THE TISSUE SYSTEM

Up to this point, we have delved into the various types of tissues found in plants, considering the diverse cell types constituting them. Now, our focus shifts towards understanding how these distinct tissues collaborate to function as a cohesive unit. We explore how these tissues amalgamate to form tissue systems, unraveling the locations and functions of these systems within the anatomy of flowering plants.

On the grounds of structure and location, plants exhibit three principal tissue systems:

- Epidermal Tissue System
- Ground or Fundamental Tissue System
- Vascular or Fascicular or Conducting Tissue System

These three tissue systems collectively shape the comprehensive framework of plants. Each tissue system carries out distinct functions, contributing to the overall vitality of the plant. In the subsequent discussion, we will dissect these systems individually to illuminate their roles and contributions within the intricate structure of flowering plants.

Epidermal Tissue System:

- The Epidermal Tissue System assumes the role of the outermost protective covering enveloping the plant body, establishing a direct interface with the external environment. This system encompasses distinct components, including:
- **Epidermis:** The epidermis, constituting the outermost layer of the primary plant body, is typically a single layer of epidermal cells. However, exceptions exist where it may manifest as a multilayered structure, as observed in plants like Nerium and Ficus. The epidermal cells are living entities with a nucleus and cytoplasm. These elongated cells are densely packed, forming a continuous layer, occasionally interrupted by epidermal structures like stomata in leaves and specific stems. Epidermal cells, being parenchymatous, feature a large central vacuole and peripheral cytoplasm along the cell wall. The wall structure varies, and in a transverse section of a stem or root, the outermost cell layer represents the epidermis.
- The external surface of the epidermis is frequently coated with a protective waxy layer known as the cuticle. This cuticle, comprised of a waxy substance called cutin, serves to prevent water loss. Notably, roots and hydrophytes lack a cuticle.

  Bulli form Cells: Certain monocot leaves boast specialized upper epidermal cells referred to as Bulli form cells, a topic to be explored further in the discussion on monocot leaf anatomy.

  Root Epidermis: The root epidermis goes by various names such as epiblema, piliferous layer, or rhizodermis, emphasizing its specific role in root function.

Stomata (Singular Stoma):

- Stomata, minute structures embedded in the epidermis of leaves, play a pivotal role in regulating transpiration and gaseous exchange. Unlike in leaves, stomata are notably absent in the epidermis of roots. Each stoma is a composite structure comprising:

  Two bean-shaped or kidney-shaped cells known as guard cells, and A tiny stomatal pore.

The cooperative arrangement of the pore encircled by two guard cells constitutes a stoma.

- **Guard Cells:** The nomenclature "guard cells" derives from their crucial function in overseeing the opening and closing of the stomatal pore. These cells are living entities, equipped with chloroplasts, and exhibit regulatory control over stomatal movement. While guard cells are typically bean-shaped or kidney-shaped, grasses feature dumbbell-shaped guard cells.

- The guard cells consist of inner and outer walls. The outer walls are thin, contrasting with the highly thickened inner walls. In the case of dumbbell-shaped guard cells, thickening is concentrated in the central part.

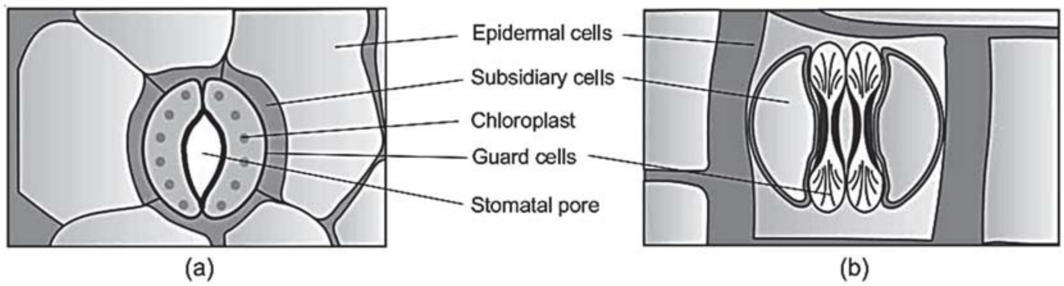

Fig. : Diagrammatic representation : **(a)** Stomata with bean-shaped guard cells, **(b)** Stomata with dumb-bell shaped guard cells

- **Function of Guard Cells:** Guard cells orchestrate the dynamic opening and closing of the stomatal pore. A turgid state (swollen) indicates an open pore, while a flaccid condition (shrunken) results in pore closure.
- **Subsidiary Cells:** These are specialized epidermal cells that, in certain flowering plants, adopt distinctive shapes and sizes surrounding the guard cells, earning the moniker "subsidiary cells" or "accessory cells." Their primary role is to provide structural support to the guard cells. Lacking chloroplasts, subsidiary cells do not partake in photosynthesis.
- **Function of Stomata:** Stomata serve as conduits for the regulation of transpiration and gaseous exchange. Transpiration, involving water loss through evaporation, and gaseous exchange, encompassing the interchange of oxygen and carbon dioxide between the plant and its surroundings, are facilitated by these epidermal structures termed stomata.
  Typically, the lower surface of a dicotyledonous leaf exhibits a higher stoma count than the upper surface. In monocotyledon leaves, the stoma count tends to be relatively equal on both surfaces.
- **Stomatal Apparatus:** The combined assembly of the stomatal aperture (pore), guard cells, and adjacent subsidiary cells is collectively referred to as the stomatal apparatus.

Epidermal Appendages:

- Epidermal appendages are characterized as outgrowths emerging from the external surface of the plant body. These structures are commonly found on both roots and shoots.
- **Root Hairs:** Root hairs, classified as epidermal appendages of roots, originate from the epidermal cells. Each root hair, a unicellular extension of an epidermal cell, possesses its own cytoplasm and nucleus. Functionally, root hairs play a vital role in the absorption of water and minerals from the soil. Their elongated, thin-walled structures significantly contribute to increased surface area for efficient absorption. Water, along with minerals, enters these structures through diffusion.
- **Trichomes:** Epidermal hairs on the stem are termed trichomes and are another category of epidermal appendages. Unlike root hairs, trichomes may be multicellular or, in some instances, unicellular.
  Branching and Softness
  Trichomes can be either branched or unbranched.
  They exhibit a spectrum of textures, ranging from soft to stiff.

Functions:

- **Transpiration Regulation:** Trichomes contribute to the regulation of transpiration by covering evaporating surfaces, hindering air flow across the plant surface, and thereby reducing water loss.

- **Secretory Role:** Some trichomes exhibit secretory functions. Sticky secretions produced by trichomes aid in trapping insects, leading to their demise and providing nutritional benefits to the plant.

Functions of Epidermal Tissue System:
The functions attributed to the structures discussed above collectively define the roles of the epidermal tissue system. Summarily, these functions include:

- **Protection:** The epidermal tissue system safeguards the plant from external injuries, excessive evaporation, and intense solar radiation. Key components like the cuticle and trichomes contribute to this protective function.
- **Secretion:** Trichomes, as part of the epidermal tissue system, facilitate the secretion of various sticky substances.
- **Gaseous Exchange:** The stomatal apparatus, a component of the epidermal tissue system, enables the exchange of gases.
- **Control of Transpiration:** The epidermal tissue system, through stomatal apparatus, trichomes, and the cuticle, plays a role in regulating and controlling the process of transpiration.
- **Absorption of Water and Minerals:** Root hairs, integral components of the epidermal tissue system, are responsible for the absorption of water and minerals from the soil. Their structural design enhances the efficiency of these absorption processes.

The Ground Tissue System

- The Ground Tissue System, also known as the fundamental tissue system, comprises the predominant volume of the plant body. This system encompasses tissues that do not fall under the categories of the epidermal tissue system and vascular tissue system. Within the ground tissue system, various simple tissues, including parenchyma, collenchyma, and sclerenchyma, contribute to the overall structure.
- The differentiation within the ground tissue system is evident through zonation, particularly observed in the transverse section of dicot stems, monocot roots, and dicot roots. In these structures, the ground tissue exhibits a distinct outer cortex and central pith. Between the cortex and pith, additional tissues are present, a topic that will be explored in the anatomy of stems and roots. Notably, this differentiation is not as pronounced in monocot stems. In leaves of both monocot and dicot plants, the ground tissue is referred to as mesophyll and lacks the clear distinction into cortex and pith.

Zonation in the Ground Tissue System: In dicot stems, dicot roots, and angiosperm roots, zonation in the ground tissue system typically follows a pattern from the outer to the inner side in both transverse and longitudinal views.

Cortex: Positioned beneath the epidermis, the cortex may consist of few to multiple layers. It further differentiates into three subzones: hypodermis, general cortex, and endodermis.

Hypodermis:

- The outermost layer of cortex in flowering plant stems.
- In dicot stems, it is collenchymatous, composed of collenchymatous cells, while in monocot stems, it is sclerenchymatous, consisting of sclerenchymatous cells.
- Functions primarily in protection, and some cells may contain chloroplasts, allowing for photosynthesis.

General Cortex:

- Located beneath the hypodermis in stems and adjacent to the epidermis in roots.
- Parenchymatous in nature, exhibiting thin-walled cells with or without intercellular spaces.
- In young stems and leaves, cortex cells may possess chloroplasts for photosynthesis.

- Offers mechanical support, facilitates photosynthesis in certain plant parts, and serves as a storage site for food material.

Endodermis:

- The innermost layer of cortex, acting as a border between the general cortex and the stele.
- Comprises a single layer of densely arranged cells, elongated parallel to the longitudinal axis of plants.
- In transverse section, endodermal cells appear barrel-shaped or oval.
- Living cells that may contain starch grains, earning it the name "starch sheath."
- Characterized by Casparian strips—thickened bands in cell walls formed by suberin deposition, making the endodermis impervious to water.
- Contains passage cells without Casparian strips, aiding in water movement.
- Prominent in roots but less distinct in stems.

Pericycle: Forms the outermost portion of the stele and is a cylinder of thin-walled parenchymatous or occasionally thick-walled sclerenchymatous tissue.

- Functions include providing mechanical support, acting as a storage organ for food materials, contributing to the cambial ring in dicot roots, and giving rise to lateral roots.
- Not present in monocotyledonous stems.

Pith

- Also known as medulla, occupies the central part in dicot stems, dicot roots, and monocot roots.
- In monocot stems, pith is indistinguishable due to the presence of vascular bundles throughout.
- Comprised mainly of large parenchymatous cells with intercellular spaces and occasional sclerenchymatous cells.
- Pith rays or medullary rays are extensions of pith, appearing as rays between vascular bundles in dicotyledons and contacting the pericycle.

Ground Tissue in Leaves:

In leaves, the ground tissue does not exhibit the differentiation observed in stems and roots, where it is divided into cortex and pith. Instead, the ground tissue in leaves is characterized by the absence of these distinct zones. This tissue in leaves is primarily responsible for photosynthesis and is referred to as mesophyll.

The Vascular Tissue System

- Ever contemplated how water ascends from the roots to the towering tips of trees or how nutrients synthesized in leaves traverse to the deep-seated root tips buried in the soil? The transportation of water, minerals, and synthesized food throughout every cell of a plant, even in the absence of a conventional circulatory system like animals, is orchestrated by the complex tissues of xylem and phloem, collectively forming the vascular tissue system.
  Xylem and Phloem in Plant Circulation: The intricate functions of transporting water, minerals, and synthesized food are accomplished by the specialized tissues in plants, namely xylem and phloem, which together constitute the vascular tissue system.
  Unlike animals, plants don't possess a traditional circulatory system or medium, relying on these intricate vascular components to fulfill essential transportation tasks.
  Vascular Bundles and Their Arrangement: Within the plant's stele, the varying numbers of vascular bundles contribute to the formation of the vascular tissue system.
  The arrangement of these vascular bundles may either be scattered within the general ground tissue or meticulously organized within the stele. For instance, monocotyledonous stems lack a distinct

separation into cortex and pith, featuring scattered vascular bundles. Conversely, dicotyledonous stems exhibit an organized arrangement of vascular bundles within the stele.

Translocation through Xylem and Phloem: The long-distance transport of substances, termed translocation, is facilitated by the vascular system, encompassing xylem and phloem.

Xylem plays a pivotal role in the translocation of water and minerals, while phloem is responsible for transporting synthesized food to various parts of the plant.

Elements of a Vascular Bundle in Dicots and Monocots:

- **Xylem:** In both dicotyledonous and monocotyledonous stems, xylem development initiates from the center towards the periphery. This endarch condition results in centrifugal xylem growth, extending from the center (pith) to the periphery.
  Conversely, in the roots of dicots and monocots, xylem development occurs from the periphery towards the center. This exarch condition leads to centripetal xylem growth, expanding from the periphery to the center (pith).
- **Phloem:** Vascular bundles in stems typically position phloem on the outer sides of xylem, with metaxylem closely situated to the phloem. Dicotyledonous plants' phloem comprises sieve tubes, companion cells, phloem parenchyma, and phloem fibers. Monocotyledonous plants' phloem consists of sieve tubes, companion cells, and phloem fibers, with phloem parenchyma being absent in most monocots.
- **Cambium:** Cambium, a thin strip of primary meristem located between xylem and phloem in dicot stems, is absent in monocots. Also known as interfascicular cambium, it plays a vital role in secondary growth, situated between the permanent tissues of xylem and phloem.

Classification of Vascular Bundles

- Vascular bundles, pivotal components in plant anatomy, are categorized into distinct types based on the presence or absence of cambium and the relative positions of xylem and phloem.

Presence or Absence of Cambium:

- **Open Vascular Bundles:** Open vascular bundles feature the presence of cambium between the xylem and phloem elements. This characteristic endows them with the capability to undergo secondary growth, forming additional xylem and phloem tissues. Dicotyledonous stems exemplify open vascular bundles, showcasing their openness to secondary growth.
- **Closed Vascular Bundles:** Closed vascular bundles lack cambium between xylem and phloem elements. Consequently, these bundles do not possess the capacity for secondary growth, remaining closed to the formation of additional xylem and phloem tissues. Monocot stems and the leaves of both dicots and monocots exemplify closed vascular bundles, emphasizing their restriction against secondary growth. It's notable that monocotyledons lack cambium in their stems and roots.

Relative Positions of Xylem and Phloem:

- **Radial Vascular Bundles:** Radial vascular bundles exhibit an alternate arrangement of xylem and phloem along different radii within the vascular bundle. This radial disposition characterizes the bundle as a radial vascular bundle. Such bundles are prevalent in the roots of both dicots and monocots, showcasing their radial organization.

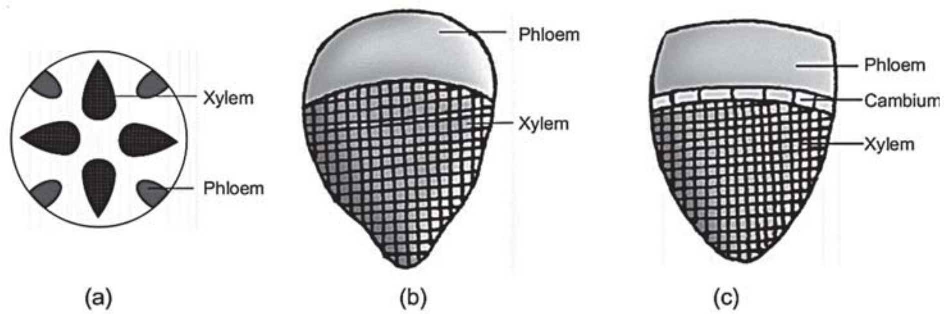

Fig. : Various types of vascular bundles:
(a) Radial, **(b)** Conjoint closed, **(c)** Conjoint open

- **Conjoint Vascular Bundles:** Conjoint vascular bundles present xylem and phloem jointly situated along the same radius within the bundle. This conjoint arrangement defines the vascular bundle as a conjoint vascular bundle. These bundles are commonly found in the stems and leaves of both dicots and monocots. Additionally, conjoint vascular bundles can be further classified as either open or closed based on the presence or absence of cambium.

  Conjoint Vascular Bundles (Open): In these bundles, cambium is present, allowing for secondary growth. The phloem is positioned on the outer side of the xylem, towards the periphery.
  Conjoint Vascular Bundles (Closed): In these bundles, the absence of cambium precludes secondary growth. Similarly, the phloem is located on the outer side of the xylem, towards the periphery.

This systematic classification provides a comprehensive understanding of the diverse types of vascular bundles and their structural characteristics.