BIL 161 – Plant Form and Function

Vascular Plant Anatomy

Plants have evolved a vast diversity of form and function. Ancestral plants, which were little more than strands of photosynthetic cells, underwent genetic drift and natural selection to give rise to descendants formed of three complex organs (Figure 1):

- **Root** takes up water from the substrate through microscopic root hairs.
- **Stem** supports aboveground structures and transports water.
- **Leaf** is the primary site of photosynthesis and water release to the atmosphere.

These organs are composed of four basic tissue types:

- **Dermal tissue** forms the "skin" of the plant.
- **Ground tissue** forms the living infrastructure of the plant.
- **Vascular tissue** forms transport tubes throughout the plant
- **Meristematic tissue** is composed of totipotent cells that can develop into any other type of plant cell. They are analogous to animal stem cells.

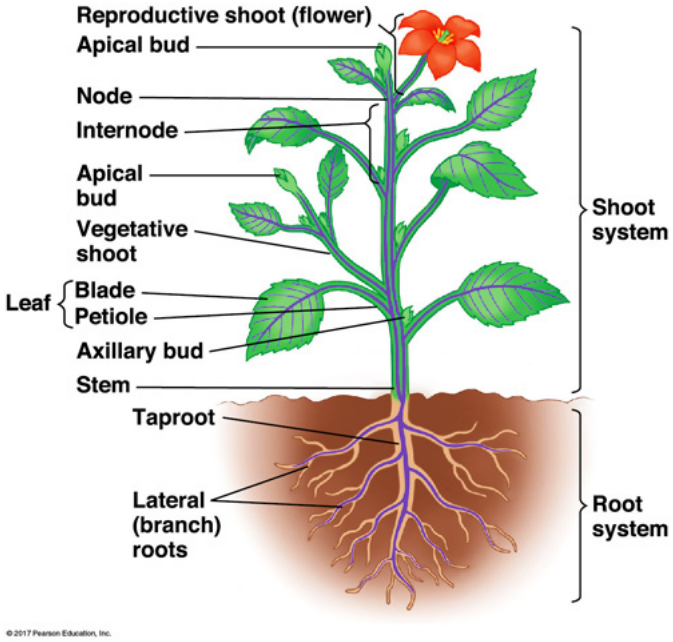


Figure 1. General Anatomy of a vascular plant.
(source: Biology by Campbell, et al.)

I. The Plant Vascular System

Most of the land plants you see around you are **tracheophytes** (**vascular plants**). Unlike their simple ancestors, these plants have **conducting tissues** that transport water and nutrients throughout the body.

In plants, water does not circulate. The plant **vascular system** is constructed of microscopic **tubular** (for transport) and **ground** (for physiological support) cells.

- **Xylem** transports water and dissolved **inorganic substances** from the roots, through the stems, to the leaves.
- **Phloem** transports dissolved **photosynthates** (organic molecules of photsynthetic origin) back and forth between areas of manufacture, use, and storage.

Xylem and phloem are arranged in the root and stem in a central bundle known as the **stele**. Xylem forms the center of the stele, with phloem forming a ring around the xylem. External to the stele, ground tissues form the bulk of the plant, and are covered by a unicellular layer of epidermis (Figure 2).

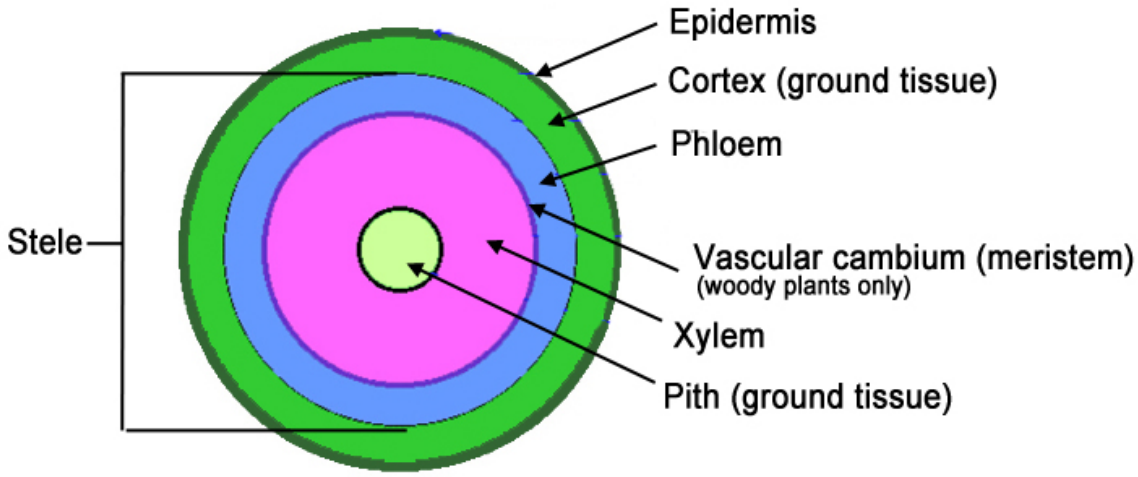


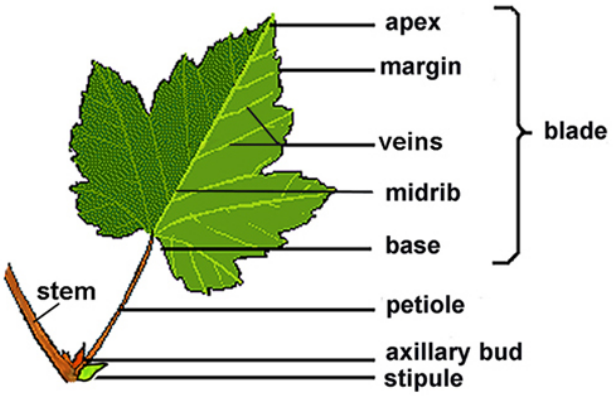
Figure 2. A generalized stem in cross section. A root has a similar arrangement, except that most roots lack the central pith seen in the stem stele. (great art by Krempels)

From the stem, vascular vessels transport water into the leaf via the

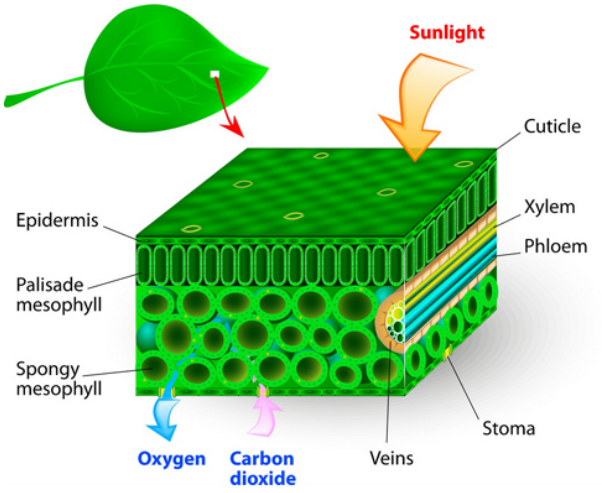
- **petiole** (stalk of the leaf) to the
- **midrib** to the
- **veins** (which branch to provide vascularization to the entire leaf)

Xylem terminates in the spongy mesophyll (Figure 3) on the lower surface of the leaf. which provide water and nutrients to the entire structure. Leaf xylem vessels terminate in the lower layer of leaf tissue, known as **spongy mesophyll**. Water travels along the apoplast to the **stomatal space**, where it vaporizes and leaves the stomate.

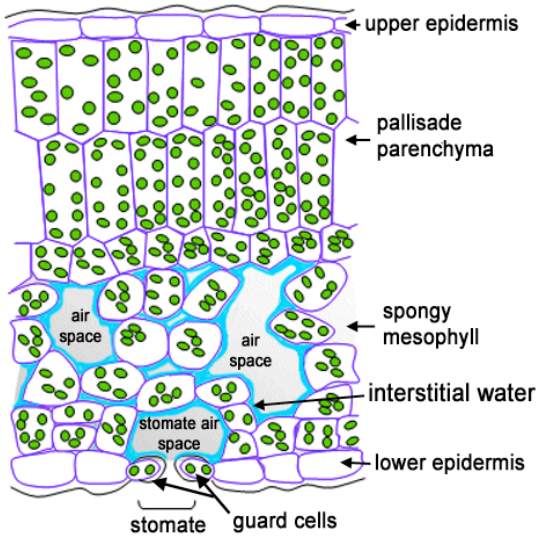
The rate of evaporation depends on environmental conditions and whether the stomates are open or closed by the bordering **guard cells**.



3a. General anatomy of a leaf.



3b. Leaf tissues and epidermal structures



3c. Spongy mesophyll and the stomate

Figure 3. General anatomy of a leaf. Water delivered by the xylem collects along the spongy mesophyll apoplast and is drawn to the to the stomatal space by shoot tension. Water evaporates and exits through the stomatal opening, which is bordered by guard cells that can open or close the stomate aperture.

II. Evolutionary Adaptations

In most plants, more than 95% of the water taken up by the roots exits via the stomates without ever entering the plant's tissues. The xylem provides a steady flow of water and minerals from root to stem to leaf, allowing the plant to take up what it needs at any given moment.

Water availability varies with environmental conditions, and the rate at which water moves through the plant is determined by both environmental factors and the plant's own evolutionary adaptations.

Different plant species exhibit evolutionary modifications of the three organs that allow them to best survive and reproduce in their particular environment.

- **Hydrophytes** are adapted for life in a very **wet environment**.
- **Xerophyes** are adapted for life in a very **dry environment**.
- **Mesophytes** are adapted for life in a **moderately wet/dry environment**.

Although many plants have roots and stems specialized to store water, it is the leaf that generally shows the most obvious evolutionary specializations for water movement and conservation in many plant species. These include such characters as

- Thick, waxy **cuticle** to prevent desiccation
- **Pubescence** (fuzz formed by hairlike epidermal projections called trichomes) to slow evaporation and deflect heat and light
- **Water storage** tissues
- Recessed (or otherwise protected) stomates
- Different **photosynthetic pathways** (C3 vs. C4 vs. CAM metabolism)

Water movement in the living plant is the result of the integrated activity of all of the plant organs--root, stem and leaf. When performing your literature search, consider which adaptations a particular plant species exhibits in all of its organs. But pay special attention to leaves, as it is this organ that we will be using in our experiments.