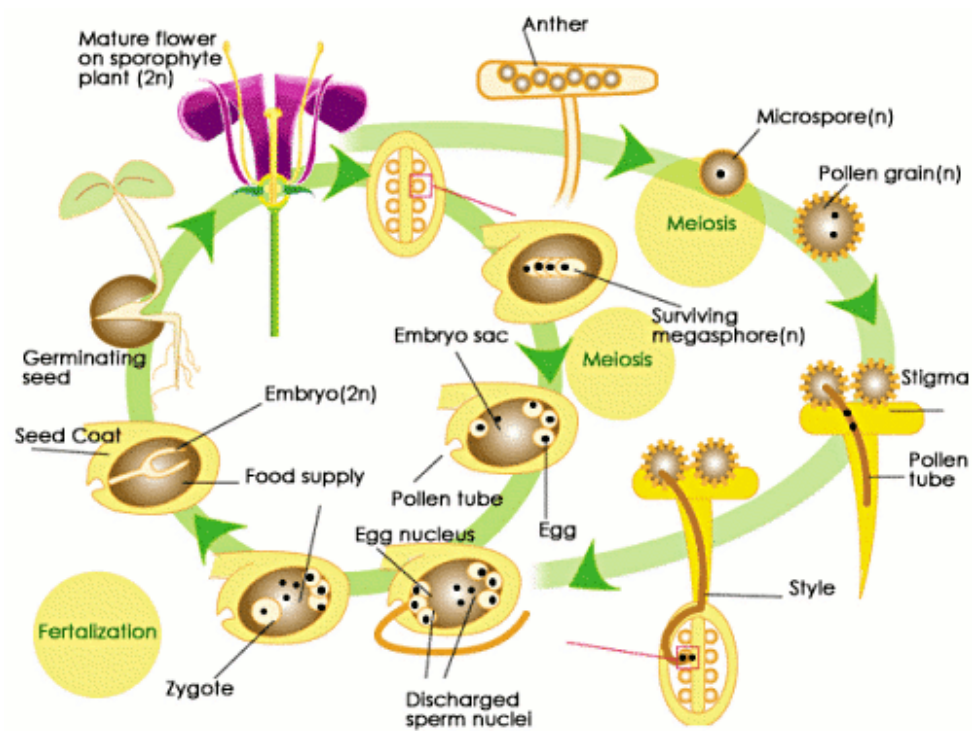
The plant is characterized by:

- 1) **Multicellular**, non-motile.
- 2) **Eukaryotic** cells, has cell walls of cellulose.
- 3) **Autotrophic**.
- 4) **Exhibits alternation of generations** - has a distinctive diploid (sporophyte) and haploid (gametophyte) phase.

Life Cycle of Seed Plants

Seed plants are **heterosporous**- they have 2 different spore sizes: **megaspores** and **microspores**. The life cycle of plants have separate male and female gametophytes (**megagametophyte** and **microgametophyte**) produced by different sized spores (**megaspores** and **microspores**).





Life Cycle of Seed Plants

The life cycle of higher plants sporophyte including two stages:

A: Dormancy stage (Seed)

B: Active stage (vegetative body)

A: Seeds

- It is the product of fertilization, and then developed from the zygote.
- A seed is a small embryonic plant enclosed in a covering called the seed coat, usually with some stored food.
- Seeds have an important role in the reproduction and spread of plants.
- Seeds are of economic important as foods, industries, clothes, medicines, etc.

Seed structure

A typical seed includes three basic parts:

1. **The embryo** is immature plant, it have:

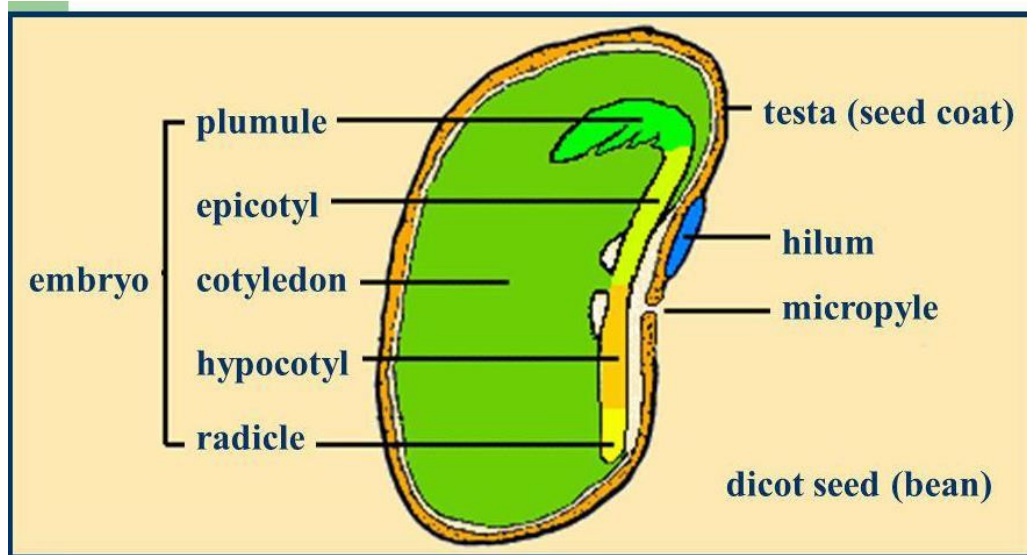
- Cotyledon or seed leaf, one in monocot, two cotyledons in dicot and two or more in gymnosperms.
- Radicle is the embryonic root.
- Plumule is the embryonic shoot.
- Epicotyl is embryonic stem above attachment of the cotyledon(s)
- Hypocotyl is embryonic stem below attachment of the cotyledon(s)

2. **Store of nutrients**, it may be:

- In angiosperms, called the endosperm, via double fertilization, usually triploid endosperm rich in oil or starch and protein.
- In gymnosperms, the food storage tissue is part of the female gametophyte, a haploid tissue contains different materials.

3. **The seed coat** (testa):

- It is protective wall surrounding the embryo and storage tissue. It develops from the integument, originally surrounding the ovule.

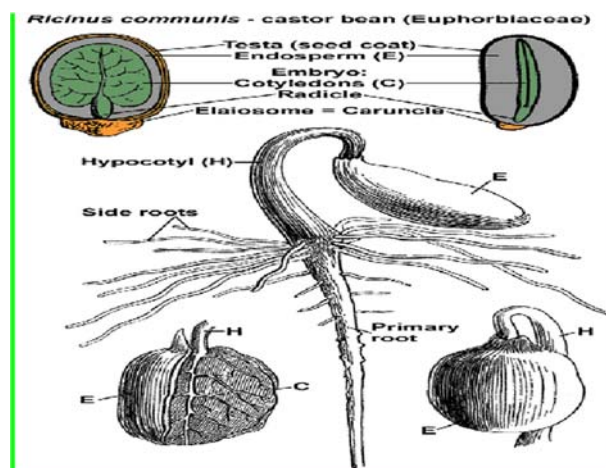
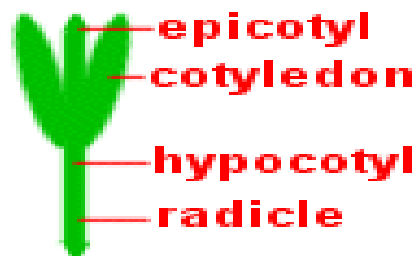


Kinds of seeds

According to storage foods

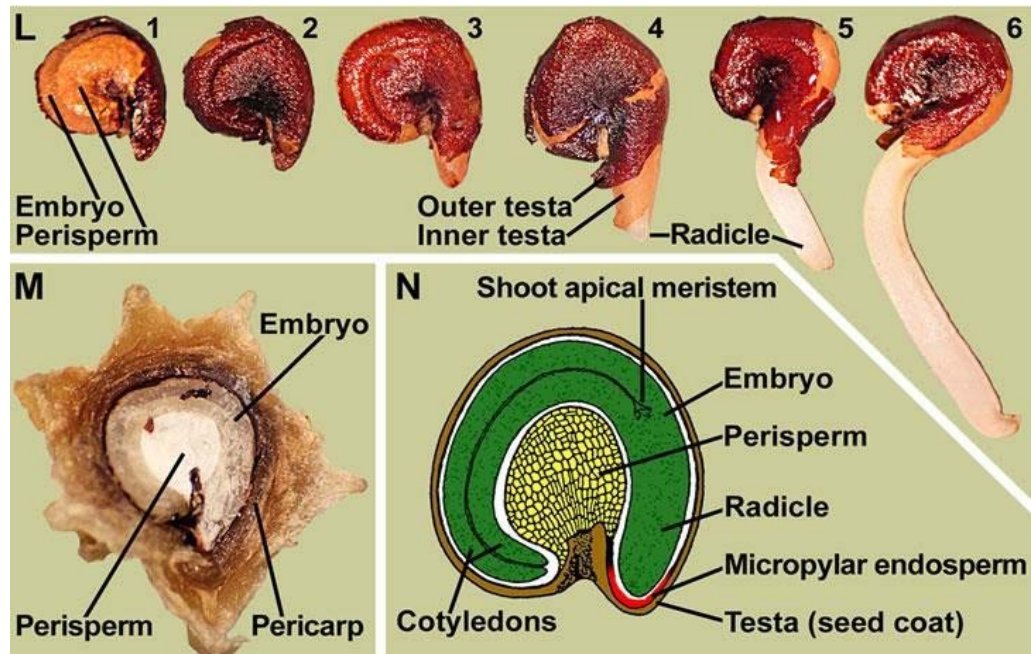
1. Endospermic seeds

- Cotyledons thin and the endosperm is the major storage tissue. The cotyledons absorb the nutrients from endosperm.



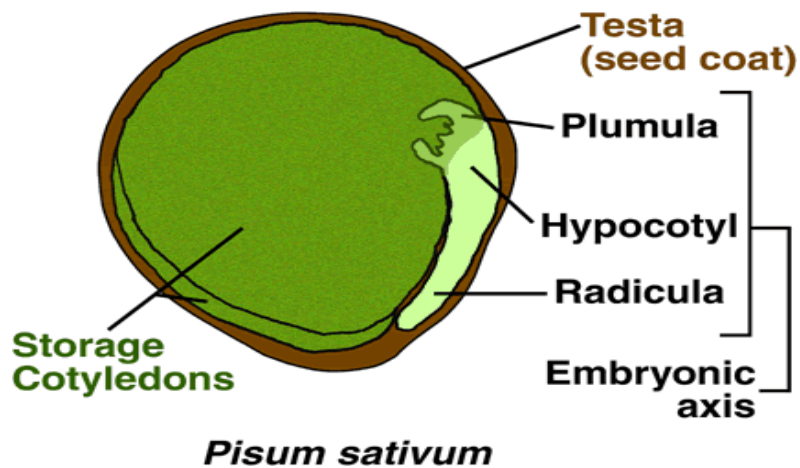
2. **Perispermic** seeds Sugar beet

- Stored food in pericarp, a fruit tissue, and then uptake by the cotyledons.



3. **Non-endospermic** seeds (legume, pea)

- Stored food in cotyledons. During embryo development **the cotyledons absorb the food reserves from the endosperm.**



According to germination

(a)

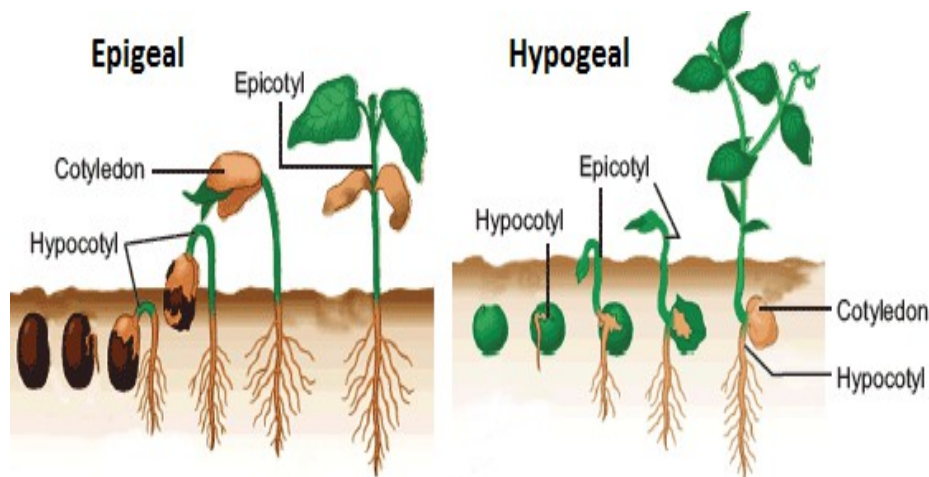
Coleorhiza	Coleoptile
It is the outer sheath covering the radicle in certain seeds.	It is the outer sheath covering the plumule in certain seeds.

(b)

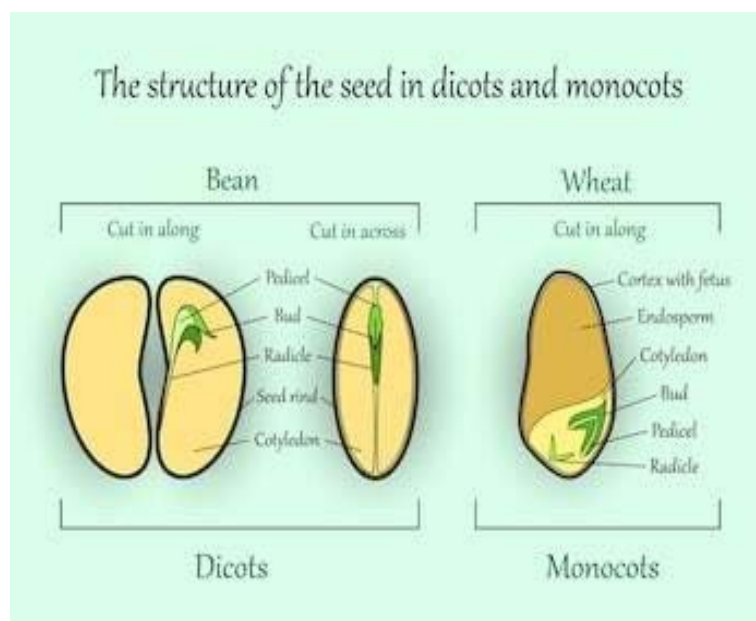
Albuminous seed	Exalbuminous seed
These seeds possess endosperm	These seeds lack endosperm
In such seeds, food is stored mainly in endosperm	In such seeds, food is stored only in the cotyledons.
Example – Castor, cereals, grasses	Example – pea, gram, lentil

(c)

Epigeal germination	Hypogeal germination
Here cotyledons are pushed above the soil.	Here, cotyledons remain inside the soil.
Here hypocotyl grows and elongates faster than epicotyl.	Here epicotyl grows and elongates faster than hypocotyl.
Example – Bean, cotton, castor, papaya	Example – Wheat, rice, groundnut, mango



According to number of cotyledons



B: Vegetative Body

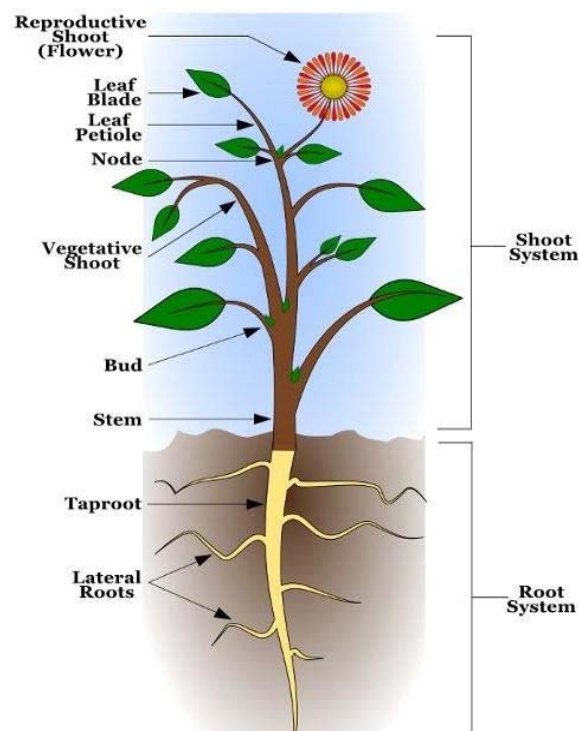
The vegetative body of a flowering plant consists of **two main parts**: the **root system** which usually grows beneath the soil surface and the **shoot system** which usually grows above the soil surface and carries the foliage leaves and the reproductive parts.

It is the external feature and absolutely **essential in**:

1. **Plant propagation**: grafting, budding, division, cuttings, layering, tissue culture
2. **Pruning**
3. **Making crosses** in plant breeding
4. **Diagnosing** plant disorders.

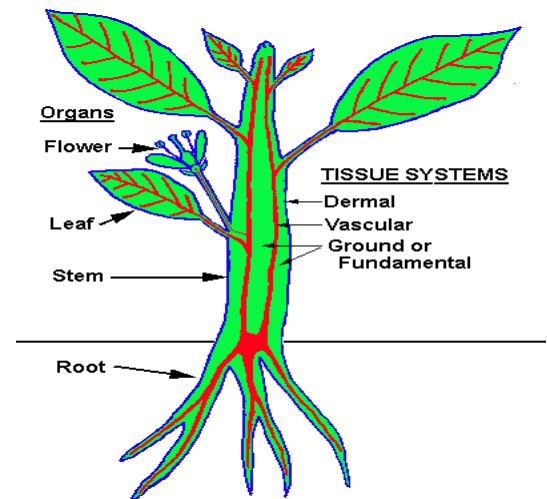
Plant is divided into four organs:

- | | | | |
|----------------|--------------------|-----|--|
| 1. Root | 3. Leaf | and | 4. Flower and resultant fruit, is |
| 2. Stem | vegetative organs. | | a reproductive organ. |



Each organ is composed of three tissue systems:

- | | |
|----------------------------------|---|
| 1. Dermal tissue system | 3. Ground or fundamental tissue system |
| 2. Vascular tissue system | |



Each tissue is composed of cells include of:

1. **Parenchyma**
2. **Collenchyma**
3. **Sclerenchyma**
4. Specialized cells as **trichomes**, **vessels**, companion cells etc

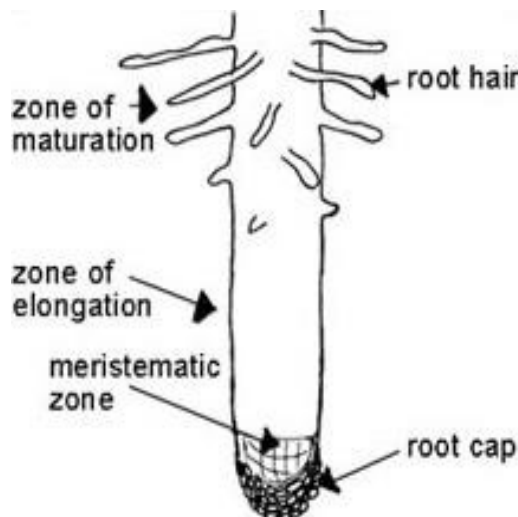
The Root System

The **root** commonly consists of a **main root** also known as the **primary root** from which arise **lateral roots** that are usually branched in turn into smaller **rootlets**. The primary root, its laterals with its rootlets are collectively known as the **root system**.

Functions of the Root

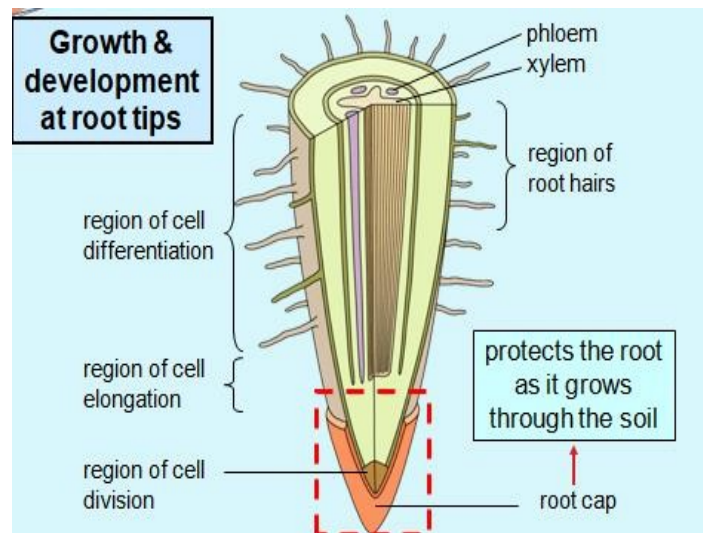
1. **Fixation** of the plant firmly in the soil.
2. **Absorption** of water and dissolved substances from the soil solution.
3. **Some roots perform special functions** not shared by other roots such as storage excessive amounts of food, climbing, etc.

Zones of the root



The root is usually differentiated into the following zones:

1. **Growing apex**: active promeristem at tip, consists of meristematic tissues, covered by calyptra.
2. **Zone of elongation**: rapid elongation zone helps root to grow.
3. **Zone of absorption (root hairs)**: fine white hairs at all sides for absorption of water and solutes.
4. **Bare zone**: oldest root hairs fall leaving region bare.
5. **Permanent zone (lateral roots)**: Lateral roots arise endogenously from the vascular cylinder branch into smaller rootlets.



Types of Roots

Roots are either tap roots or adventitious roots.

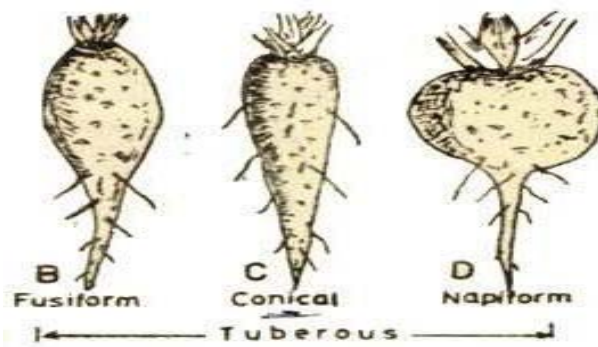
I. Tap roots

They originate from the **radicle**. The root is differentiated into a main root known as the primary root from which arise the lateral roots with its rootlets. The tap roots are either **normal non- tuberous tap roots** or **tuberous tap roots**.

1. **Normal non-tuberous tap roots**: They store normal amounts of food. The root is **cylindrical in shape** with somewhat broad base and a tapering apex, e.g. root of Cotton or *Ricinus*.



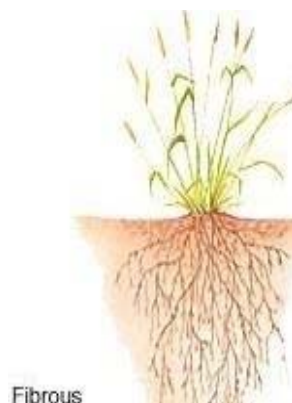
2. **Tuberous Tap roots**: Such roots store excessive amounts of food. According to its shape they are either **fusiform** e.g. *Raphanus sativus* (Radish), **conical** e.g. *Daucus carota* (Carrot) or **napiform** e.g. *Brassica rapa* (Turnip).



II. Adventitious roots

They do not arise from the radicle but they usually arise from adventitious root primordia either on the embryo axis e.g. cereals or on mature organs such as the base of the stem or lower surface of leaves. The adventitious roots include:

1. **Fibrous roots:** They are fine thread-like roots common in the family Gramineae e.g. *Cynodon dactylon*.



2. **Prop roots:** They develop from the lower nodes of stems or culms of some cereals e.g.



Zea mays (Maize).

3. **Aerial roots:** They arise from the lower surface of some large trees e.g. *Ficus benghalensis*.



4. **Pillar roots:** When some of the prop roots reach the soil surface and penetrate inside the soil they are termed as pillar roots e.g. *Ficus benghalensis*.



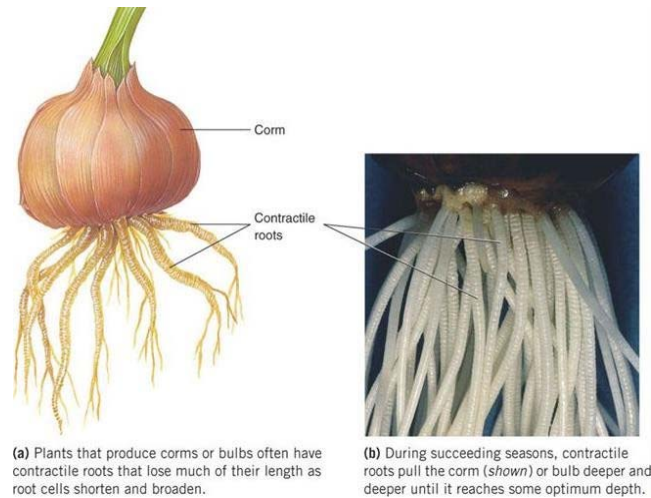
5. **Tuberous roots:** Where the main adventitious roots or their laterals store excessive amounts of food e.g. *Ipomoea batatas* (Sweet potato).



6. **Climbing roots:** As in climbing stems of *Hedera helix* and *Cereus* where they help in supporting the plant to a wall or a tree trunk.



7. **Contractile roots:** They are strong and **coiled adventitious** roots developing from the lower side of discoid stems or bulbs e.g. *Urginea* and *Crocus*.



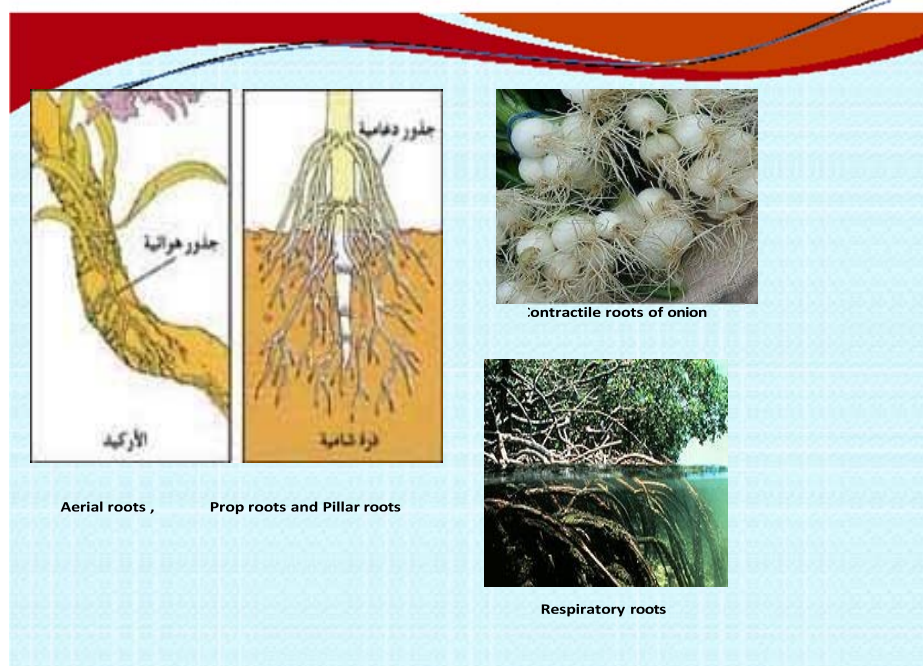
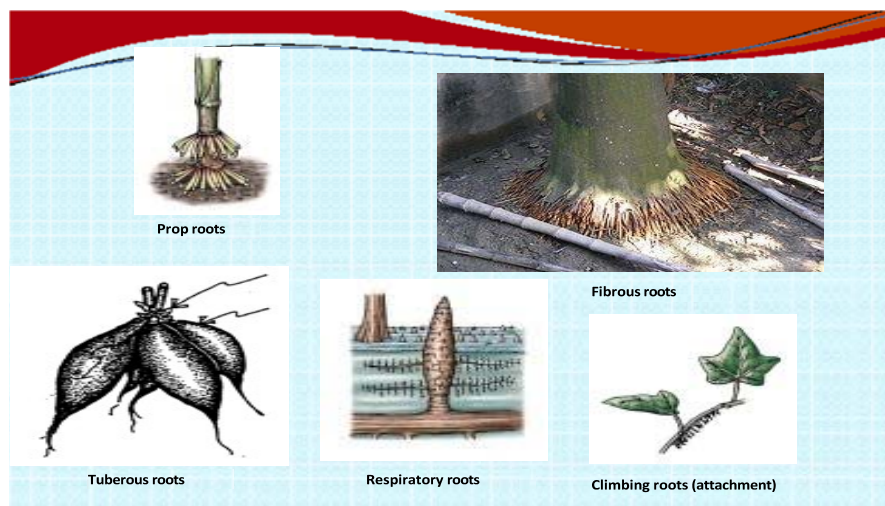
8. **Respiratory roots:** They are common among swamp plants where the soil is very soft, water logged and the aeration is almost absent e.g. *Avicennia officinalis*. Some of the roots of the plant instead of growing normally downwards will grow upward. On their surface are present lenticels to carry out gaseous exchange. The part of the respiratory root exposed to air is known as **pneumatode**. The inner pneumatode tissues are intermingled with wide air spaces known as **pneumatophores**.



9. **Haustorial roots:** They are produced by the parasitic flowering plants; stem parasite e.g. *Cuscuta* (Dodder) or root parasite e.g. *Orobanche*.



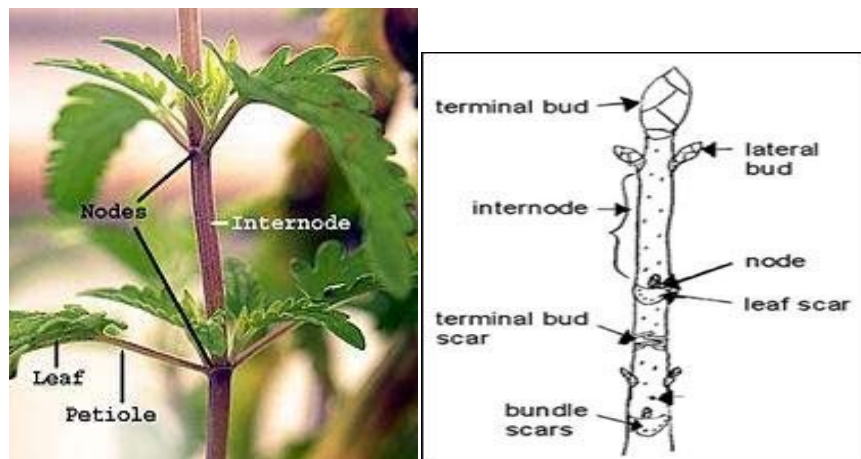
Cuscuta



The Shoot System

The shoot system consists of the stem which is the portion of the main axis of the plant usually above the soil surface. It carries the leaves and other vegetative parts of the plant as well as the flowers and fruits.

A normal stem is divided into nodes and internodes. The node is the point of leaf attachment whereas the internode is the elongated portion of the stem between two successive nodes. Sometimes the stem might be very short so that its nodes and internodes are not differentiated from each other i.e. **dwarf stem**.



I-Stem

Functions of the Stem

1. **Bearing** the branches, buds, leaves, flowers, and fruits of the plant.
2. **Conduction** of soil solution from root system and prepared food from leaves.
3. **Metamorphosed** for **special functions** as storage, perennation, climbing, etc.

Description of Stem

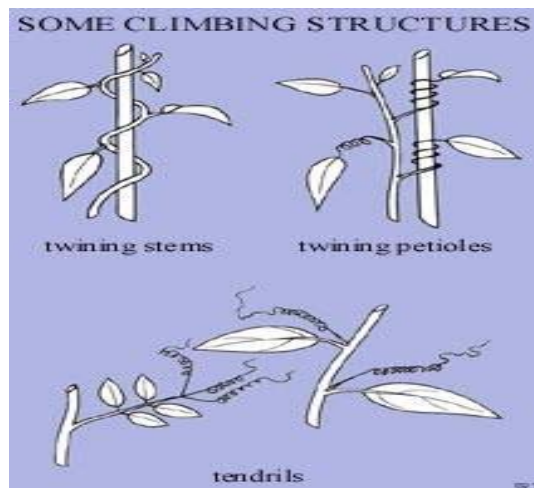
A. Habit

1. **Herb:** With a smaller amount of lignified and woody tissues e.g. *Trifolium* (clover).
2. **Shrub:** With a large amount of woody and lignified tissues. The shrub is smaller than tree. It has no main stem and the branches arise close to the soil surface e.g. *Rosa*.

3. **Tree:** A plant with a large amount of woody and lignified tissues and having a single main stem or trunk e.g. *Eucalyptus*.

B. Nature

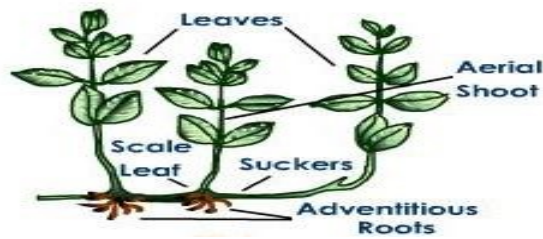
1. **Erect stems:** They are able to carry the branches, leaves, flowers and fruits without needing a support due to the sufficient amount of woody and mechanical tissues e.g. *Gossypium*, *Vicia faba*.
2. **Weak stems:** They are unable to have a self support due to the insufficient amount of woody and mechanical tissues. Weak stems are either:
 - a. **Climbing stems:** Either by **twining** e.g. *Convolvulus* or by **tendrils**; which may be modified terminal or axillary buds e.g. *Vitis* or modified leaflet e.g. *Pisum* or by **prickles** e.g. *Rosa* or by **adventitious roots** e.g. *Cereus*.



- b. **Creeping stems**, they are either prostrate or running:-
 - **Prostrate stem:** does not usually produce adventitious roots when its nodes touch the soil surface e.g. *Tribulus*.



- **Running stem:** produces adventitious roots and aerial shoot from the nodes which touch the soil surface e.g. *Fragaria*.



C. Shape

The shape of stem may be **cylindrical** e.g. *Arundo* or **angular** e.g. *Vicia faba* or **flattened** e.g. *Ruscus*.

D. Surface

The surface of the stem is either **glabrous** e.g. *Trifolium* or **Hairy** e.g. *Helianthus annuus* (Sunflower) or provided with prickles i.e. **prickly** e.g. *Rosa*.



Trifolium



Helianthus



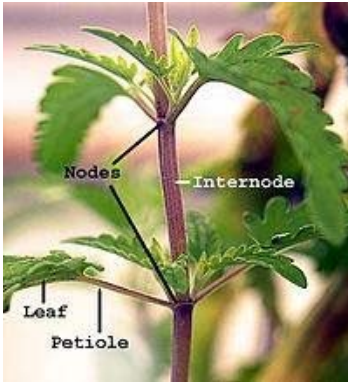
Rosa

E. Internal structure

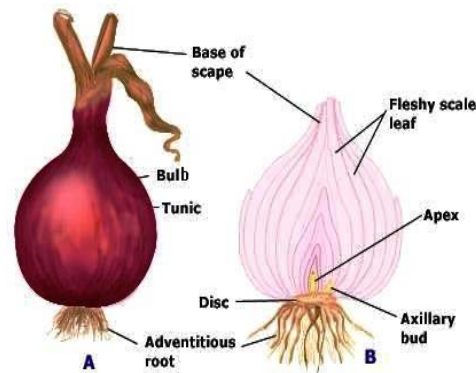
The stem is either **solid** i.e. filled inside with a pith e.g. *Salvia* or **hollow** i.e. without a pith e.g. *Vicia faba*.

F. Dwarfness

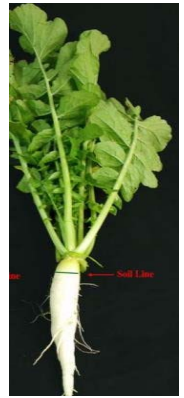
The stem is either **normal** i.e. divided into apparent nodes and internodes e.g. *Duranta* or **dwarf** i.e. the stem becomes very short so that its nodes and internodes are not differentiated from each other e.g. discoid stem of *Allium cepa* (Onion) or dwarf stem of radish.



Normal



Dwarf (discoid)



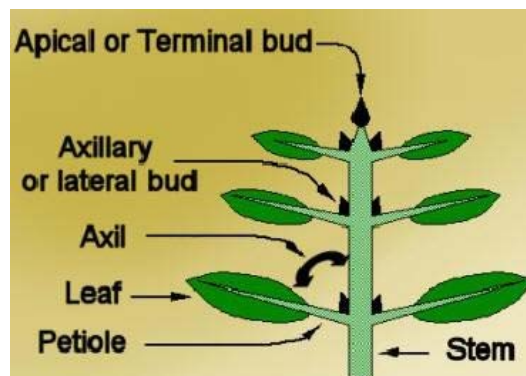
Dwarf stem

G. Buds

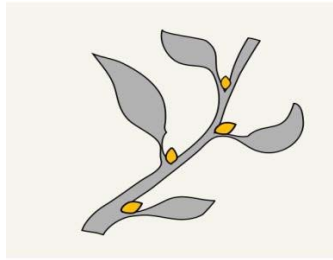
The bud is a **very short axis** not differentiated into nodes and internodes. Buds are classified according to their position, development, and duration into:

a. According to position:

1. **Terminal (apical) buds:** They are present at the apex of the stem and its lateral branches. Their normal function is elongation and differentiation of the stem and its branches e.g. *Casuarina* and cabbage.



2. **Lateral (axillary) buds:** They mostly arise at the nodes in the axils of leaves. More than one lateral bud may be present in the axil of the leaf. The largest, oldest and most active lateral bud is the **principal bud** while the other lateral buds present are **accessory buds** e.g. *Clerodendron*.



Axillary buds are located at the intersection of the leaf and stem of a plant

3. **Adventitious buds:** They do not arise in a normal position on the plant body e.g. leaves of *Begonia* or root of *tuber*.

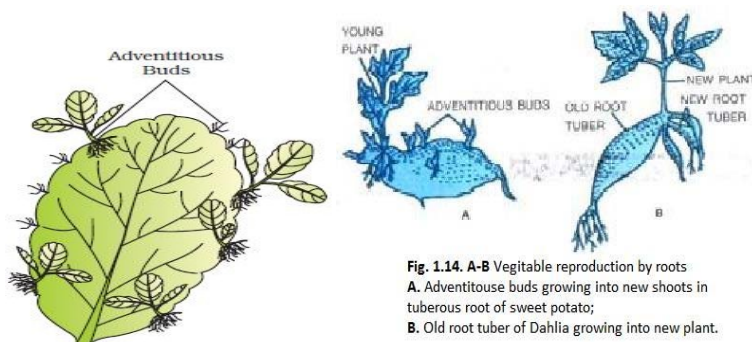
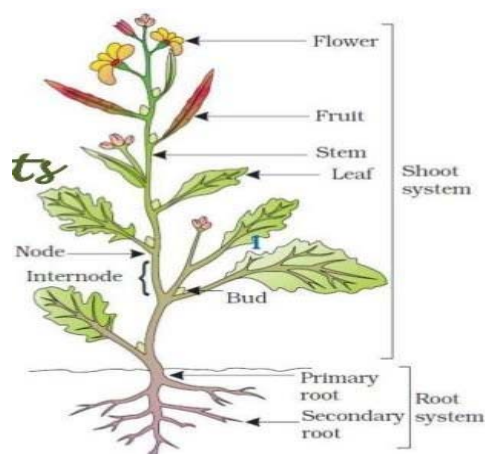


Fig. 1.14. A-B Vegetable reproduction by roots
 A. Adventitious buds growing into new shoots in tuberous root of sweet potato;
 B. Old root tuber of Dahlia growing into new plant.

- b. **According to development:** Buds are classified as follows:

1. **Leafy or branch buds:** They develop to branches carrying foliage leaves.
2. **Flower buds:** They give rise to flowers.
3. **Mixed buds:** They develop to branches bearing both foliage leaves and flowers.



- c. **According to duration:** The buds may be:

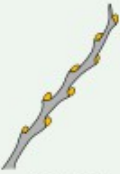
1. **Summer buds** and common among herbaceous and evergreen plants e.g. *Duranta*



2. **Winter buds** protected by scale leaves, common among perennials e.g. *Populus*.



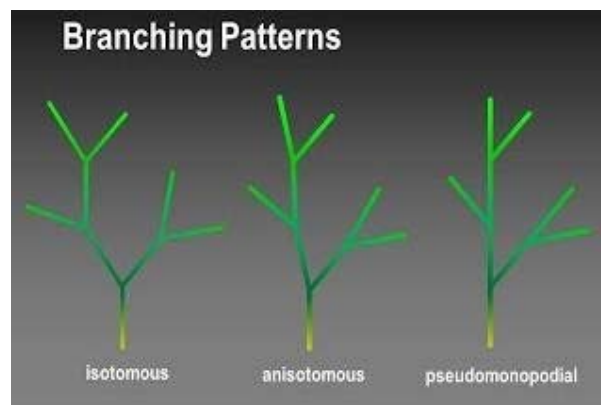
Types of Buds

by Location	by Status	by Morphology	by Function
 Terminal	 Accessory	 Scaly	 Vegetative
 Axillary	 Pseudoterminal	 Covered	 Reproductive
 Adventitious	 Dormant	 Hairy	 Mixed bud
		 Naked	

I. Branching

Branching of the stem is due to the activity of the terminal and lateral buds present on the main axis or its lateral branches. There are two main types of branching of the stem as follows:

- a. **Apical dichotomous branching:** It is common among the lower plants e.g. *Fucus*, where the apical growing point of the thallus becomes divided into two meristematic cells or groups of cells each of which grows and develops into a branch. The same way of dichotomy is repeated throughout in the subsequent branches of the thallus.

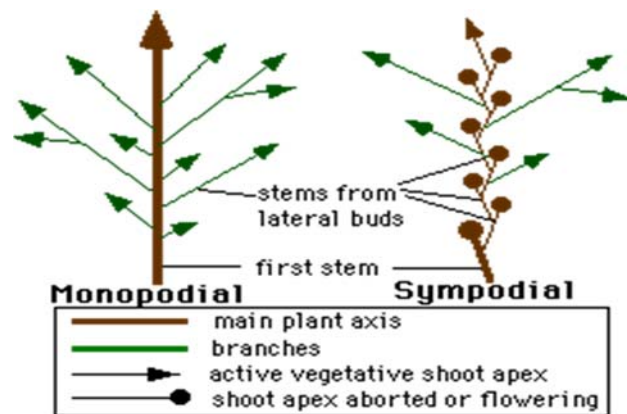


b. **Lateral branching:** It includes two types of branching

1. **Monopodial branching:** Where the main axis of the plant is developed from the terminal bud whereas the lateral buds develop to the lateral branches. Oldest and largest branches of the plant are away from the terminal bud while the youngest and smallest ones are close to it i.e. the lateral branches are in an **acropetal succession** e.g. *Casuarina*.

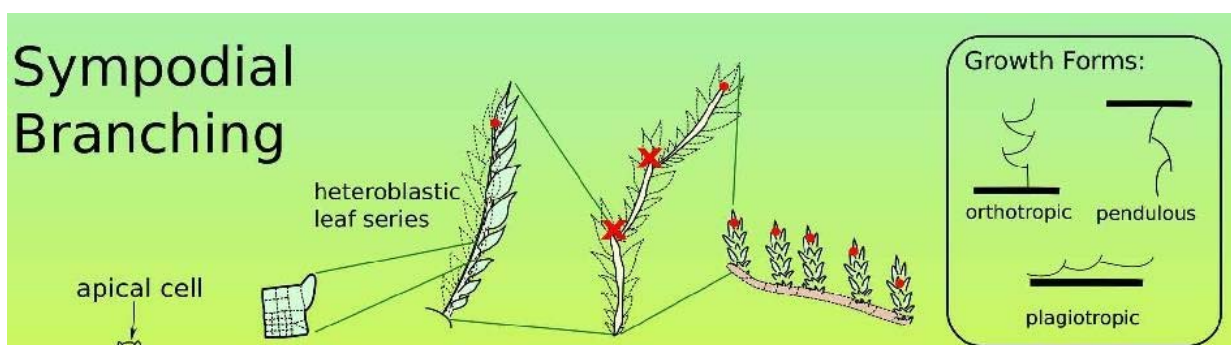


2. **Sympodial branching:** The terminal bud of some flowering plants may only grow for a short time after which it is transformed to a tendril or a flower e.g. *Vitis* and *Tribulus* respectively. The axillary bud just starts its activity continuing the vegetative growth of the shoot. However after giving one or more internodes this bud also modifies into a flower or a tendril and a new axillary bud continues the vegetative growth and this process is repeated.



Thus, the axis of the shoot system results from the successive growth of a number of buds and not from a single bud.

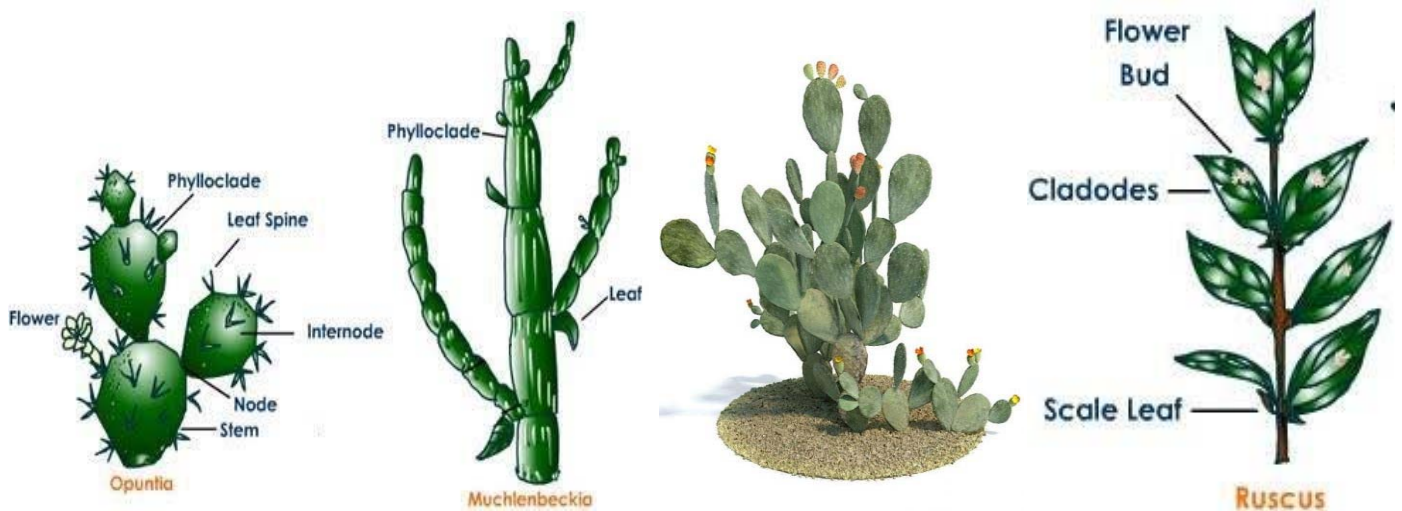
Underground rhizomes are commonly characterized by **sympodial branching**. The terminal bud of the rhizome develops to an aerial vegetative shoot above the soil surface. The main axis of the rhizome continues its elongation and growth by lateral buds which are successively developed in the axils of scale leaves behind the terminal bud of each segment of the rhizome.



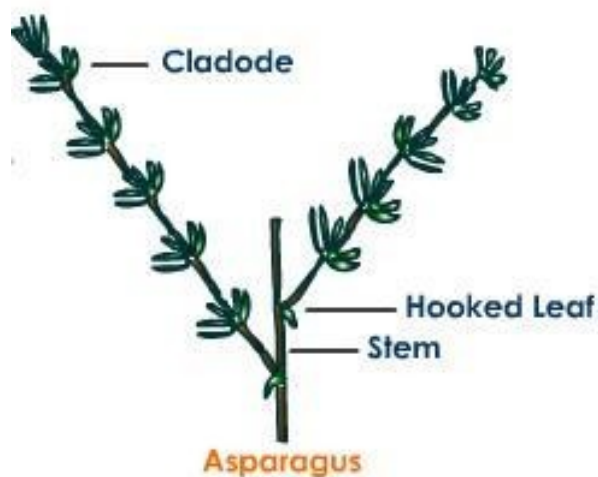
J. Metamorphosis: Stems may be metamorphosed to perform functions other than their normal functions as follows:

a. **For assimilation**

Phylloclades: The stem is flattened, with several internodes, green and leaf- like both in appearance and function e.g. *Ruscus* and *Muehlenbeckia*. Phylloclades of *Opuntia ficus indica* are green, flattened and fleshy. They are being photosynthetic and store water and food. Thus they are termed as **succulent stems**. The lateral buds of *Opuntia* are metamorphosed to spines.



Cladode: It is a single internode i.e. the stem is being flattened, green and each cladode is represented by a single internode e.g. *Asparagus*.



b. For reduction of the transpiring surface and protection

Most **xerophytic** plants carry **Spiny lateral branches** which help in **reducing the transpiration surface**. In addition, the spines usually **protect the plant**

against grazing animals e.g. *Alhagi*.



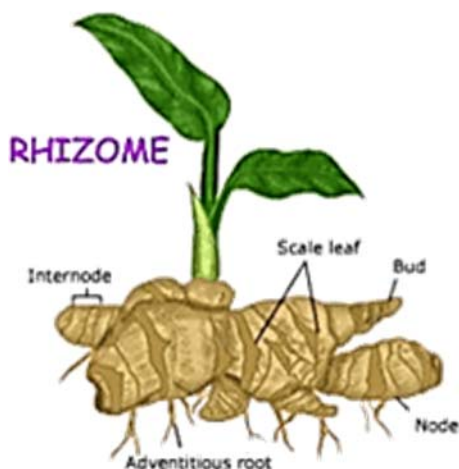
c. For climbing

The weak stems may modify for climbing either **by tendrils** which are either a modified terminal bud as in *Vitis* or a modified axillary bud e.g. *Antigonon* or climb by **hooks, prickles or spines** which may be metamorphosed lateral branches as in *Bougainvillea*.

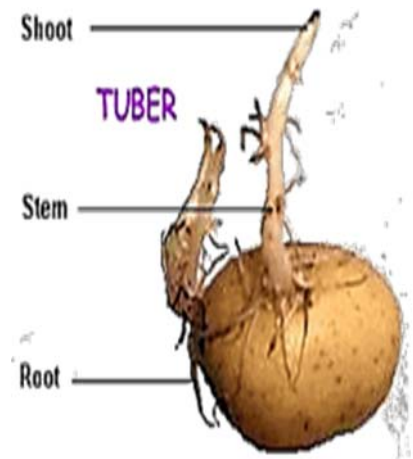


d. For perennation, storage and vegetative reproduction

- **Rhizome:** A horizontal underground stem growing horizontally beneath the soil surface e.g. *Cynodon dactylon*. It is usually branched and divided into nodes and internodes. Scale leaves and adventitious roots arise from the nodes. Aerial green shoots arise from the upper surface of the rhizome at the nodes. Branching of the rhizome is mostly sympodial.



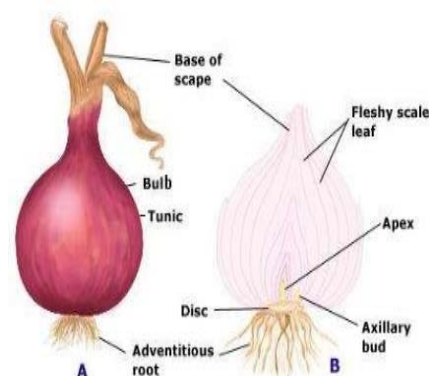
- **Tuber:** It is an enlarged portion of an underground perennial stem e.g. potato. They penetrate the soil surface, grow horizontally below, branch in different directions and their tips are swollen to produce the tubers of potato. The surface of the tuber is full of shallow depressions known the **eyes**. The eyes represent the **nodes of the underground stem**. The eye is surrounded by very small scale leaves and in the centre may be found one or more axillary buds.



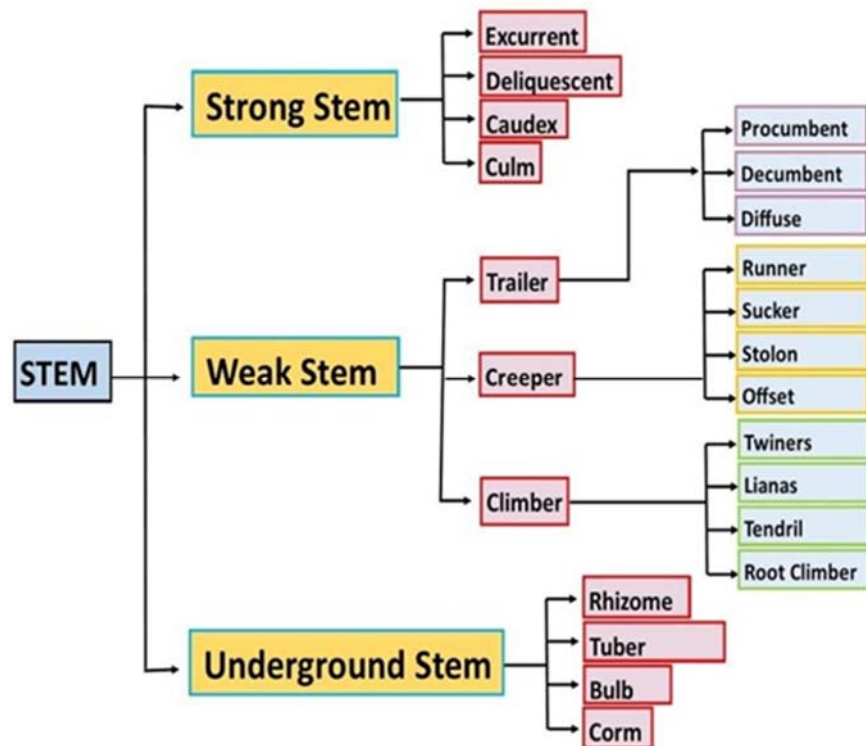
- **Corm:** A short, thickened underground stem, upright in position (*Colocasia*). It is divided into **nodes and internodes**. The nodes are circular rings around the surface of the corm. The internodes in between the nodes are covered by **papery brown scale leaves**. Adventitious roots and lateral buds are also produced at each node. If the corm is left in the soil the buds will grow to produce **corms of the next year**.



- **Bulb:** It is an **underground short discoid stem** composed chiefly of enlarged and fleshy leaf bases which are termed the **scales**. Food is chiefly stored in the scales



e.g. **onion**. The discoid stem carries a terminal bud on its upper surface which is surrounded by the scales. Other axillary buds may be also present in the axils of the scales. **The bulb of garlic** is divided into **small bulbils**.



II. The Leaf

Leaves are thin, expanded structures, commonly rich in chlorophyll and arising laterally from stems at the nodes.

Functions of the leaf

1. Leaves are mainly the organs of photosynthesis.
2. Respiration and transpiration.
3. Additional functions such as storage, climbing, etc.

Description of the leaf

A. Insertion

1. **Radical:** arise from a reduced underground stem (Onion and radish).



2. **Cauline:** arise along main axis of stem (*Vicia faba*).



B. Duration

1. **Evergreen:** Leaves remain throughout the whole year green (Olive).



2. **Deciduous:** Leaves fall down in autumn or winter (*Vitis*).



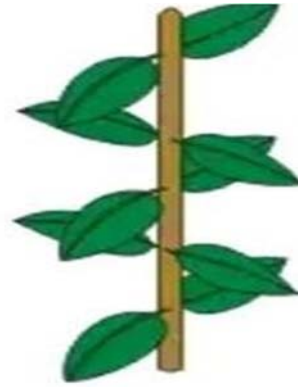
C. Arrangement

1. **Alternate:** one leaf at each node (Eucalyptus).



2. **Opposite:** Two leaves at each node, may be:

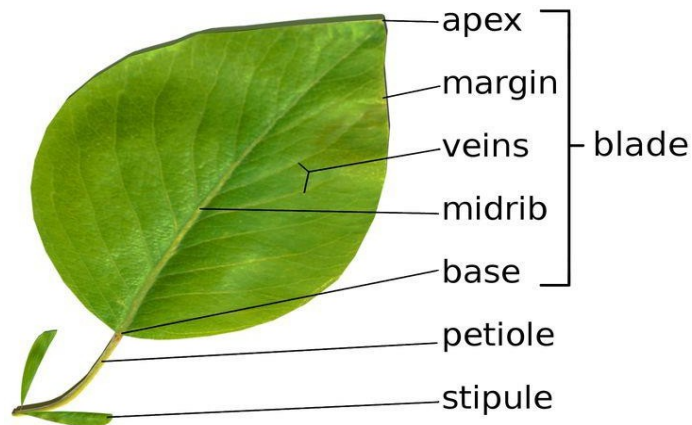
- **Superposed** successive pairs of leaves over each other.
- **Decussate** successive pairs of leaves at right angles to each other.



3. **Whorled (Verticillate)**: more than two leaves at each node.



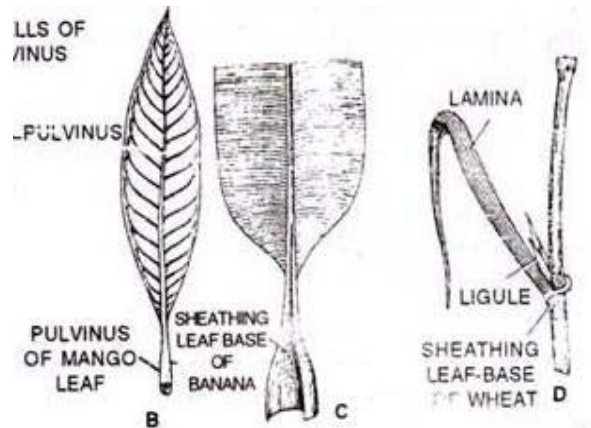
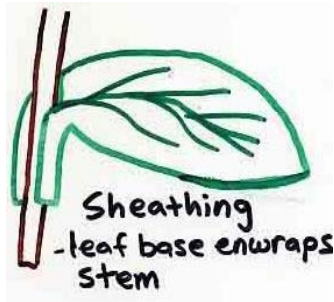
Main Parts of Leaf



D. **Leaf base**: It is the part of the leaf which is directly attached to the stem at the node and it many different kinds:

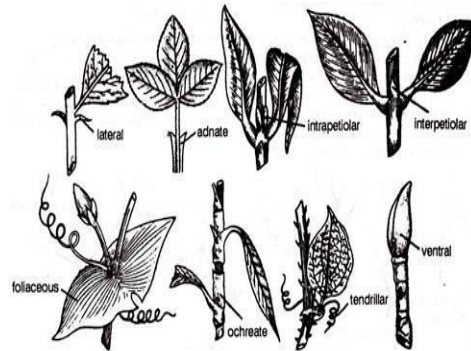
1. **Normal (exstipulate)** no swollen than petiole.
2. **Pulvinus** swollen than petiole.

3. **Sheathed** a broad flattened base.

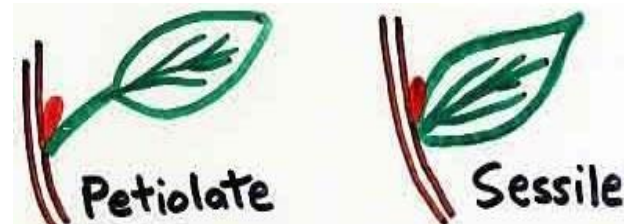


- a. **Exstipulate**, no appendages
b. **Stipulate**, leaf base with two lateral appendages.

Stipule may be ordinary, leafy, spiny, tendrillar, **hairy** ...



E. Leaf petiole: The long or short cylindrical portion between the leaf base and the blade. Leaves with no petiole are described as **sessile** e.g. *Linum* while leaves with a petiole are **petiolate** or **stalked leaves** e.g. *Eucalyptus*.

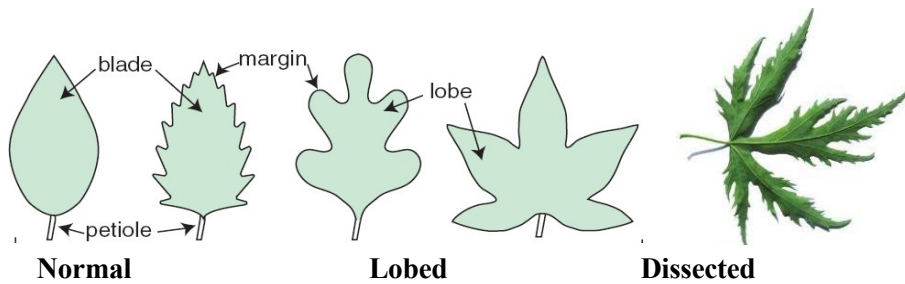


F. Leaf blade: It is the green photosynthetic dorsiventrally flattened portion of the leaf.

1. Composition:

a. Simple

1. **Normal:** When its blade is entire or slightly divided e.g. *Eucalyptus*.
2. **Lobed:** When the blade is divided into portions which are still united together by blade tissue as *Ricinus*.
3. **Dissected:** When the blade is deeply divided into thin segments e.g. *Daucus*.



b. Compound

Composed of 2 or more leaf-blade unites attached directly to leaf stalk or rachis (leaf stalk extension) it may be:

1) Pinnate

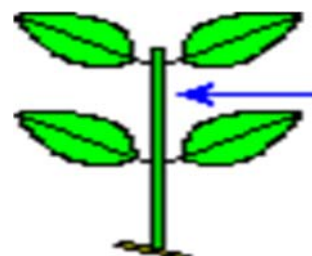
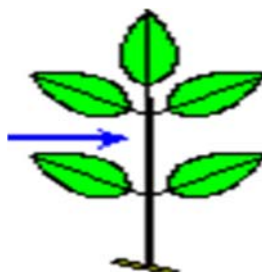
Each portion of the compound leaf is known as **leaflet or pinna**. Pinnae arise along the extension of the petiole which is known as the **rachis**.



2) Palmate, all leaflets come out from one point at the top of the apex of the petiole



- **Compound imparipinnate:** The rachis terminates by one leaflet e.g. *Rosa*.
- **Compound paripinnate:** The rachis terminates by a pair of leaflets e.g. *Cassia*



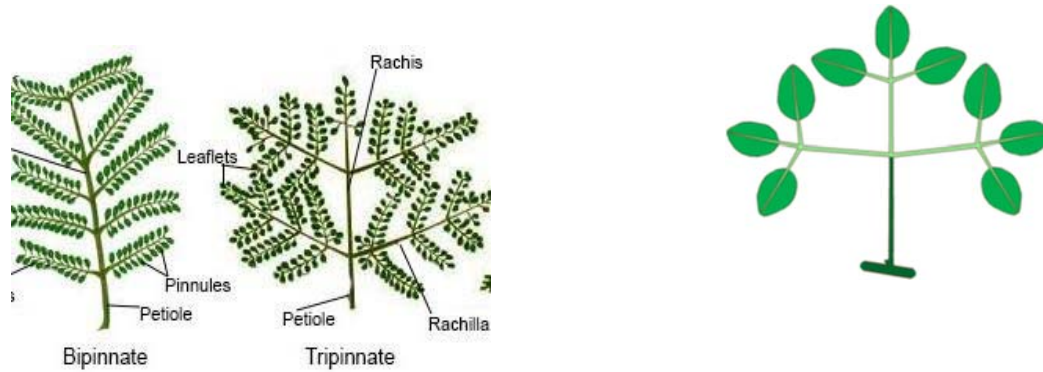
*Compound bipinnate:

Pinnae are further divided into pinnules e.g. *Delonix*.

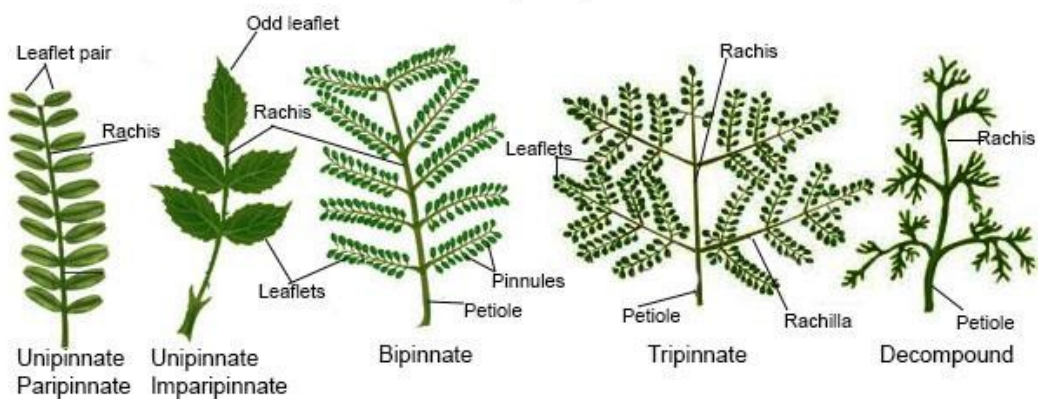
• ***Compound tripinnate:** The rachis is further

divided into secondary pinnules e.g. certain fern fronds.

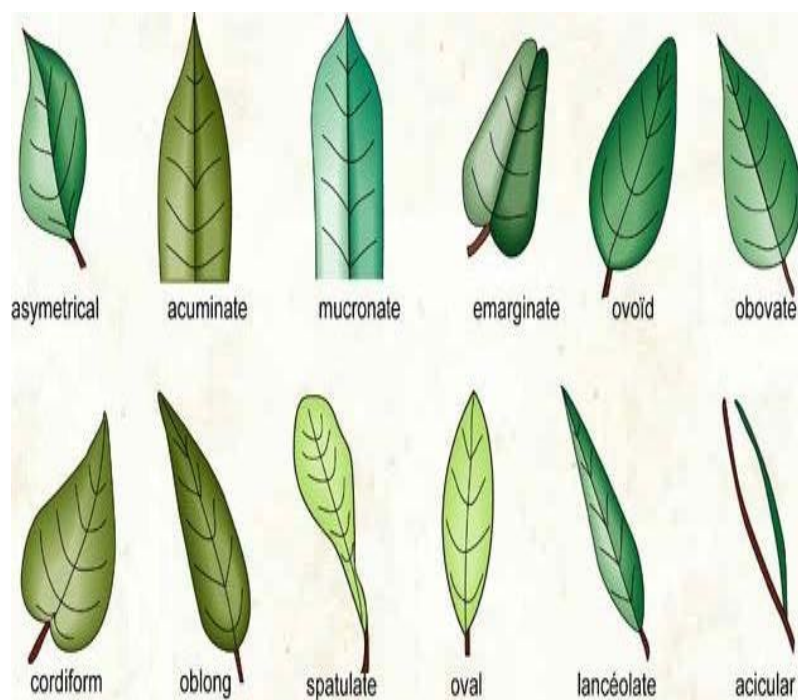
- ***Trifoliate:** The only three leaflets e.g. *Trifolium* (Clover).
compound leaf with



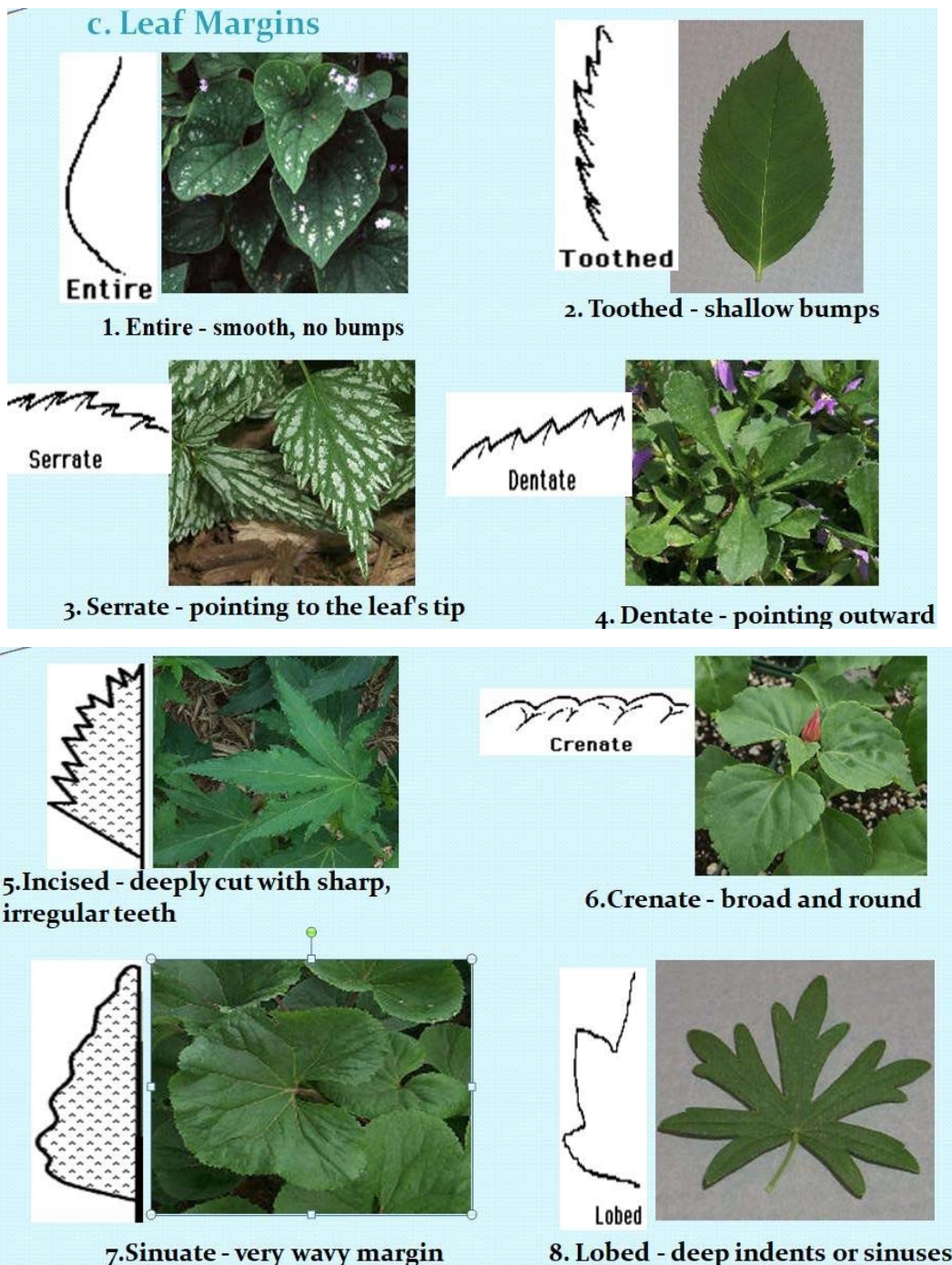
Pinnately compound leaf



2. Shape may be:



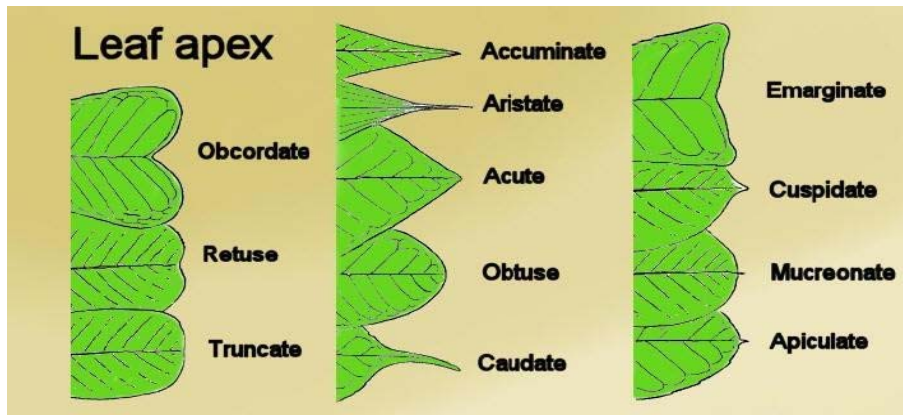
3. **Margin:** the leaf or leaflet margin may be:



4. **Apex:** The leaf apex is also of various shapes:

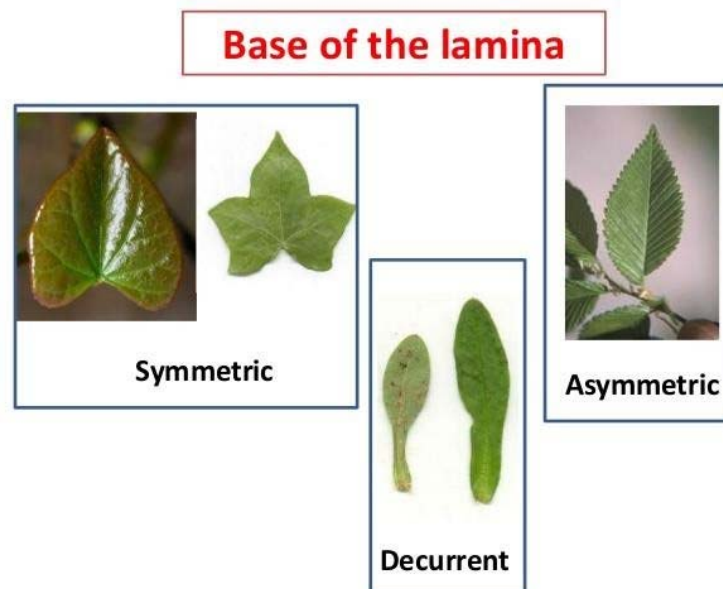
- Acute:** Ending in a point forming an acute angle e.g. *Duranta*.
- Acuminate:** Drawn out into long point e.g. *Dalbergia*.
- Caudate:** Drawn out into a long slender tail e.g. *Ficus religiosa*.
- Obtuse:** With rounded end e.g. *Pittosporum*.
- Notched (Retuse):** Obtuse with a shallow notch in middle e.g. *Trifolium*.
- Emarginate:** With a deep notch e.g. *Bauhinia*.

- g. **Mucronate**: A rounded apex provided with a small sharp projection at the end of the midrib e.g. *Medicago*.
- h. **Cuspidate**: The apex terminates into a sharp pointed end which is usually rigid e.g. Date palm.

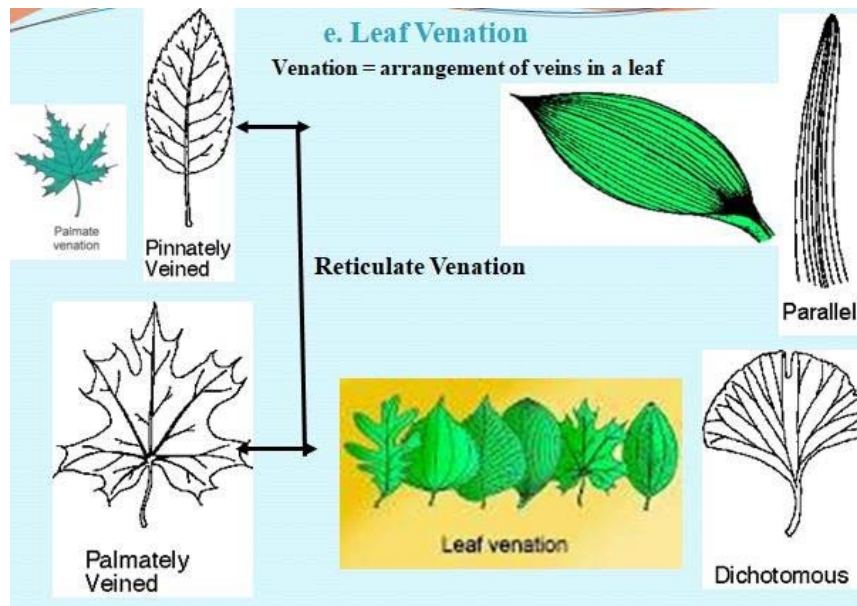


5. Base of lamina:

- a. **Symmetrical**: The two sides of the blade are equal in size e.g. *Hibiscus*.
- b. **Asymmetrical**: The two sides of the blade are unequal in size e.g. *Datura*.
- c. **Decurrent** متقطع: leaf blades that partly wrap or have wings around the stem or petiole and extend down along the stem.



6. **Venation** arrangement of vascular bundles or veins (midrib or the principal vein, lateral veins and veinules) of a leaf.



Parallel longitudinal venation (Basal)

Parallel transverse venation (Costal):

G. Metamorphosis: Leaves are supposed to be flattened and green to perform the main function which is photosynthesis. However in some plants the leaf may become modified to perform several special functions as follows:

- **For reduction of transpiring surface:** The leaves may be modified into scales e.g. *Ruscus* to reduce the transpiring surface.



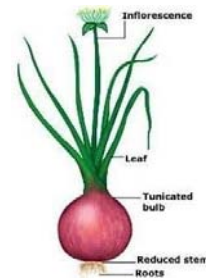
- **For protection:** The leaves and/or stipules may become spiny for protection of the plant against grazing animals.



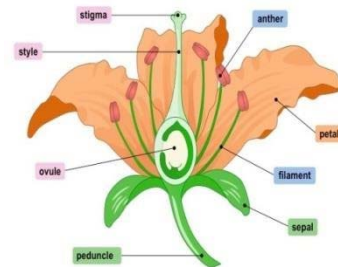
- **For climbing:** The leaf or the stipules may become spiny or modified into a tendril for climbing e.g. *Lathyrus* plant.



- **For storage:** In onion the white scales (fleshy leaf bases) do not perform photosynthesis but they store food and water.



- **For reproduction:** The flower is a modified stem, its receptacle usually carries sepals, petals, stamens, and carpels which are actually modified leaves.



E. Heterophylly: The same plant carries two or more different form of leaves e.g. *Vicia* seedling.



Model Questions

Q₁- MCQ

1. Roots not developed from the radical (a. adventitious roots b. tuberous roots c. normal roots).
2. Leaf arises along the main axis of the stem (a. radical leaf b. evergreen leaf c. cauline leaf).
3. The plant cell wall arises at (a. Telophase b. Metaphase c. Anaphase).
4. Two lateral appendages around leaf base are (a. stipulates b. pulvinus c. sheath).
5. When some of the prop roots reach the soil surface and penetrate it (a. Contractile roots b. Pillar roots c. Haustorial roots).
6. Root system performs many functions to the plant not from them (a. Fixation b. Absorption c. Photosynthesis).
7. Leaflets come out from one point of the petiole (a. compound pinnate b. compound bipinnate c. compound palmate).
8. Mid rib in middle of blade and lateral veins more or less perpendicular (a. reticulate pinnate venation b. parallel costal venation c. parallel basal venation).
9. Leaves fall down in winter (a. Evergreen b. Radical c. Deciduous).
10. If two leaves at each node the arrangement is (a. Alternate b. Whorled c. Decussate).
11. Roots produced by the parasitic flowering plants (a. Haustorial roots b. Climbing roots c. Aerial roots).
12. Bud not arise in a normal position e.g. on leaves (a. apical bud b. adventitious bud c. lateral bud).
13. Flattened, with several internodes, green and leaf- like stem (a. tuber b. phylloclades c. Cladode).
14. Modified stem nodes are circular covered by papery brown scale leaves (a. corm b. tuber c. bulb).
15. Biology is (a. Living organisms b. Dealing with living organisms c. Dealing with biological processes).

16. If two leaves at each node the arrangement is (a. Alternate b. Whorled c. Decussate).
17. Roots produced by the parasitic flowering plants (a. Haustorial roots b. Climbing roots c. Aerial roots).
18. Bud not arise in a normal position e.g. on leaves (a. apical bud b. adventitious bud c. lateral bud).
19. Root system performs many functions to the plant not from them (a. Fixation b. Absorption c. Photosynthesis).
20. Plant morphology deals with (a. Internal forms b. Mixed forms c. External forms).
21. Flattened, with several internodes, green and leaf- like stem (a. tuber b. phylloclades c. Cladode).
22. Zone of the root system formed of meristematic cells (a. Growing apex b. Zone of absorption c. Elongation zone).
23. Modified stem nodes are circular covered by papery brown scale leaves (a. corm b. tuber c. bulb).
24. Functions of the stem are (a. Bearing and absorption b. Bearing and connection c. Bearing and fixation).
25. Cladode is (a. flattened several internodes b. flattened single internode. c. fleshy leaf bases).
26. Roots not developed from the radical (a. adventitious roots b. tuberous roots c. normal roots).
27. Branching of the rhizome is mostly (a. apical branching b. monopodial branching c. sympodial branching).
28. Leaf arises along the man axis of the stem (a. radical leaf b. evergreen leaf c. cauline leaf).
29. Two lateral appendages around leaf base are (a. stipulates b. pulvinus c. sheath).
30. Tuberous tap root originate from the (a. Base of the stem b. Radical c. Root primordia).
31. Fine thread-like roots common in family gramineae (a. Fibrous roots b. Tap roots c. Tuberous roots)
32. Leaflets come out from one point of the petiole (a. compound pinnate b. compound bipinnate c. compound palmate).

33. Mid rib in middle of blade and lateral veins more or less perpendicular (a. reticulate pinnate venation b. parallel costal venation c. parallel basal venation).
34. When some of the prop roots reach the soil surface and penetrate it (a. Pillar roots b. Contractile roots c. Haustorial roots).
35. Midrib and lateral veins are similar in size and shape (a. reticulate pinnate venation b. parallel costal venation c. reticulate palmate venation).
1. Midrib in middle and lateral veins arises at different points along its sides (a. reticulate pinnate venation b. parallel costal venation c. reticulate palmate venation). The broad flattened leaf base named (A. Sheathed B. Pulvinus C. Normal).
2. In gymnosperms, the food storage is part of the female gametophyte (A. Triploid tissue B. Diploid tissue C. Haploid tissue)
3. Transpiration important function of the leaves for (A. Conduction B. Photosynthesis C. Respiration).
4. Branching common in lower plants from apical point (A. Monopodial B. Apical C. Sympodial).
5. The surface appendages that have vascular tissue (A. Glabrous B. Hairs C. Pricks).
6. Adventitious roots varied on tap roots with (A. Function B. Original C. Structure).
7. If two leaves at each node the arrangement is (A. Alternate B. Whorled C. Decussate).
8. Roots produced by the parasitic flowering plants (A. Haustorial roots B. Climbing roots C. Aerial roots).
9. Bud arises on plant leaves (A. Apical bud B. Adventitious bud C. Lateral bud).
10. Flattened, with several internodes, green and leaf-like stem (A. Tuber B. Phylloclades C. Cladode).
11. The compound leaf with only three leaflets (A. Trifoliate B. Dissected C. Palmate).
12. Discoid stem of dwarf plants may be (A. Corm B. Tuber C. Bulb).
13. Very wavy margin (A. Sinuate B. Serrate C. Dentate).
14. The tendrils of weak stems are represented as (A. Prostrate B. Creeping C. Metamorphosed).

15. Arrangement of leaves on the stem depend on (A. Position B. Number C. Shape).
16. The most organ of enzyme content in the plants is (A. Root B. Stem C. Leaf).
17. Enlarged portion of an underground perennial stem have eyes (A. Corm B. Tuber C. Bulb).
18. Leaf arises from a reduced underground stem (A. Cauline B. Deciduous C. Radical).
19. When some of the prop roots reach the soil surface and penetrate it (A. Contractile roots B. Pillar roots C. Haustorial roots).
20. The two sides of the blade base are unequal in (A. Symmetrical B. Asymmetrical C. Decurrent).
-

21. All of the below are functions of the root system except:

- A. Storage B. Water absorption C. Photosynthesis D. Fixation in the soil.
-

Q₂- TRUE (T) or FALSE (F)

1. Leaf is the only photosynthetic organ in the plant.
2. Monopodial branching is apical branching in acropetal succession.
3. Summer buds in perennial plants protected by scale leaves.
4. Radical leaf arise from node along main axis of stem
5. Root apex is active promeristem present at the tip of the root.
6. Prostrate stem produces adventitious roots and aerial shoots at nodes.
7. Haustorial root store excessive amounts of food.
8. Contractile roots is coiled adventitious roots developing from discoid stem.
9. Dwarf shoot long stem that nodes and internodes are differentiated.
10. Sheathed leaf base is appendages from discoid stem.
11. Apical bud response to elongation and differentiation the main axis of the plant.
12. Root system must grow beneath the soil surface.
13. Discoid stem very short that its nodes and internodes are not differentiated.
14. Community is the highest level of biotic organization.
15. Leaf is the only photosynthetic organ in the plant.
16. Prostrate stem produces adventitious roots and aerial shoots at nodes.

17. Trees have woody and lignified tissues and the branches close to the soil.

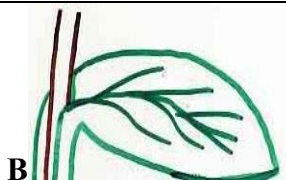
18. Cotyledon is the seed leaf.

19. Evergreen plants have winter buds common among trees.

20. Growing apex of the root has rapid elongation cells.

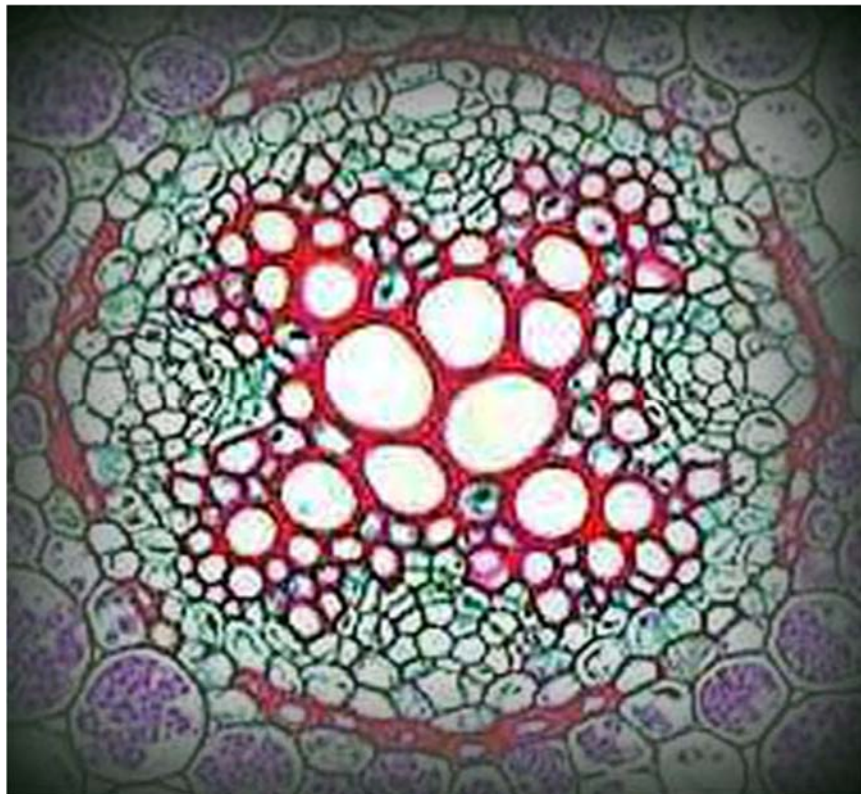
21. The terminal bud grows for a short time at sympodial branching.

Q₃- MATCHING BETWEEN COLUMN ONE AND TWO

Column : One	Column : Two
1. Simple dissected leaf	
2. Decurrent base of lamina	
3. Palmately venation	
4. Sheathed leaf base	
5. Whorled arrangement	
6- Trifoliate compound leaf	

Part 2:

Pant Anatomy



**Prof. Ragab
Teama**

2025-2026

Part 2: Plant Anatomy

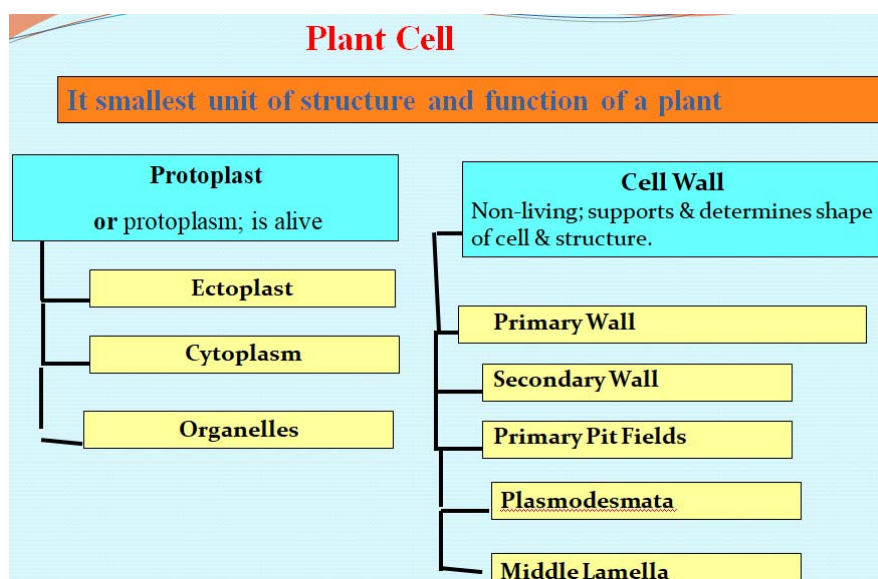
Plant anatomy is the study of the internal structure and cellular organization of plants, focusing on their tissues and organs like roots, stems, and leaves. It involves microscopic examination of plant components to understand their specialized functions, such as the xylem and phloem for transport, the epidermis for protection, and parenchyma for storage. This knowledge is crucial for understanding how plants function, grow, and respond to their environment.

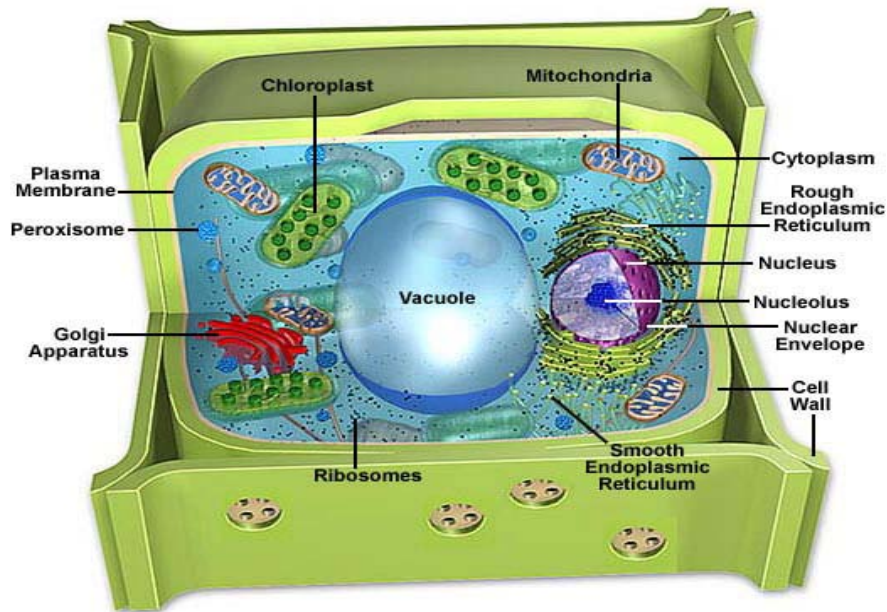
Plant anatomy deals with **elements and tissues** from which the plant is constructed. It mainly studied **under the microscopes**.

The Plant Cell

The term **cell** is derived from the Latin word 'cellula' which means a small apartment (**Robert Hooke, 1665**). **Hanestein (1880)** coined the term **protoplast** to indicate the unit of protoplasm found in a single cell.

The plant cell is the **basic smallest unit of structure and function** of a plant. It consists of the **protoplast** bounded by a **cell wall**. The protoplast is divided into: **protoplasmic or living** and **non- protoplasmic or non- living components**.





I. Protoplast (protoplasm) is alive.

Protoplasmic components:

A. Ectoplast - plasma membrane; next to wall; controls passage of materials into and out of cell.

B. Cytoplasm - appears as a transparent semi-fluid substance. Water form 85%- 95% of it, proteins constitute the most important components. It is viscous material inside ectoplast but outside nucleus, it cyclosis - cytoplasmic streaming.

C. Organelles - membrane bound components that include:

1. Nucleus

Centre of the activity, the site of the hereditary, in all living cells except the sieve tube elements. Normally round; in young cells, located in the center of cell; as cell matures, it is pushed to the side, consists of:

- a. **Nuclear Membrane** - two of them.
- b. **Chromatin** - chromosomal material; made of DNA & histones.
 - 1) **DNA** - Deoxyribonucleic Acid; consists of nucleotides.
 - i. **Pentose Sugar**

ii. Nitrogenous Bases

- Cytosine
- Guanine
- Thymine
- Adenine

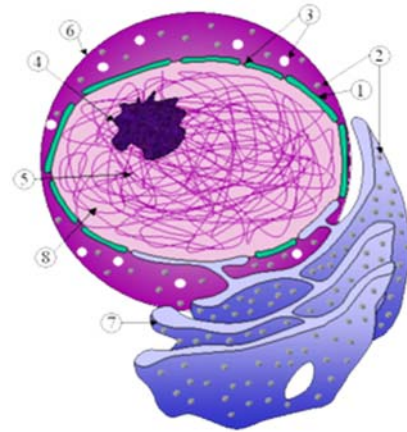
A-T , G-C

iii. Phosphate

- 2) **RNA** - different pentose sugar than DNA; Uracil instead of Thymine.

c. **Nucleoplasm** - material in nucleus contains ribosomes, enzymes, proteins.

d. **Nucleolus** - synthesis of nuclear material & R-RNA.



2. Plastids

Spherical or discoid bodies present in the cytoplasm of plant cells and absent from bacteria, blue green algae, slime molds and true fungi. Plastids **are** classified on the basis of their pigmentation into:

a. Chloroplasts

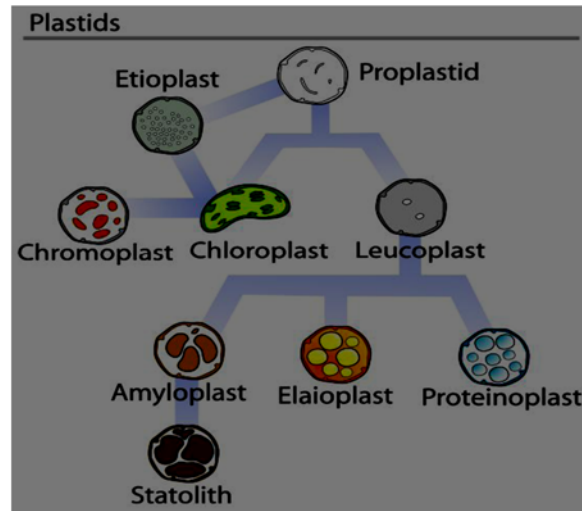
- 1) **Chlorophyll** - green; photosynthetic.
- 2) **Carotene** - orange; precursor to vitamin A; prevents photooxidization; accessory to photosynthesis.
- 3) **Xanthophyll** - yellow-green; same function as carotene but no vitamin A synthesis.

b. **Chromoplasts** - no chlorophyll but has carotenoid pigments.

c. **Leucoplasts** - no pigments; colorless.

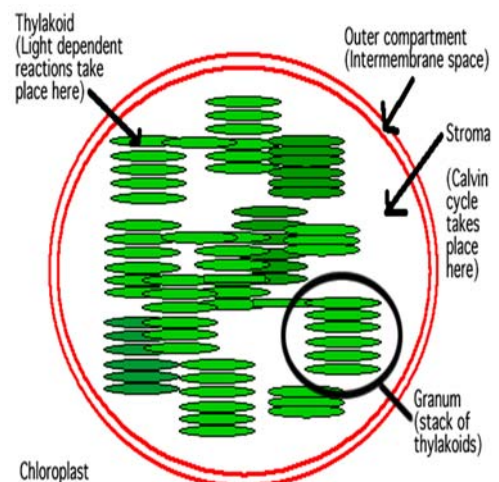
- 1) **Amyloplasts** - stores starch; hilum & starch layers.
- 2) **Elaioplasts** - stores oils.
- 3) **Proteinoplast** - stores proteins

The Plastids arise from pre-existing bodies called proplastids as follows:



Ultra-structure of chloroplast

Each chloroplast has a double-layered membrane surrounding the colourless matrix called **stroma**. The **grana** (chlorophyll bearing units) are embedded in the stroma. Each **granum** consists of a series of double-membraned lamellae or **thylakoides** stalked one upon the other. The grana are interconnected by a system of **intergranal lamellae or frets** that pass through the stroma.

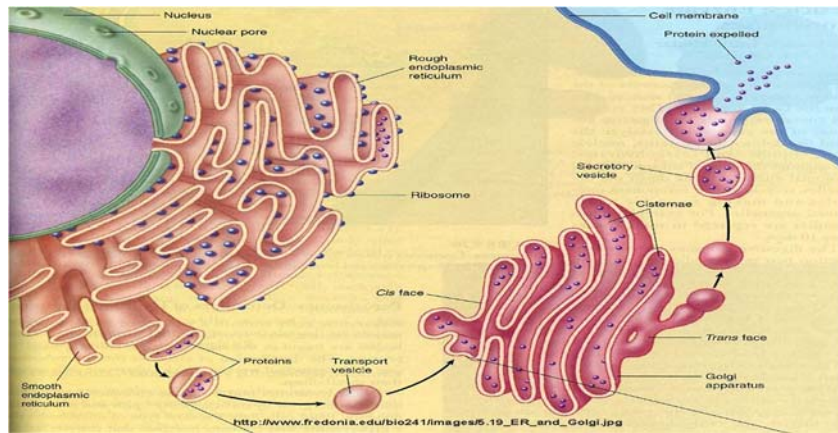


3. Endoplasmic Reticulum (ER)

An intricate network of tube-like structures distributed extensively throughout the cytoplasm.

The endoplasmic reticulum is believed to occur in two forms:

- Smooth** - lipid & membrane synthesis.
- Rough** - ribosomes attached; protein synthesis



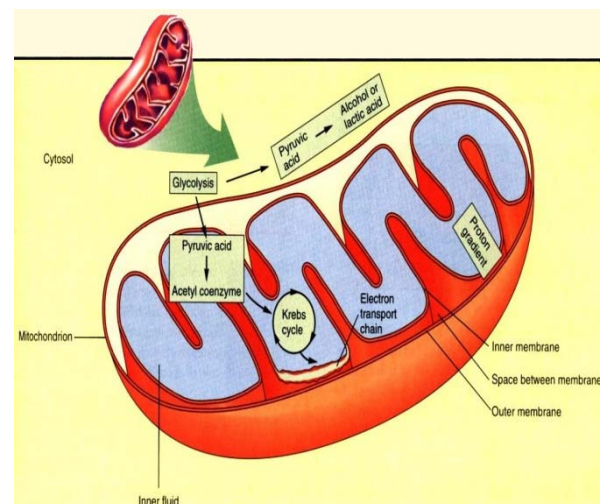
4. Ribosomes

They are minute bodies found free in the cytoplasm, in plastids and mitochondria consist of protein and RNA. They are the sites of protein synthesis.

5. Mitochondria

It spherical or rod-shaped bodies present in the cytoplasm composed of lipoproteins, has a double membrane; inner membrane is thrown into folds called cristae into the cavity (lumen) of the mitochondrion. It contains sugars, organic acids, DNA, RNA, respiratory enzymes. The power houses of cells as they are the sites of synthesis of the energy rich compound ATP (Adenosine triphosphate). Besides, they associated with respiration as most of the oxidative enzymes of the respiratory cycle

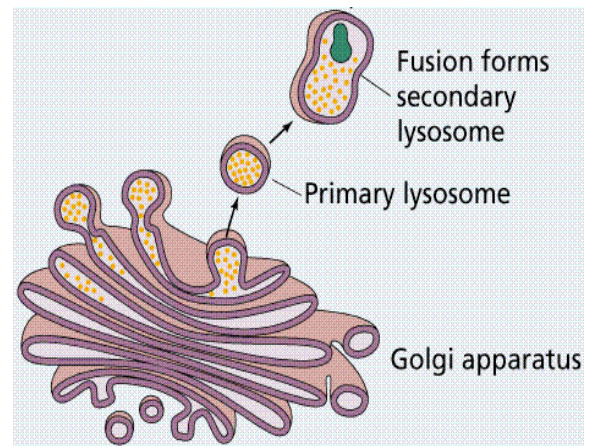
particularly those of the Krebs cycle are located in them.



6. Golgi Bodies

It a net- like bodies, stack of parallel flattened sacs each with two membranes, and clusters of very small

vesicles pinched off ends of sacs, secretion of proteins and complex polysaccharides.



7. **Microbodies** - very small bodies.

- a. **Peroxisomes** - photorespiration.
- b. **Glyoxysomes** - convert fats to sugars.
- c. **Lysosomes** - contains hydrolytic

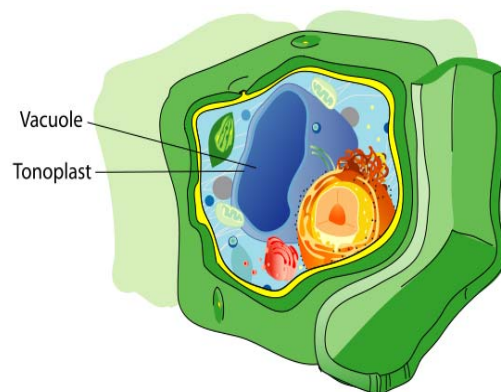
enzymes, breaks down molecules in presence of water.

8. **Spherosomes** - stores lipids.

II. Non-Protoplasmic components

1. Vacuoles

It a cavity within the cytoplasm filled with liquid (cell sap) separated from the cytoplasm by **tonoplast**. All vacuoles of a cell are collectively termed **vacuome**. Two kinds, **oil vacuoles** and **water vacuoles**.

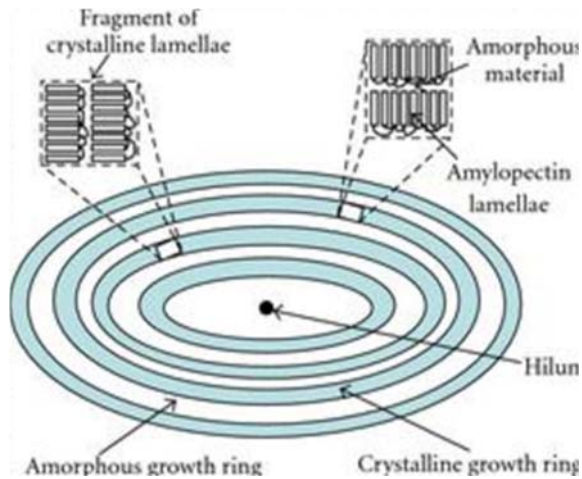


2. Ergastic Substances

They are **reserve food materials** or by-products of metabolism. They are **inorganic and organic** substances.

- A. **Starch Grains**, formed as minute particle hilum, layers of

starch deposited around hilum.

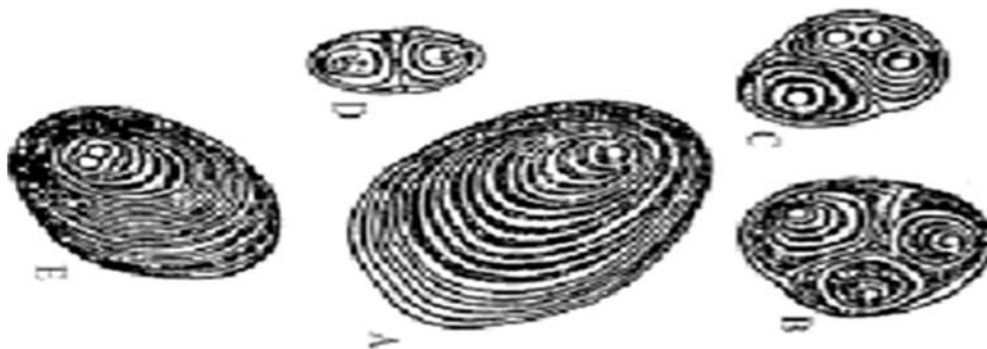


According to hilum position they may be:

- Centric
- A centric

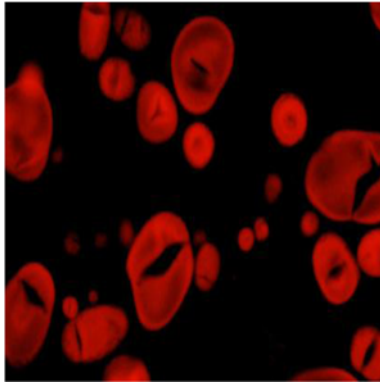
According to type of deposition they may be:

- Simple grains possess a single hilum.
- Semi-compound grains union of two or more grains surrounded by a common envelope.
- Compound grains aggregates of individual grains, no common envelope.



According to hilum shape they may be:

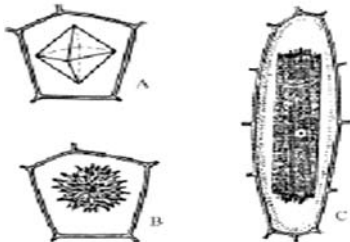
- A point (Potato)
- Slightly elongate (*Phaseolus*)
- Stellate and radiating from the centre
- (*Pisum*)
- Elongated and branched (*Zea*).



B. Crystals - solid waste products often deposited in plant tissues in the form of calcium salts and silica.

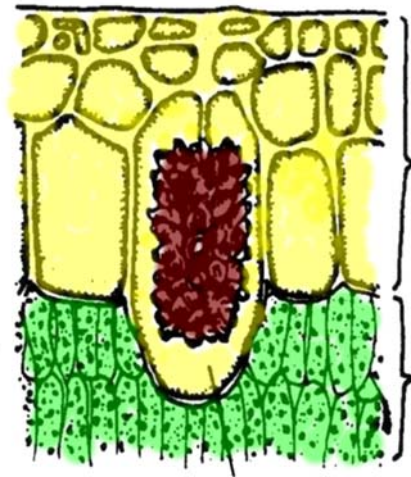
a. **Calcium oxalate crystals**

- i. **Druses**, solitary; rosette- shaped
- ii. **Raphides**, elongated in bundles in vacuoles; tooth pick shaped.



b. **Calcium carbonate crystals**

Cystolith, like a bunch of grapes suspended from a stalk, in *Ficus* leaves.



II- The Cell Wall

A. Characteristics

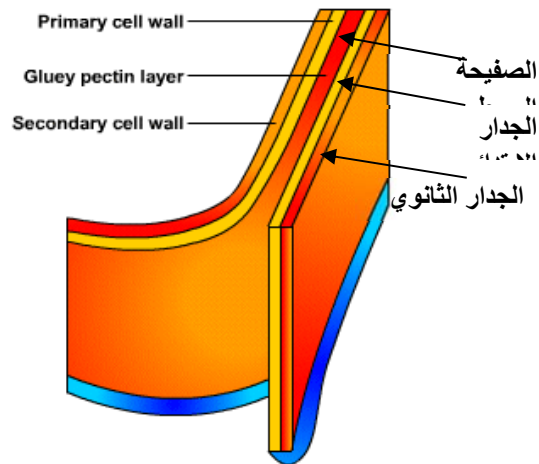
It produced by protoplast; non-living; supports & determines shape of cell & structure. **It also** plays role in **absorption, transpiration, translocation and secretion.**

B. Formation of the cell wall

1. The cell wall arises at telophase.
2. A partition appears inside the phragmoplast (spindle fibrils), called the cell plate.
3. The plate becomes viscous to form middle lamella.
4. Two new cells lay down a wall on both sides of the middle lamella, wall formed of cellulose, primary wall.
5. Additional wall thickening deposited, form secondary wall of additional cellulose or hemicellulose, lignin, cutin, suberin and waxes.

C. Parts

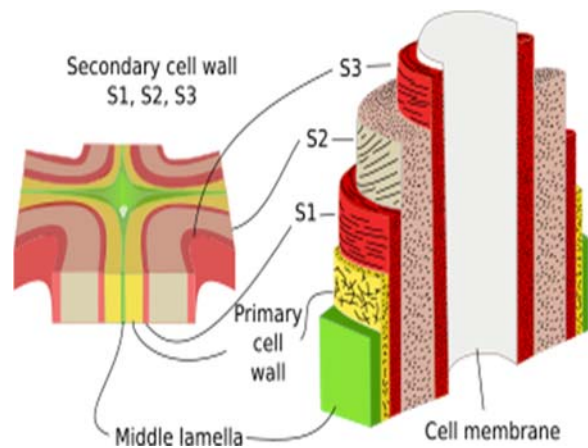
1. **Primary Wall** - very plastic; made of cellulose, hemicellulose, & cutin.
2. **Secondary Wall** - found only in older cells; thicker; adds strength; strengthened with lignin.
3. **Primary Pit Fields** - permeable area on Primary Wall.
 - **Simple Pits** - found only when secondary wall is present.
 - **Bordered Pits** - found only when secondary wall is present.
4. **Plasmodesmata** - cytoplasmic strands through cell walls connecting the protoplast of adjacent cells.
5. **Middle Lamella** - layer of cementing substance between adjacent primary walls; made of pectin.



D. Growth of the cell wall

Two ways for growth of the cell wall:

1. **Intussusception**: growth of cell wall in surface area through addition of the new wall material among parts of the expanding wall.
2. **Apposition**: growth of the cell wall takes place in thickness through deposition of successive layers of wall material layer upon layer.



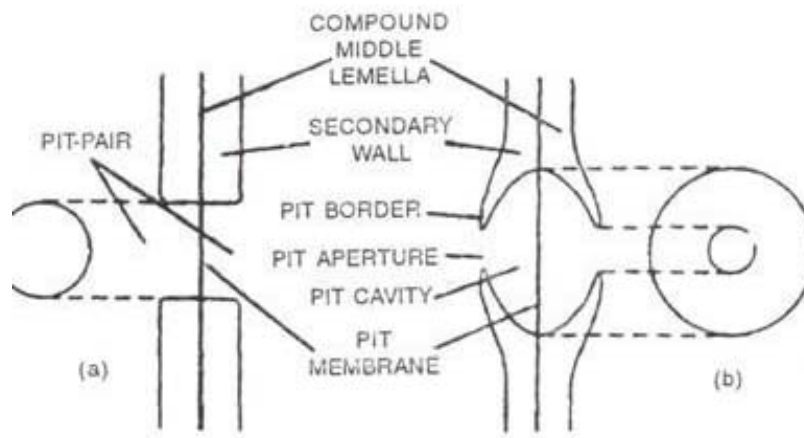
E. Pits

They are depressions on either the primary or secondary wall:

- Of primary wall called primary **pit fields** (permeable area)
- Of the secondary walls are termed **pits**.

A pit consists of:

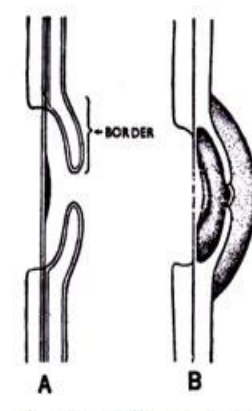
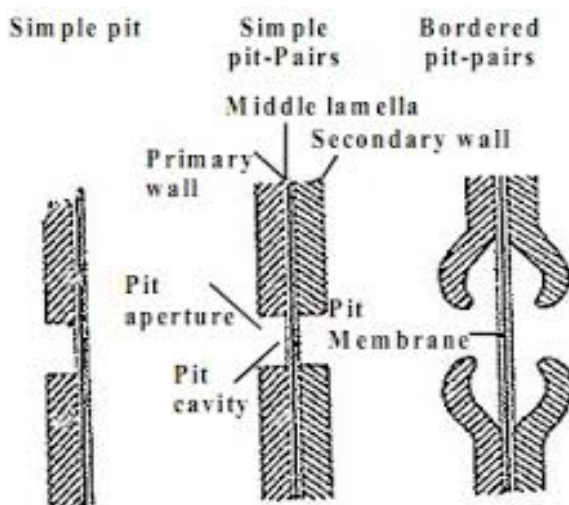
1. **Pit cavity** opens internally into the lumen of the cell.
2. **Pit membrane** which closes the pit cavity.
3. **Pit aperture** opening of the pit on the inner side of the cell wall.



Generally, two pits appear opposite each other in the walls of the two adjacent cells (pit pair). When no complementary pits are in the adjacent cell they called a blind pit.

Pits of secondary walls may be:

1. **Simple pits**, occur in parenchyma cells, phloem fibres and sclereids, cavity in form of a canal, branched canal pits (ramiform pits), when canals unite together, often aggregated (sieve pitting).
2. **Bordered pits**, in the tracheids, xylem vessels and fibres, secondary wall overarches the pit cavity forming the pit chamber and narrows down its opening called the pit aperture (may be circular, lenticular or linear) some pit membrane is thickened in central termed torus.
3. **Half-bordered pit**, a bordered pit becomes opposite a simple pit a half-bordered pit is formed.



III- Tissues

It is a group of cells of same type (simple tissue) or of mixed type (complex tissue e.g. xylem and phloem) having a common origin and performing one specific function.

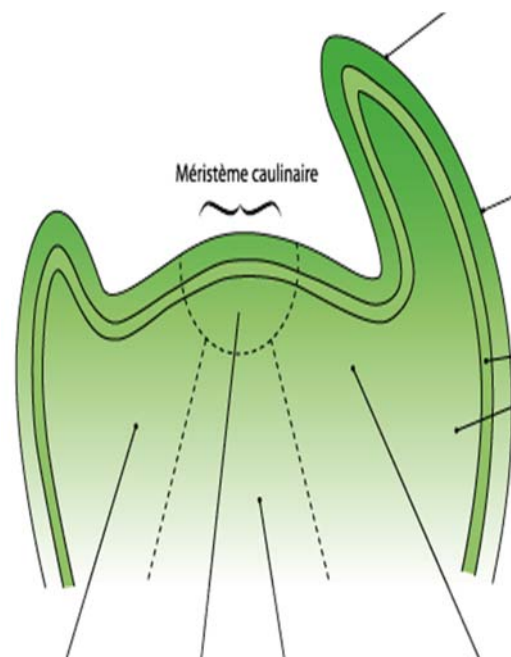
Tissues classified into **meristematic tissues** (meristems) and **permanent tissues** (derived from meristems).

A. Meristems

- i. **Young tissues of embryo** or mature plant for its growth and development composed of meristematic cells in a state of division.
- ii. **Meristematic cells** thin-walled, isodiametric; being spherical, oval or polygonal in shape, rich in protoplasm, with large nuclei, lacking plastids (in proplastid stage), vacuoles small or absent.
- iii. **Meristems classified** according to various criteria:

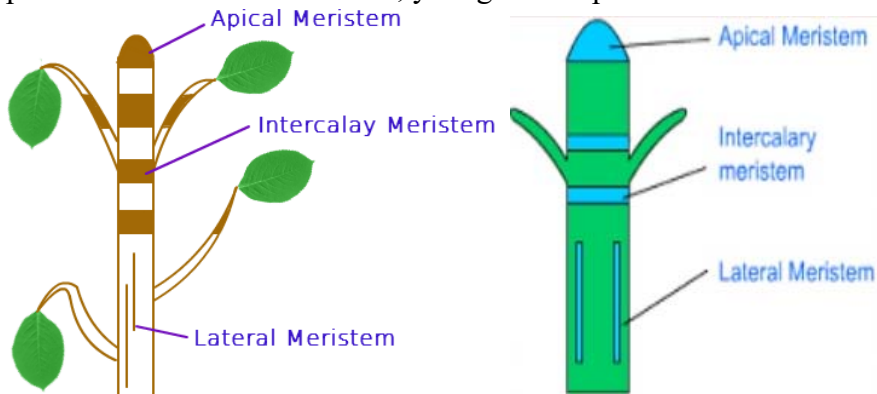
a. According to their origin and development

- ❖ **Promeristem:** earliest, youngest stage from which later meristems formed, small area at tips, its cells division give primary meristems.
- ❖ **Primary meristems:** present at apices of stem and root and the primordia of leaves (i.e. **protoderm, ground meristems and procambium**) develop primary body of the plant.
- ❖ **Secondary meristems:** originate from mature living or permanent tissues and secondary meristems (Cork cambium developed from epidermis, cortex or pericycle).

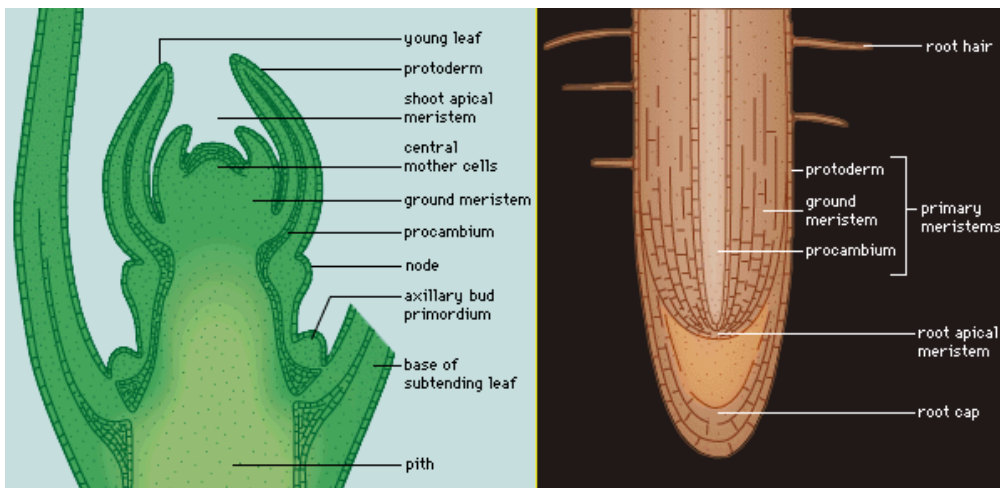


b. According to their Position

- ❖ **Apical meristems**: at the apices, as shoot apex and root apex. **Shoot apex** activity to formation of leaf primordia and lateral branches, young shoot apex differentiated into three meristems:

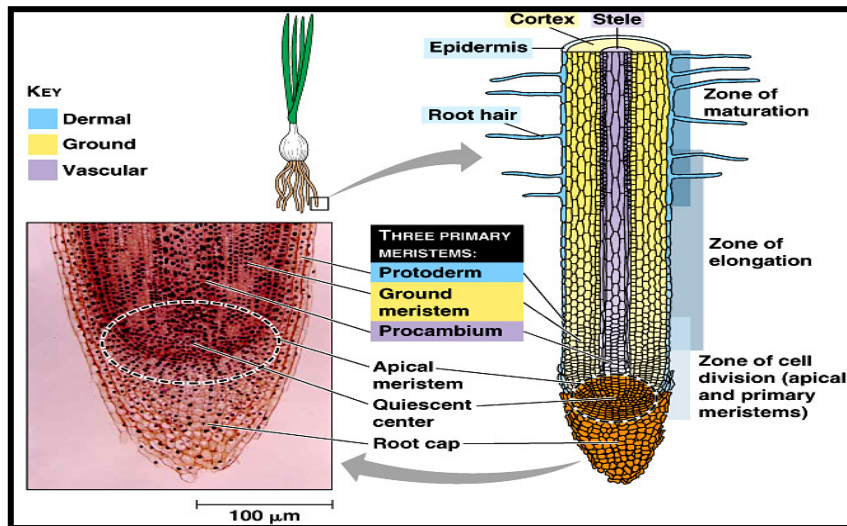


- **Protoderm** which produces epidermis.
- **Ground meristem** producing cortex and pith or ground tissue.
- **Procambium** producing vascular cylinder.



Root apex, protected by root cap, differentiated into:

- **Calyptragen** forming the root cap.
- **Protoderm, ground meristem, procambium** as shoot apex.

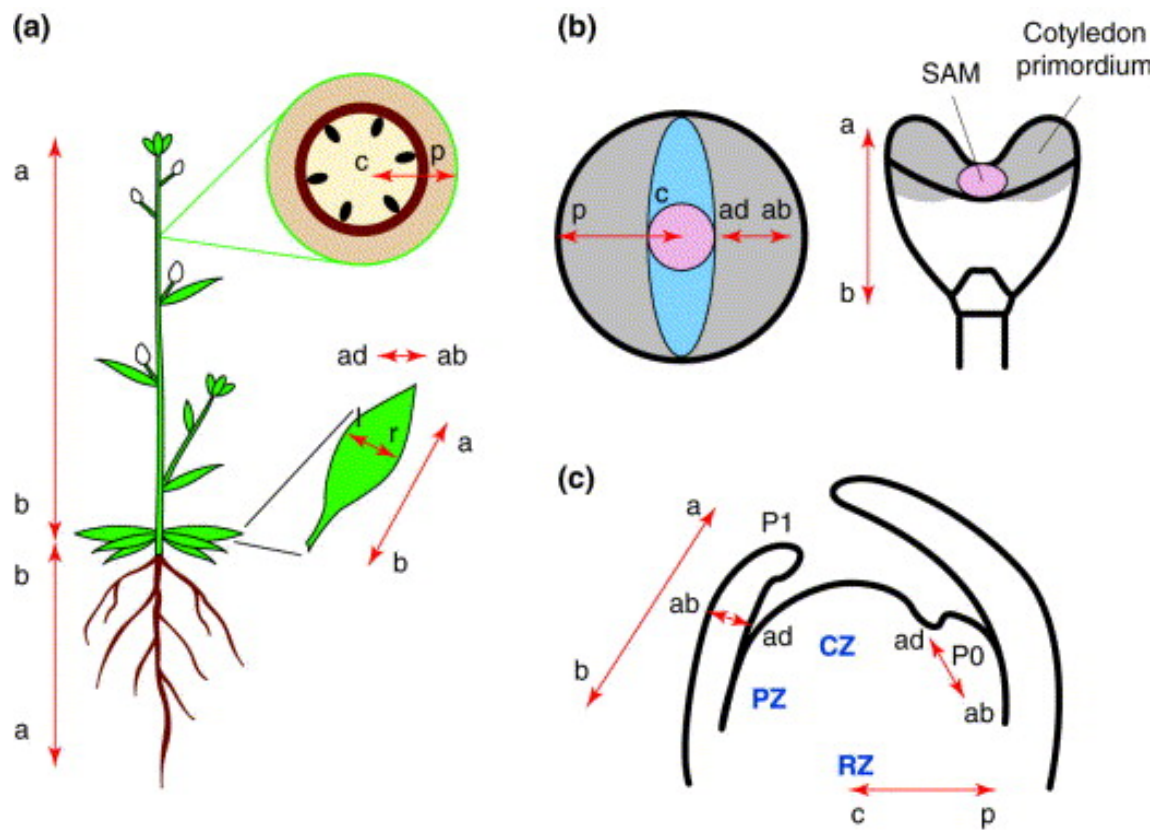
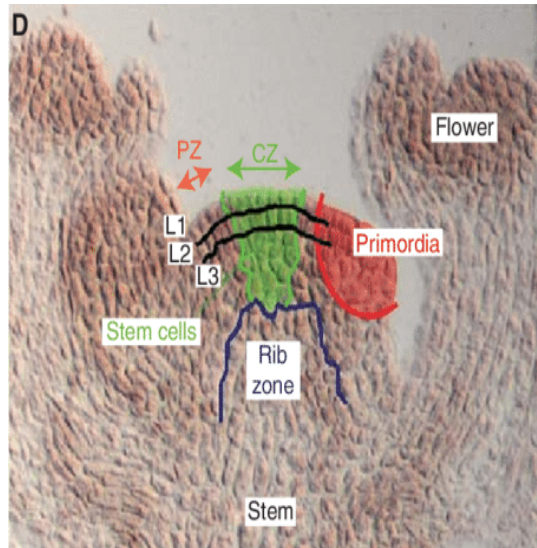


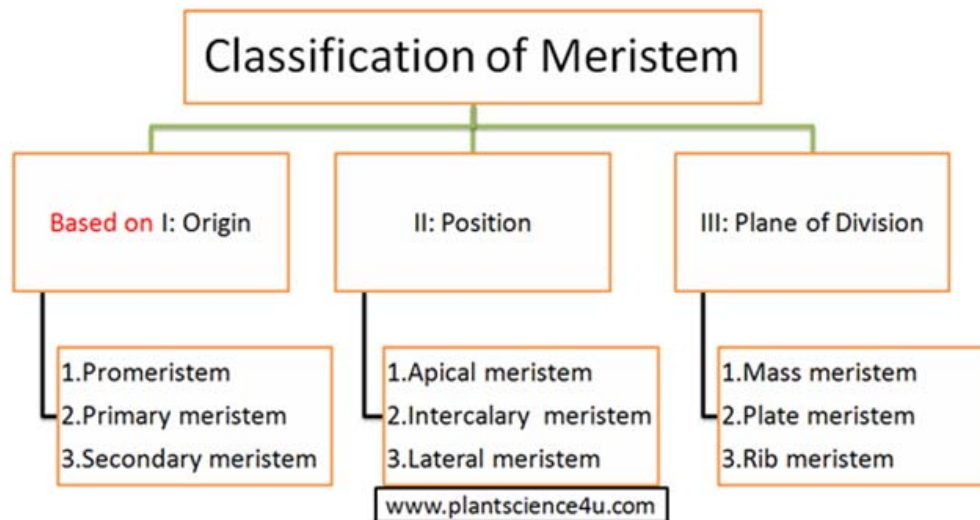
- ❖ **Intercalary meristems:** parts of apical meristem, separated from apex, during the growth by regions of mature tissues. Lie between regions of permanent tissues e.g. meristems at base of leaves and internodes, increases in length.
- ❖ **Lateral meristems:** along the sides, divide in one plane, increase the diameter of plant organ e.g. the vascular cambium and the cork cambium (phellogen).

TYPE	LOCATION	FUNCTION
i) APICAL MERISTEM	Growing tips of shoot (shoot apex meristem) and root (root apex meristem)	Increases length (height) of the plant – PRIMARY GROWTH
ii) INTERCALARY MERISTEM	At base of leaves or internode	Increase in length of organ like leaves and internodes
iii) LATERAL MERISTEM (found in woody trees and plants)	On sides of stem and roots. 2 TYPES - 1. cork cambium (found beneath bark) 2. vascular cambium (found in vascular bundles)	Increase the diameter and girth – SECONDARY GROWTH

c. According to their plane of cell division

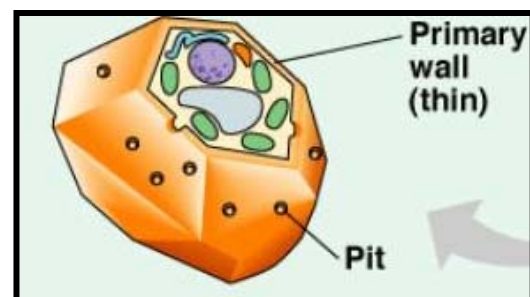
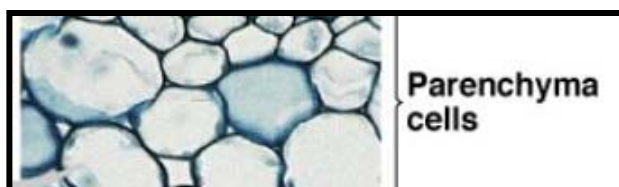
- a) **Mass meristem:** cells divide in all planes resulting in an increase in volume e.g. development of cortex and pith.
- b) **Plate meristem:** cells divide in two planes, increase in the area of the organ e.g. in epidermal growth and leaf formation.
- c) **Rib meristem:** cell division is in one plane formation of row of cells in pith and cortex of young stems in higher parts.

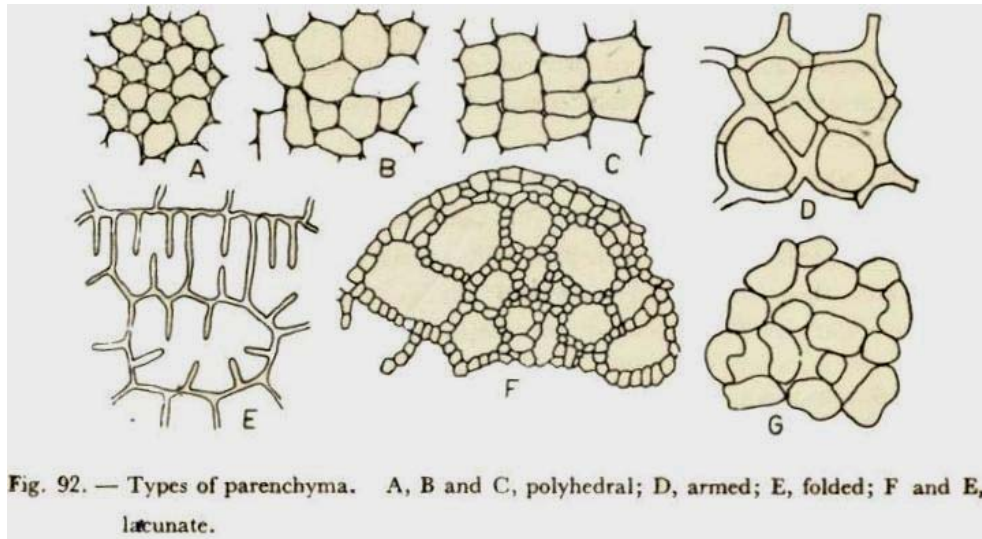




B. Permanent tissues

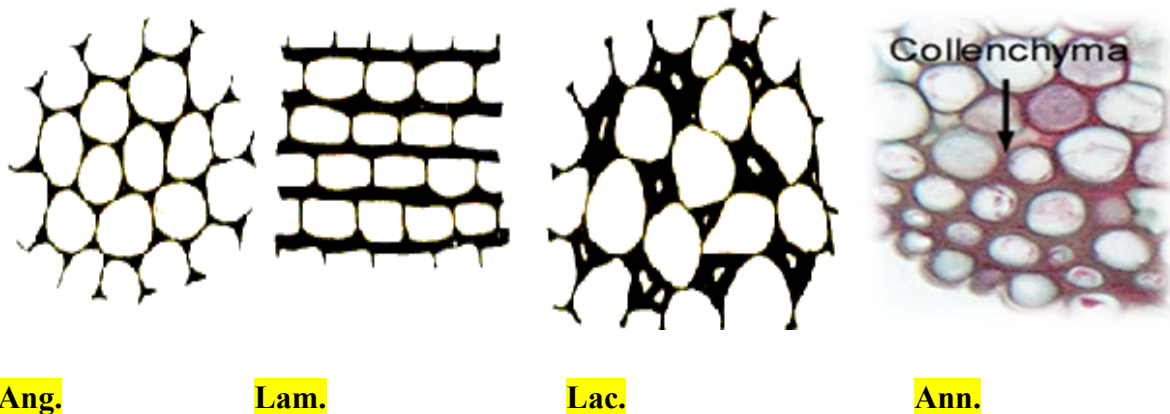
- i. **Derived** from meristems, cells lost the power of dividing, having definite form and size.
- ii. **Living or dead**, thin- walled or thick- walled cells, change morphologically and physiologically (**tissue differentiation**) to specialized for specific functions.
- iii. **Change** include increase amount of vacuolar sap, increase in ergastic substances, proplastids develop into plastids with different colours, increase in cell wall thickness and structure.
- iv. **Permanent tissues classified** according cell **types into**:
 - a. **Simple Tissues**, homogeneous and consists of one type of cells.
 - 1) **Parenchyma** main ground tissues, **living of cellulose walls and primary pit** fields, **perform storage, respiration, photosynthesis and conduction** of food material and water. Of wide air spaces (**aerenchyma**) with chloroplasts (**chlorenchyma**). Have different shape (polyhedral, armed, folded, lacunate).





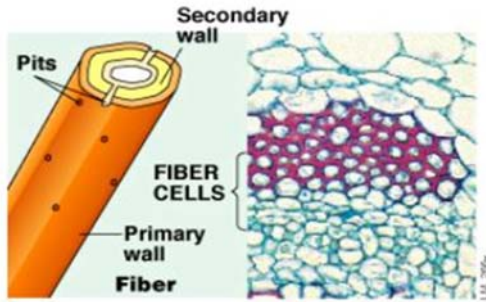
2) Collenchyma: living elongated cells, thick cellulosic primary non-lignified walls to support, may contain chloroplasts and carry out photosynthesis. Originating jointly with vascular tissues from the procambium. It usually polygonal in T.S. according to the distribution of wall thickening they:

- ❖ **Angular:** common type wall thickening at the corners or angles of cells.
- ❖ **Lamellar:** thickening more heavily on tangential than on the radial walls.
- ❖ **Lacunar:** have intercellular spaces, thickening walls around intercellular spaces.
- ❖ **Annular:** walls more or less uniformly thickened, cell lumen circular in T.S.

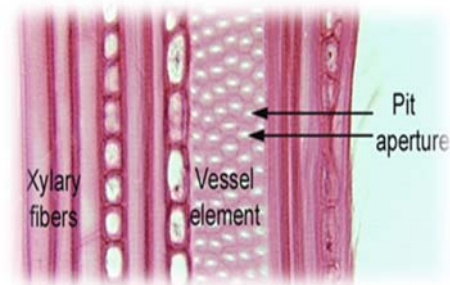


3) Sclerenchyma, thick-walled lignified, non-living cells, resist stresses of stretching, bending, weight and pressure without damage of other thin-walled cells (mechanical, stereomes). It classified into:

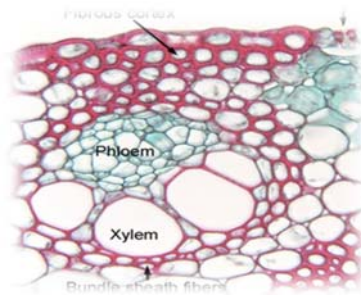
- i. **Fibres:** elongate cells, tapering ends a narrow lumen and thick lignified secondary walls, two main types:



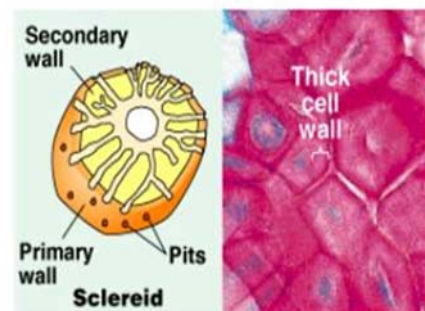
- ❖ **Xylem fibres** in primary and secondary xylem and develop from procambium and vascular cambium respectively.



- ❖ **Extraxylary fibres** not included in xylem e.g. in phloem, ground tissue or bundle sheath of monocotyledonous plants.

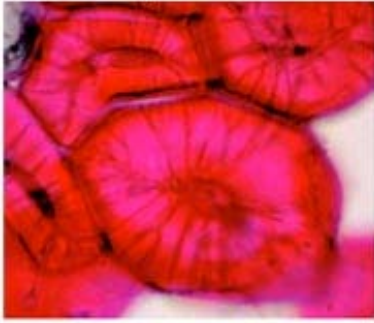


- Sclereids:** thick strongly lignified secondary walls, isodiametric, polyhedral, short cylindrical, slightly elongated or irregular, narrow lumen, simple pits, classified into:

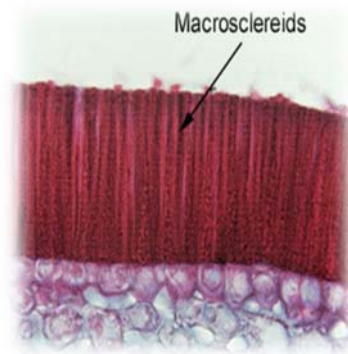


- ❖ **Brachysclereids (stone-cells):** short, roughly isodiametric sclereids, pitted wall with branched canal pits, in cortex, phloem and pith and in flesh fruits.

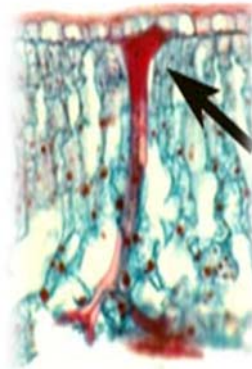
Brachysclereide



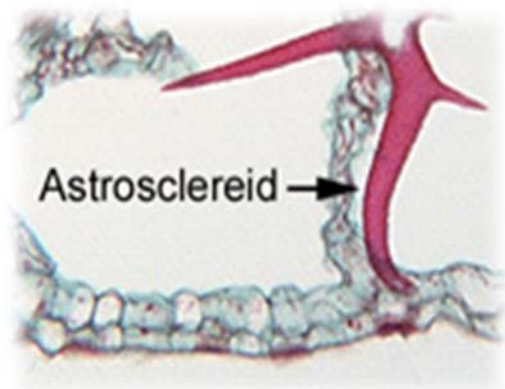
- ❖ **Macroscleireids:** elongated rod- like in epidermal layer of leguminous seeds.



- ❖ **Osteosclereides:** bone-shaped, columnar cells, enlarged at ends (*Hakea* leaf).



- ❖ **Astrosclereids:** star-shaped, ramified to varying degrees (*Nymphaea* petiole).

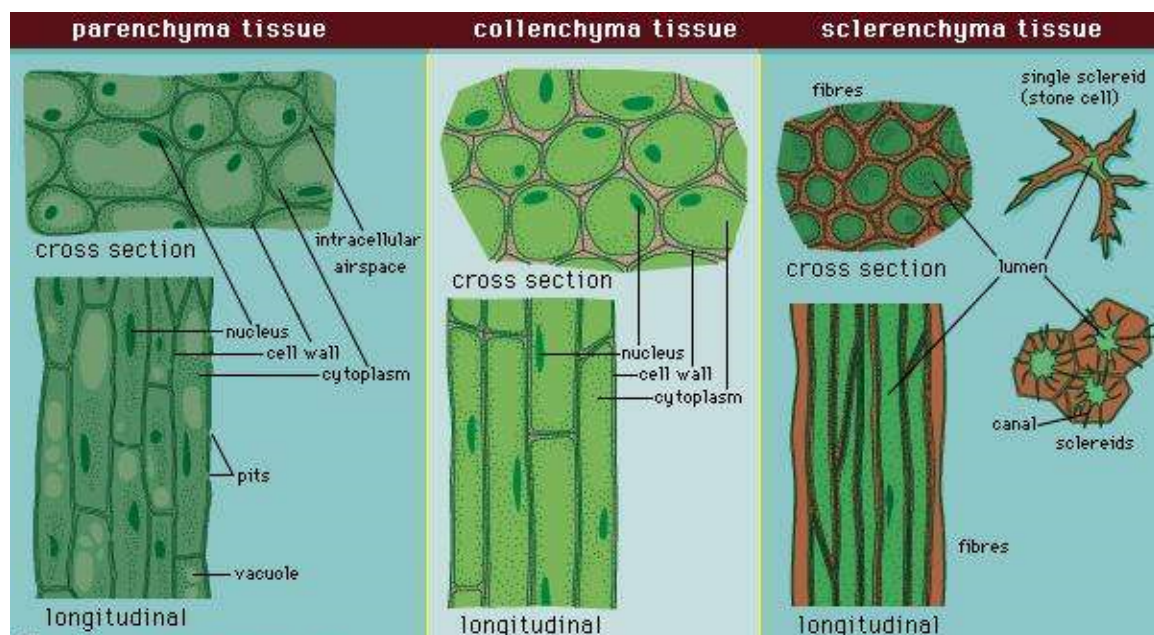
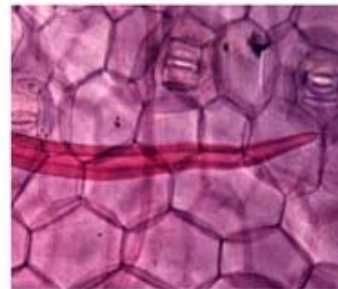


- ❖ **Filiform sclereids**: very long (Olive leaf).

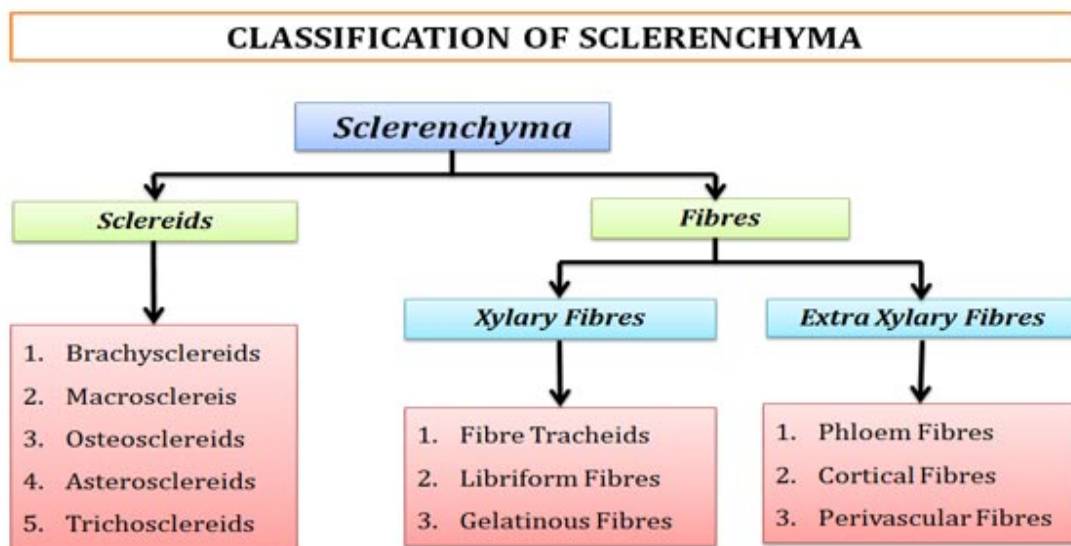
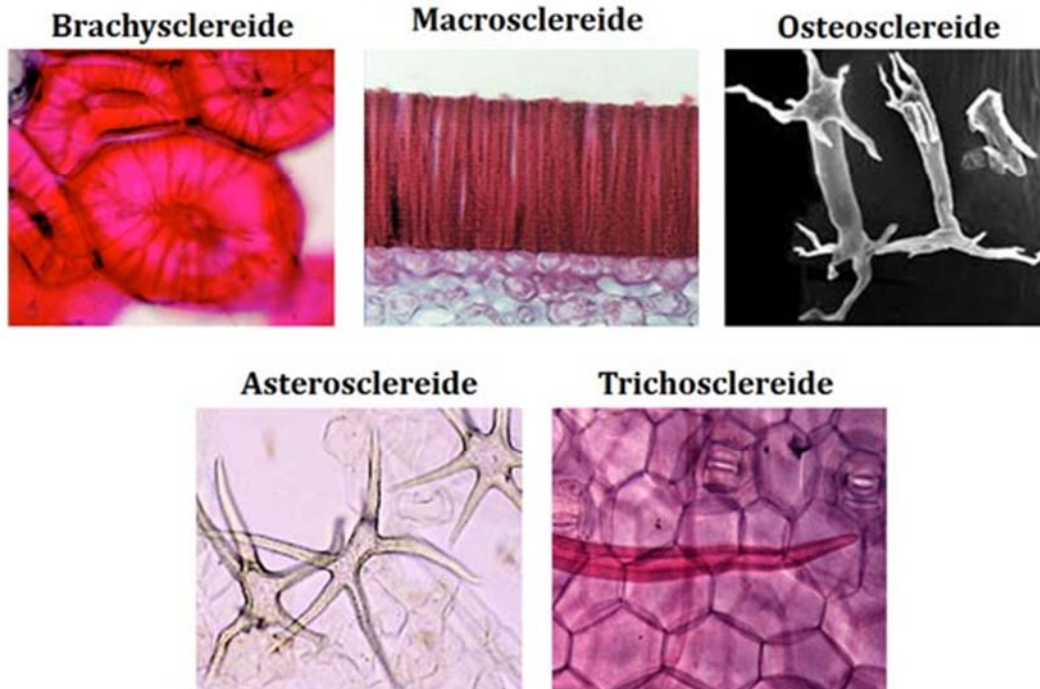


- ❖ **Trichosclereids**: branched thin walled as hairs, extend to intercellular spaces.

Trichosclereide



Types of Sclereids

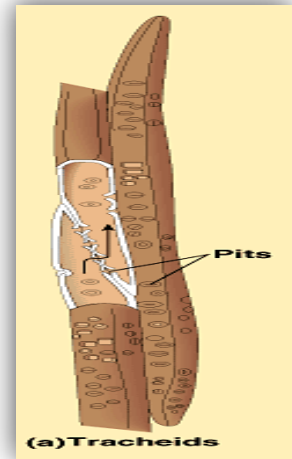


b. **Complex Tissues** (Vascular tissues), two or more types of cells (xylem and phloem, stele), in roots the stele is covered by pericycle.

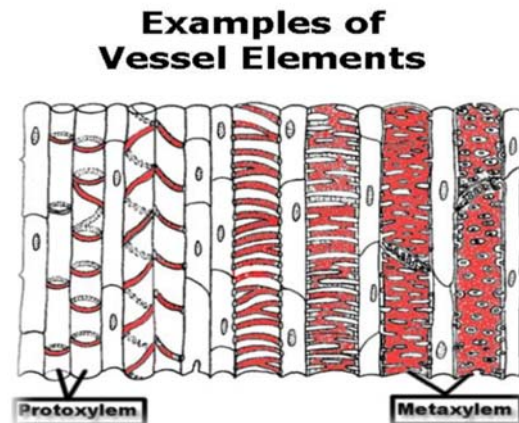
i. **Xylem**: a complex tissue, water conducting, mechanical support, originates from the procambium or vascular cambium, **formed of** :

1. **Tracheids**: non-living elongate, tube-like cells with tapering ends more primitive with hard, thick and lignified walls bordered pits, dead

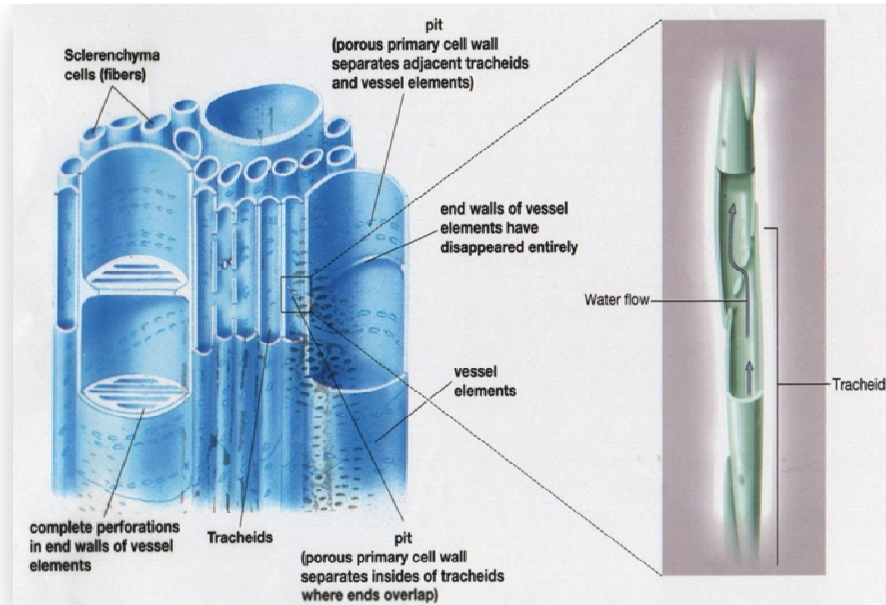
cells, polygonal (alone in ferns and gymnosperms, in angiosperms with vessels).



2. **Vessels:** cylindrical tube-like formed of a longitudinal series of meristematic cells placed end to end transverse walls are completely dissolved, walls thickened and according to mode of thickening may be: annular, spiral, scalariform, reticulate and pitted.



3. **Xylem fibres:** derived from tracheids by increase in wall thickness, decrease in length and reduction in size of bordered pits as simple pits. Fibres appear longer than tracheids.
4. **Xylem parenchyma:** living cells walls may be thin or lignified for conduction and storage of food; it may be xylem parenchyma (axial parenchyma) and xylem ray parenchyma.



ii. **Phloem**: is the principal food conducting formed of several elements, not necessary all phloem cells present.

a. **Sieve elements**: do not contain nucleus and possess thin cellulose cell walls, they include the followings.

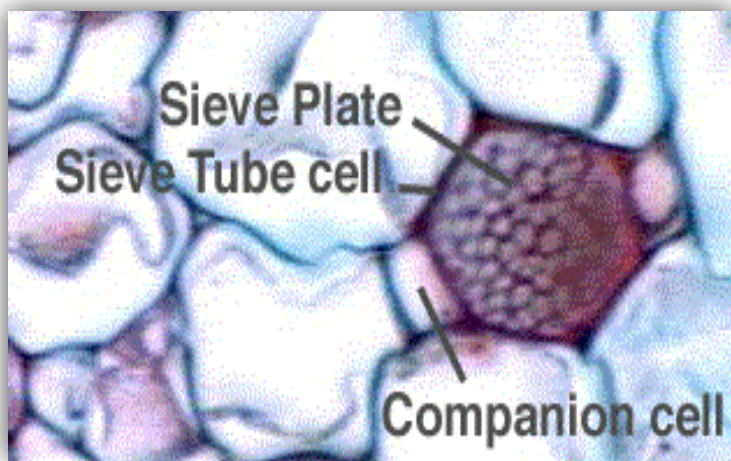
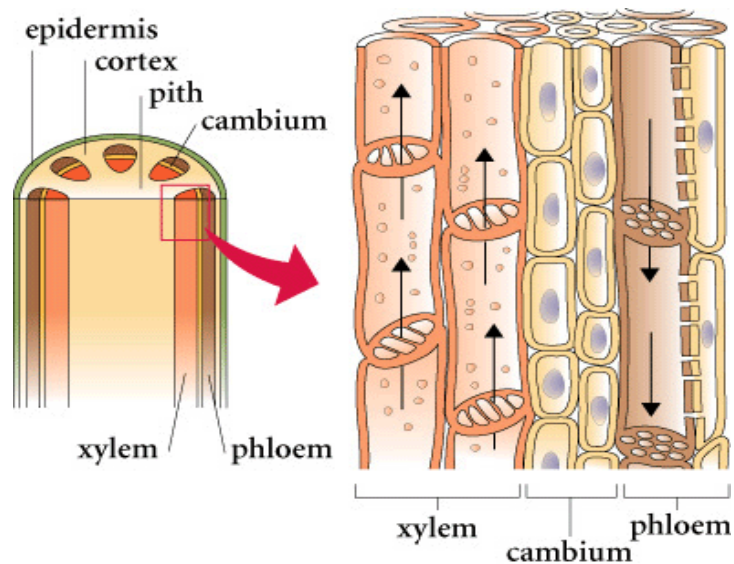
- ❖ **Sieve cells**: in gymnosperms, long and slender with tapering ends, have sieve areas on their walls.
- ❖ **Sieve tube members**: in angiosperms, arranged end to end in long series to form the sieve tubes have specialized sieve areas (form sieve plates).
- ❖ **Sieve areas and sieve plates**: areas in the wall with groups of perforations or pores through which the adjacent sieve elements are interconnected by strand-like prolongations of their protoplasts (primary pit fields or modified pits). If a sieve plate of a single sieve area called a **simple sieve plate** and many sieve areas constitute a **compound sieve plate**.

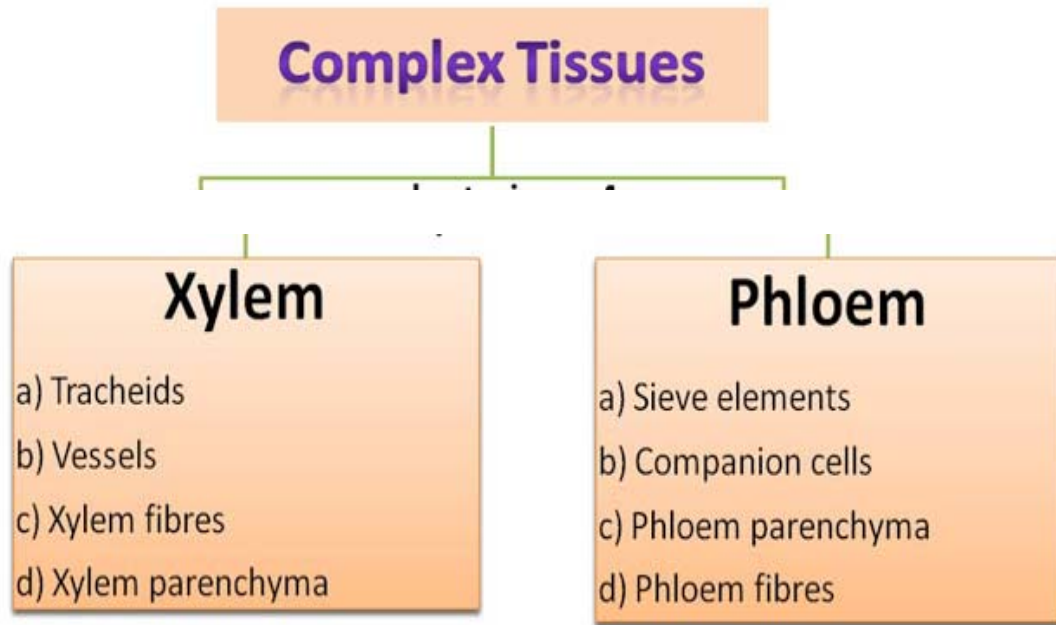
b. **Companion cells**: living parenchyma associated with sieve tube assist in conduction, develop from same meristematic cell of a sieve tube. The plasmodesmata connect the companion cells to their sieve tubes.

c. **Albuminous cells**: special type of cells associated with the sieve cells, deeply with cytoplasmic stains rich in **proteins**, similar to companion cells in structure and function differs in their origin.

d. Phloem parenchyma: most dicotyledons and a few monocotyledons contains parenchyma cells essentially for storage food, classified into **phloem parenchyma** and **phloem ray parenchyma**.

e. Phloem fibres and sclereids: in the primary and secondary phloem of many seed plants, and are rare or absent of living Pterophyta.



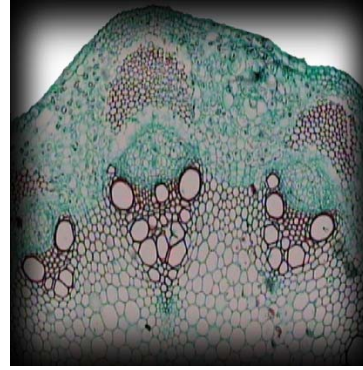


Vascular bundles

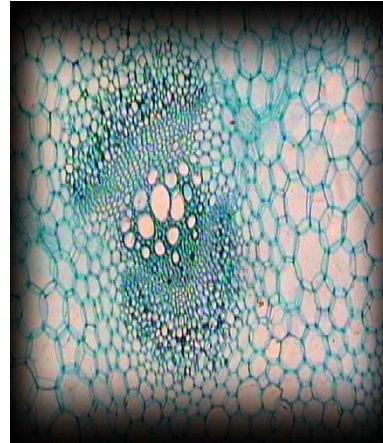
1. **The tissue derived** from the procambium is called the vascular tissue system (vascular bundles), consists of xylem and phloem, cambium; a strip of meristem, may or may not be present. Bundles with cambium open bundles and without closed bundles.
2. **The primary xylem may be:**
 - ❖ **Exarch xylem** develops centripetally , from the outside towards the centre.
 - ❖ **Endarch xylem** develops centrifugally , away from the centre.
 - ❖ **Mesarch xylem** develops partly centripetal and partly centrifugal.

phloem is always centripetal.
3. **The first differentiated xylem and phloem** are protoxylem and protophloem, and last metaxylem and metaphloem.
4. **In primary xylem** both proto- and metaxylem are present. Protophloem sometimes consists of only phloem parenchyma.
5. **According to the arrangement** of primary xylem and primary phloem, vascular bundles are divided into:

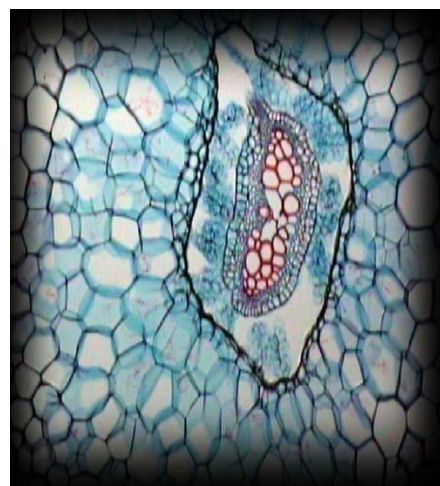
- a. **Collateral bundles:** phloem occurs on one side of xylem strand (stems, leaves).



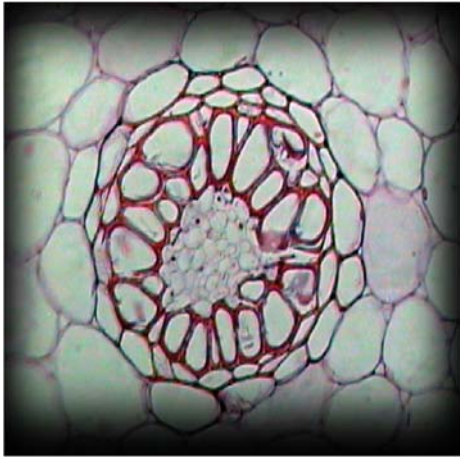
- b. **Bicollateral bundles:** phloem occurs on both sides of xylem (*Cucurbita* stem).



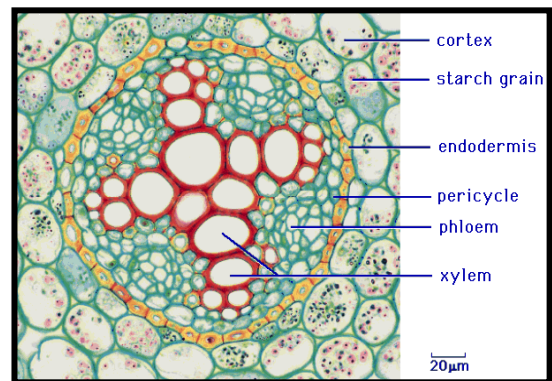
- c. **Concentric bundles:** One type of vascular tissue (xylem or phloem) completely surrounds the other, two types:
- ❖ **Amphicribral bundles:** Xylem is surrounded by phloem (ferns, flowers).



- ❖ **Amphivasal bundles:** Phloem is surrounded by xylem (*Dracaena* stem)



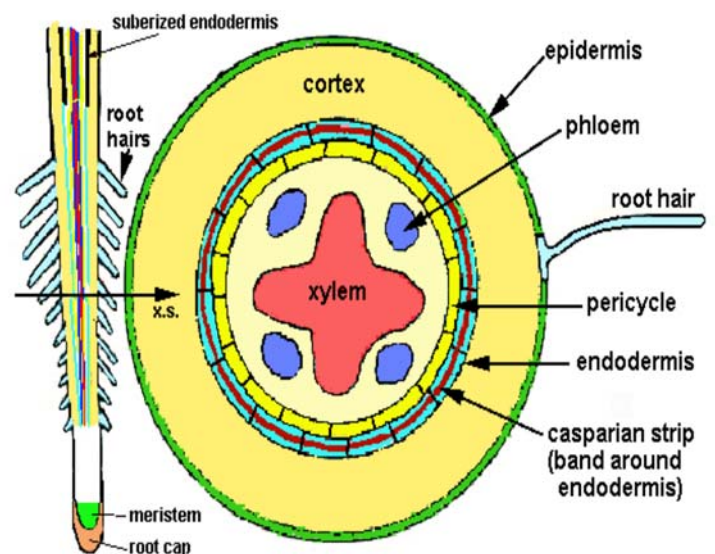
- d. **Radial arrangement:** phloem and xylem are separated from each other and lie on different radii of axis alternating with each other (roots).

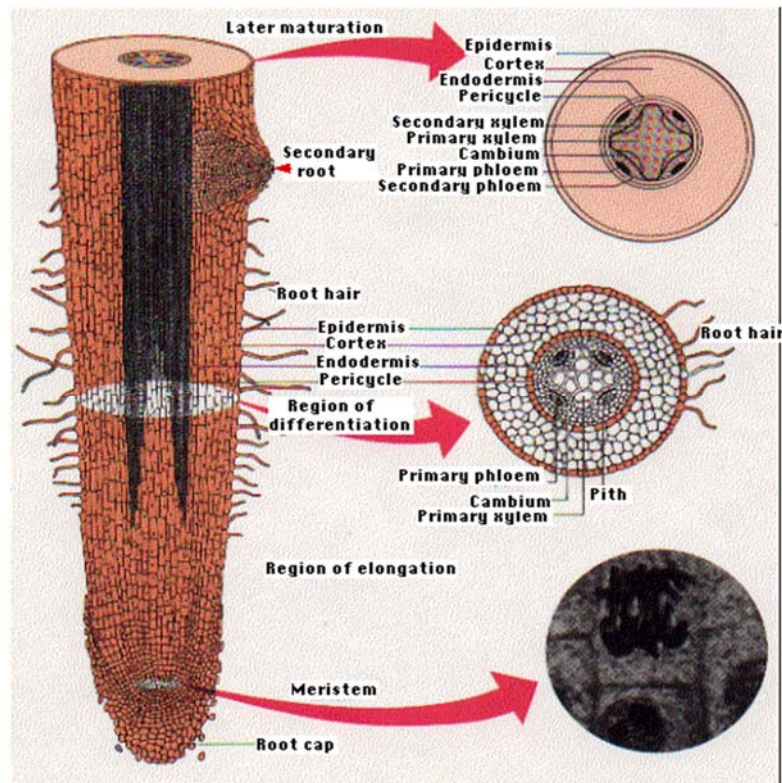


The Primary Vegetative Body of the Plant

Anatomy of the Root

Epidermis: This is the primary surface tissue of the entire plant. Epidermal cells are compactly and continuously arranged; the continuity is lost by the presence of root hairs. Epidermis provides mechanical protection, allows gaseous exchange. Epidermal cells often thin-walled and devoid of cuticle.





Cortex: The region inner to epidermis is called cortex and it is homogenous. The cortex is composed of thin walled, sparsely arranged parenchyma cells that constitute many layers.

The vascular cylinder: In the central portion of the root, it includes:

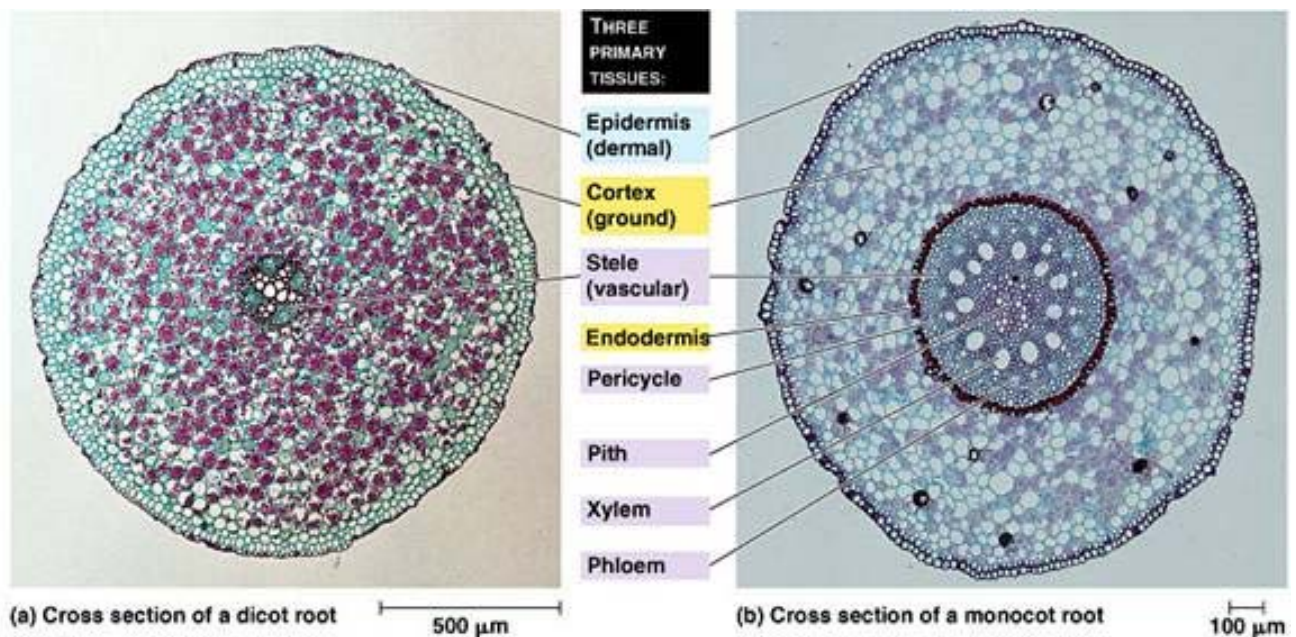
Pericycle Inner to the endodermis, one or two layers of parenchyma are present, constituting pericycle. **Stele: Xylem and phloem patches** are in equal number and alternate with each other.

Four patches of xylem or phloem usually in dicot root. In xylem, the protoxylem elements face pericycle; between xylem and phloem elements, parenchyma cells are present constituting conjunctive tissue, which later becomes a secondary meristem. Hence vascular bundles are described as radial, **exarch** and open.

Pith: is very small, with closely packed parenchyma cells.

Comparison between Dicot and Monocot roots:

	Dicot Root <i>Ex: Beans</i>	Monocot Root <i>Ex : Canna</i>
1. Vascular bundles	Diarch to hexarch, open	Polyarch closed.
2. Pith	Small or absent	Relatively large
3. Cambium	Conjunctive tissue becomes meristematic and results in secondary growth	Conjunctive tissue does not become a meristem and complete absence of secondary growth.
4. Pericycle	It may give rise to cork cambium and lateral branches	It may give rise to only lateral branches.



Anatomy of the Stem

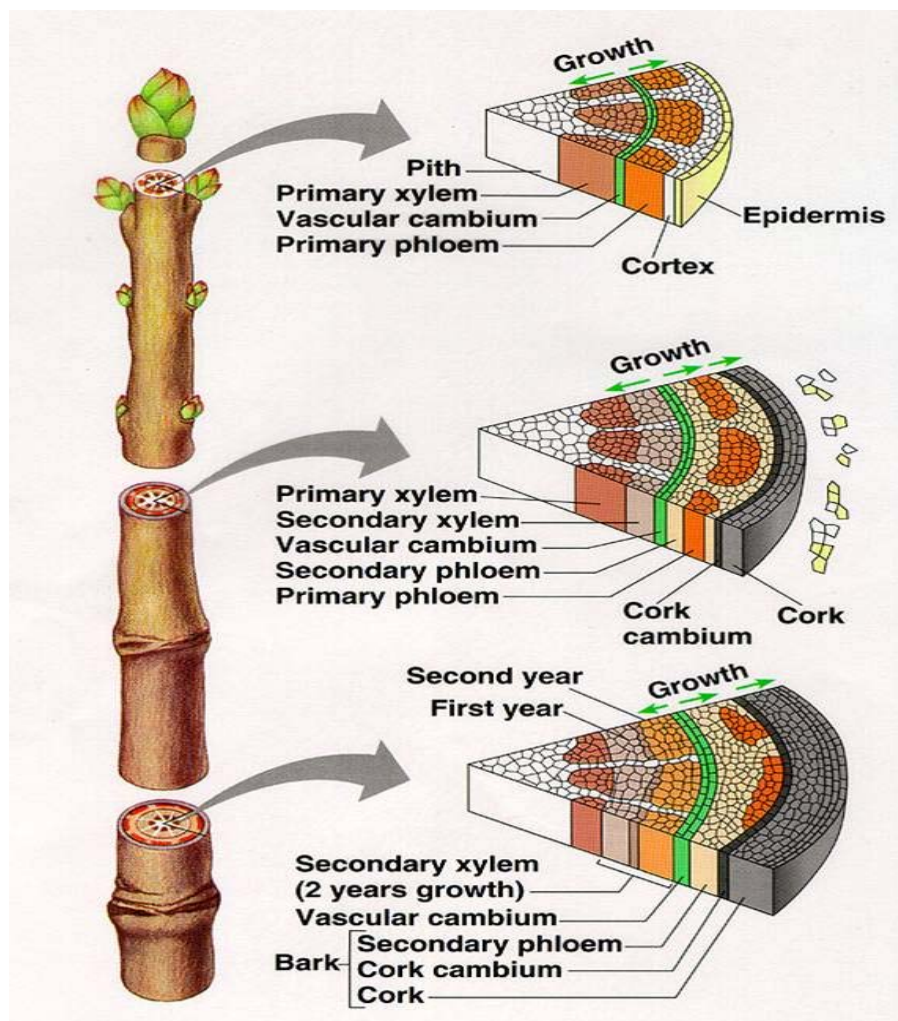
Dicotyledonous stem

Epidermis: The outermost layer, uniseriate, covered with thin cuticle, and bears a few stomata and many Multicellular trichomes.

Ground Tissue: This fundamental tissue is differentiated into outer cortex and central pith.

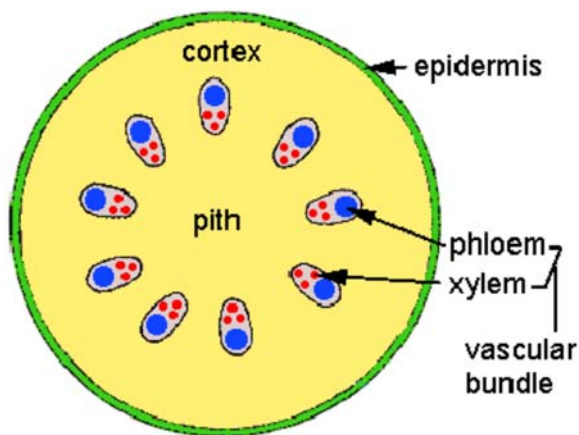
Cortex: This is many layered and differentiated into hypodermis and inner cortex. Hypodermis is found below the epidermis, and is constituted with angular collenchyma which is 3-5 layered.

The inner part of cortex is constituted with chlorenchyma and parenchyma; large numbers of intercellular spaces are present between these cells. The inner most cortical layer is wavy in outline, rich in starch grains, with barrel shaped cells and is called endodermoid layer. (Endodermis is generally absent in stem; endodermoid layer differs from endodermis in lacking casparian thickenings).

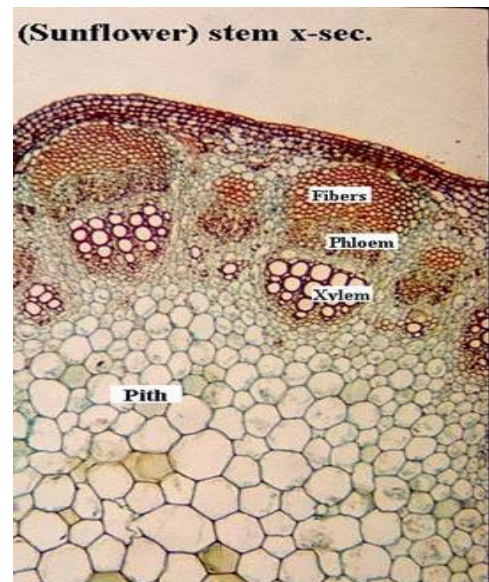


Pericycle: This is the outermost region of vascular tissue. This consists of alternately arranged patches of sclerenchyma and parenchyma. The sclerenchyma is also known as hard bast fibers. Since it is found external to vascular bundle, the patch of sclerenchyma is also called bundle cap.

Vascular tissue: This consists of many vascular bundles arranged regularly in the form of broken ring (**Eustele**). In each vascular bundle the xylem and phloem elements are in the same line; the presence of one to few stripped intrafascicular cambium is found in between xylem and phloem; the cambial cells are thin walled and are almost rectangular phloem is only external to xylem: the protoxylem is nearest to centre. The vascular bundles are conjoint, collateral, endarch, open and wedge shaped.



Diagram



Sector

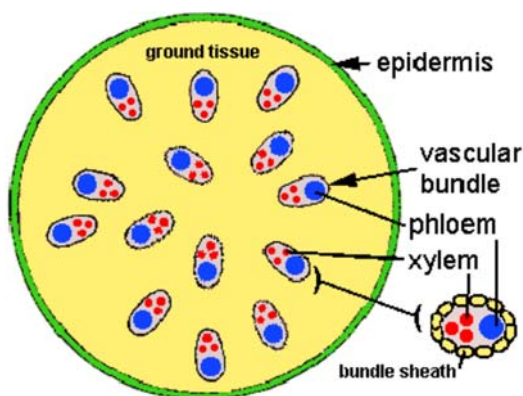
Pith or Medulla: This is inner to vascular tissue and occupies the central region. It is composed of cells of parenchyma, with intercellular spaces. Extensions of these cells into the areas in between vascular bundles are called medullary rays.

Monocotyledonous stem

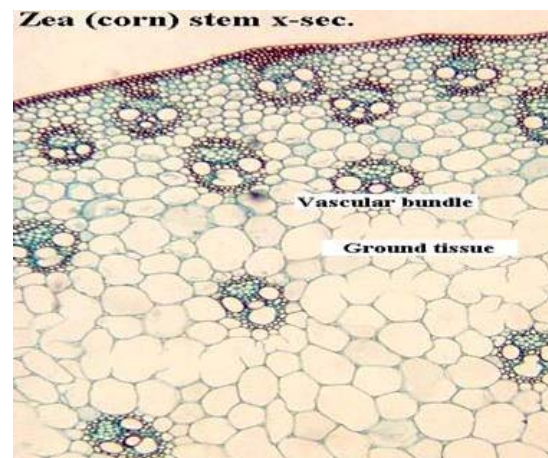
Epidermis: This is the uniseriate, outermost layer and is covered with thick cuticle. Trichomes are absent.

Ground tissue: The ground tissue is not differentiated; into cortex and pith, since there is scattered arrangement of vascular bundles. Even endodermoid layer and pericycle are also not differentiated. Hypodermis constitutes the exterior ground tissue, and is composed of 2 – 3 layers of sclerenchyma. The major part of the ground tissue is parenchymatous.

Vascular tissues: Consists of numerous, oval shaped vascular bundles scattered throughout the ground tissue, hence the arrangement of vascular tissue is called **atactostele**. Peripheral vascular bundles are small-sized but many in numbers. The central vascular bundles are large sized but a few in numbers. In all the vascular bundles the xylem and phloem are in the same line; cambium is absent; phloem is only external to xylem; protoxylem faces the center. Hence the vascular bundles are described as conjoint, collateral, endarch and closed. Each vascular bundle is surrounded by a bundle sheath of sclerenchyma, which is prominent at the base and tip of vascular bundle. Xylem comprises usually 2 oppositely arranged metaxylem elements (pitted, facing periphery) and a few protoxylem elements (facing the center of stem) in a linear row. If an imaginary line is drawn connecting the two metaxylem elements with that of protoxylem, xylem appears 'Y' shaped. Usually the lower protoxylem elements break down and form a **lysogenous cavity**. Above the metaphloem, a small band of obliterated protophloem is seen. Metaphloem consists of sieve tubes and companion cells but not phloem parenchyma.



Diagram



Sector

Comparison between the stems of Dicot and Monocot:

	Dicot stem <i>Ex: Sunflower</i>	Monocot stem <i>Ex : Maize</i>
1. Epidermal trichomes	Present multicellular	Absent
2. Hypodermis	Collenchymatous	Sclerenchymatous
3. Ground tissue	Differentiated into cortex and Pith	Undifferentiated
4. Endodermoid layer and Peri-cycle	Present	Absent
5. Stele	Eustele	Atactostele
6. Vascular bundles	Many open, wedge- shaped	Numerous, closed, oval-

		shaped
7. Lysigenous cavity	Absent	Present
8. Bundle cap	Present	Absent
9. Bundle sheath	Absent	Present
10. Secondary Growth	Occurs later	Does not occur

Comparison between the structures of stem and root:

	Stem	Root
1. Cuticle	Present, thick / thin	Usually absent
2. Trichomes	When present, is multi-cellular or unicellular on the Epidermis.	Epiblema hairs are unicellular
3. Stomata	Present	Absent
4. Hypodermis	Either collenchymatous or sclerenchymatous.	Not distinct from inner cortex.
5. Cortex	When present, is heterogeneous, with collenchyma, parenchyma and sclerenchyma.	Homogenous with cells of parenchyma.
6. Endodermis	Usually absent; endodermoid layer may be present	Generally present
7. Pericycle	Two to few layered/absent	One layered
8. Vascular bundles	Many, conjoint, collateral or bicollateral, regularly arranged forming a broken ring or scattered in ground tissue, endarch.	2-12, radial, exarch, form a broken ring.
9. Pith	Well marked and large or not differentiated	Relatively small or absent.
10. Branching	Exogenous, originating from cortex	Endogenous, arising from pericycle.

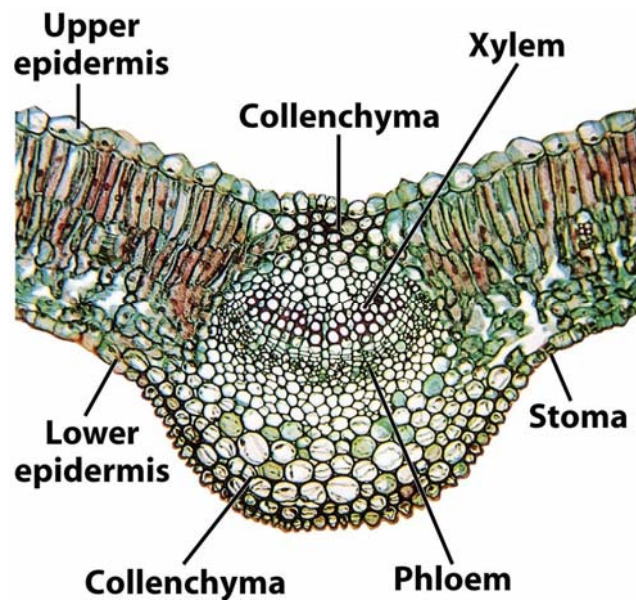
Anatomy of the Leaf

Dicotyledonous leaf

The leaf is horizontal and dorsiventrally differentiated (upper = ventral, lower = dorsal).

Epidermis: The two surfaces are bounded by their respective epidermal layers. The epidermal cells are barrel-shaped, compactly arranged; upper epidermis is covered with thick cuticle and lacks stomata; lower epidermis is light green, covered with thin cuticle and is interrupted by stomata.

Mesophyll: This is the ground tissue. It is differentiated into upper palisade and lower spongy parenchyma.



Palisade parenchyma is found immediately below the upper epidermis, 2 to 3 layered, with compactly arranged tubular cells, rich in parietal chloroplasts.

Spongy parenchyma is found above the lower epidermis; these cells are varied in shape and sizes, very loosely arranged enclosing air spaces some of which open into stomata. Chloroplasts are parietal in the parenchyma cells.

Vascular tissue: Vascular bundles vary in size; each bundle is conjoint, collateral and closed. The vascular bundle is covered by a bundle sheath of parenchyma cells. An extension of bundle sheath is seen above and below the vascular bundle, reaching the epidermal layers. Phloem is towards lower epidermis; xylem is towards upper epidermis, with metaxylem facing phloem. Fibers are absent in both xylem and phloem. The xylem and phloem elements are conspicuous only in large vascular bundles.

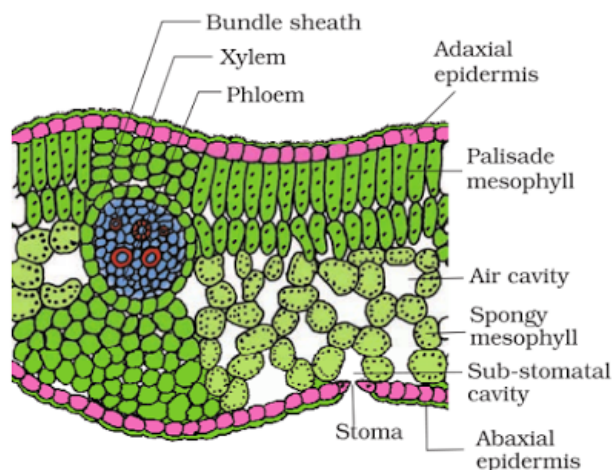
Monocotyledonous leaf

The leaf is isobilateral in nature and is vertically oriented.

Epidermis: This is uniseriate, with barrel-shaped, compactly arranged cells and is covered with thick cuticle. Stomata are found on both upper and lower epidermal layers hence it is called amphistomatic (more on the lower epidermis). Though the leaf is referred to as isobilateral, it is only in upper epidermis, a few large, empty and colorless bulliform or motor cells are present. During dry weather, these motor cells help the leaf to roll over, due to the changes in turgidity. This rolling of leaf reduces the rate of stomatal transpiration.

Mesophyll: There is no differentiation of mesophyll into spongy and palisade parenchyma. All the cells of chlorenchyma are alike, isodiametric, almost compactly arranged with numerous parietal chloroplasts.

Vascular tissue: The vascular bundles are numerous, arranged in parallel series (venation is palmate-parallel), conjoint, collateral and closed. Phloem is towards lower epidermis. Each vascular bundle is surrounded by chlorenchymatous bundle; this sheath also serves for temporary storage of starch. A few vascular bundles are larger in size, with more amounts of xylem and phloem and with large bundle sheath cells. A patch of sclerenchyma is present above and below the large sized vascular bundles.



Comparison between the of Dicot and Monocot leaf.

	Dicot leaf <i>Ex: Mango</i>	Monocot leaf <i>Ex : Maize</i>
1. Orientation of leaf	Horizontal, dorsiventrally differentiated	Vertical, isobilateral
2. Stomata	Usually on lower epidermis	On both epidermal layers
3. Cuticle	Thick on upper epidermis	Thick on both epidermal layers
4. Motor cells	Absent	Present in upper epidermis
5. Mesophyll	Differentiated into upper palisade parenchyma and lower spongy parenchyma	No differentiation of mesophyll
6. Vascular bundles	All of them are not seen in parallel series and are supported by bundle sheath extension	Vascular bundles are in parallel series and are supported by sclerenchyma patches

Anatomical Features of Ecological Group of Plants:

Hydrophytes:

Plants grow in water or very wet places. They may be submerged or partly submerged, floating or amphibious. Their structural adaptations are mainly due to the high water content and the deficient supply of oxygen.

The various adaptations are as follows:

-
- (i) The reduction of protective tissue (epidermis here is meant for absorption and not for protection).
 - (ii) The reduction of supporting or mechanical tissue (i.e., lack of sclerenchyma).
 - (iii) The reduction of conducting tissue (i.e., minimum development of vascular tissue).
 - (iv) The reduction of absorbing tissue (roots chiefly act as anchors, and root hairs are lacking).
 - (v) There is special development of air-chambers (aerenchyma) for aeration of internal tissues.

Epidermis:

In aquatic plants, the epidermis is not protective but absorbs gases and nutrients directly from the water. The epidermis in the typical hydrophyte has an extremely thin cuticle, and the thin cellulose walls permit ready absorption from the surrounding water.

Commonly the chloroplasts are found in epidermal cells of leaves, especially when the leaves are very thin; these chloroplasts utilize the weak light under water for photosynthesis. In submerged plant, stomata are not present, and exchange of gases takes place directly through cell walls. The floating leaves of aquatic plants have abundant stomata on the upper surface.

Lack of sclerenchyma:

Submerged plants usually have few or no sclerenchymatous tissue and cells. The water itself gives support to the plant, and protects it to some extent from injury. The thick walls of tissues, their density and the presence of collenchyma in some plants give some rigidity.

The strands of sclerenchyma occasionally occur, especially along the leaf margins, and increase tensile strength. A few star shaped idioblasts or sclereids are present, which give mechanical support to the body of aquatic plant (e.g., *Limnanthemum*, *Nymphaea*).

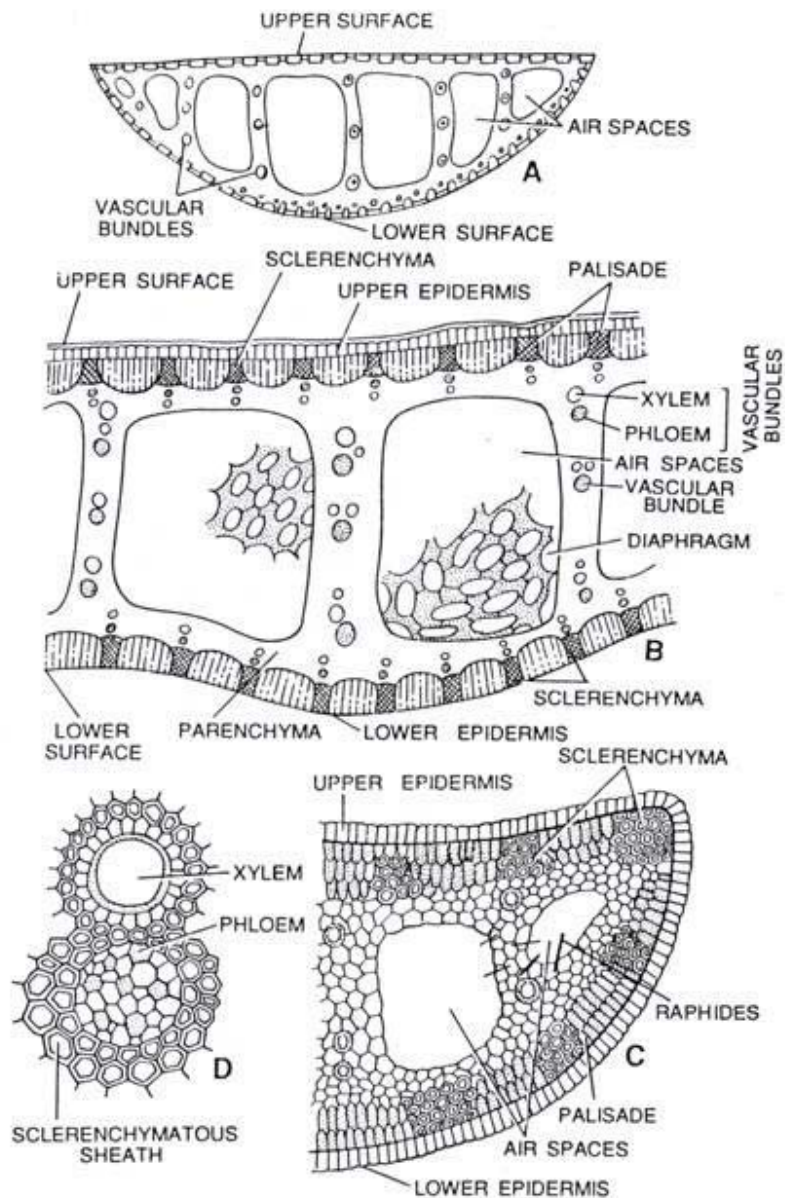


Fig. 41.23. Anatomy of hydrophytic leaf of *Typha* (monocot.). A, T.S. of leaf (diagrammatic); B, detail of a part of A; C, detail of a corner of leaf; D, single vascular bundle.

Minimum development of vascular tissue:

In the vascular tissues, the xylem shows the greatest reduction and in many aquatic plants consists of only a few elements, even in the stele and main vascular bundles (e.g., *Elatine alsinastrum*). In

some aquatic plants (e.g., *Potamogeton pectinatus*, *P. epihydrus*), in the stele and large bundles, and frequently in the small bundles, xylem elements are lacking.

In these plants there is well developed xylem lacuna in the position of xylem. These lacunae resemble typical air-chambers (air spaces). In many aquatic plants, the phloem is fairly well developed as compared with the xylem. The endodermis is usually present around the stele, but it is weakly developed.

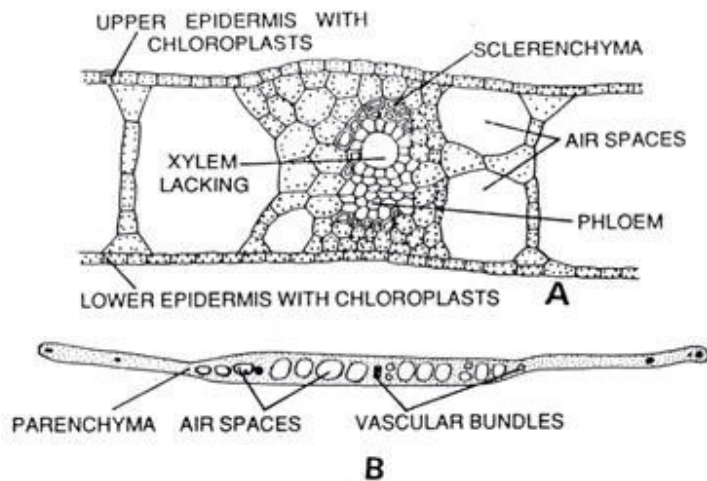


Fig. 41.24. Anatomy of hydrophytes. A, cross section of submerged leaf of *Potamogeton epihydrus* (detail); B, diagrammatic representation of the same.

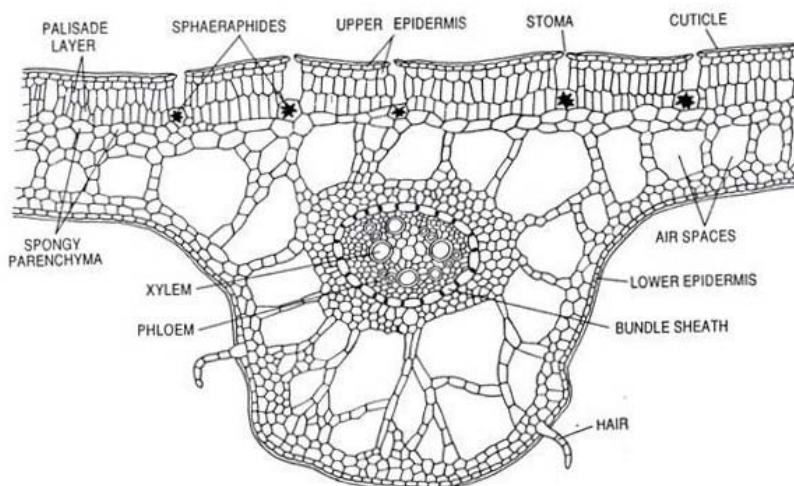


Fig. 41.25. Hydrophytes. T.S. floating leaf of *Trapa bispinosa*, showing big air spaces; the stomata confined to upper epidermis only.

Reduction of absorbing tissue:

The root-system in hydrophytes is feebly developed and root hairs and root cap are absent. In some floating plants such as *Utricularia*, *Ceratophyllum*, etc., no roots are developed, and in submerged plants such as *Vallisneria*, *Hydrilla*, *Naias*, etc., water dissolved mineral salts and gases are absorbed by their whole surface.

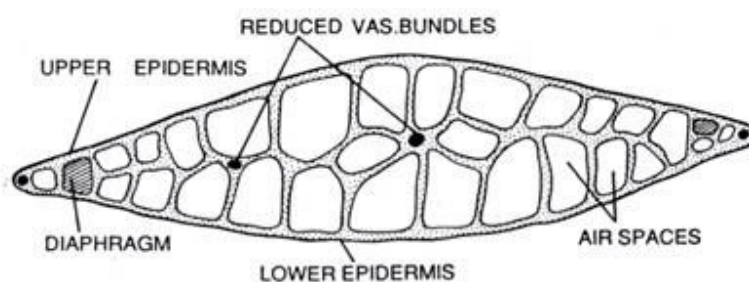


Fig. 41.26. Structure of hydrophyte. Cross section of submerged leaf of *Pontederia* showing diaphragm and air spaces. The airchambers on the one hand give buoyancy to the plant for floating and on the other they serve to store up air. The cross partitions of air passages, known as diaphragms prevent flooding.

In plants like *Pistia*, *Eichhornia*, *Lemna*, etc., no root cap develops, but root pocket is formed instead. An aquatic plant is, in reality, submerged in or floating upon a nutrient solution. In hydrophytes the root system is functioning chiefly as holdfasts or anchors, and a large part of the absorption takes place through the leaves and stems.

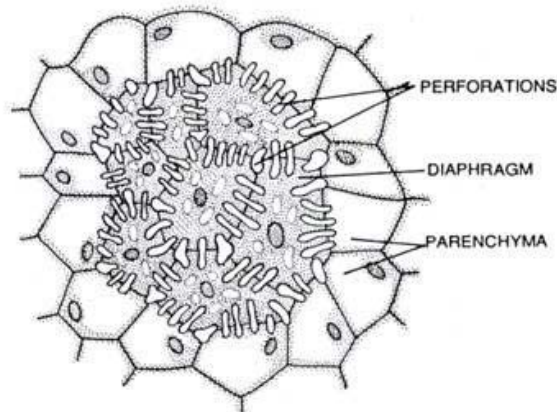


Fig. 41.27. Structure of hydrophyte. Detailed structure of C.S. of diaphragm of *Pontederia*. The diaphragms are provided with minute perforations through which gases but not water may pass.

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