Topic 8: Structure and Function of Vascular Plant Cells and Tissues (Chs. 35-39)

I. INTRODUCTION

A. Most vascular plants continue growing throughout their lives
   1. can achieve great size and attain great age
   2. genetically identical individuals have propagated for generations

B. Vascular plants have a fundamental unity of structure
   1. two basic parts: root system, shoot system
   2. three basic organ types: roots, stems, leaves
   3. three basic tissue types: dermal, ground, vascular

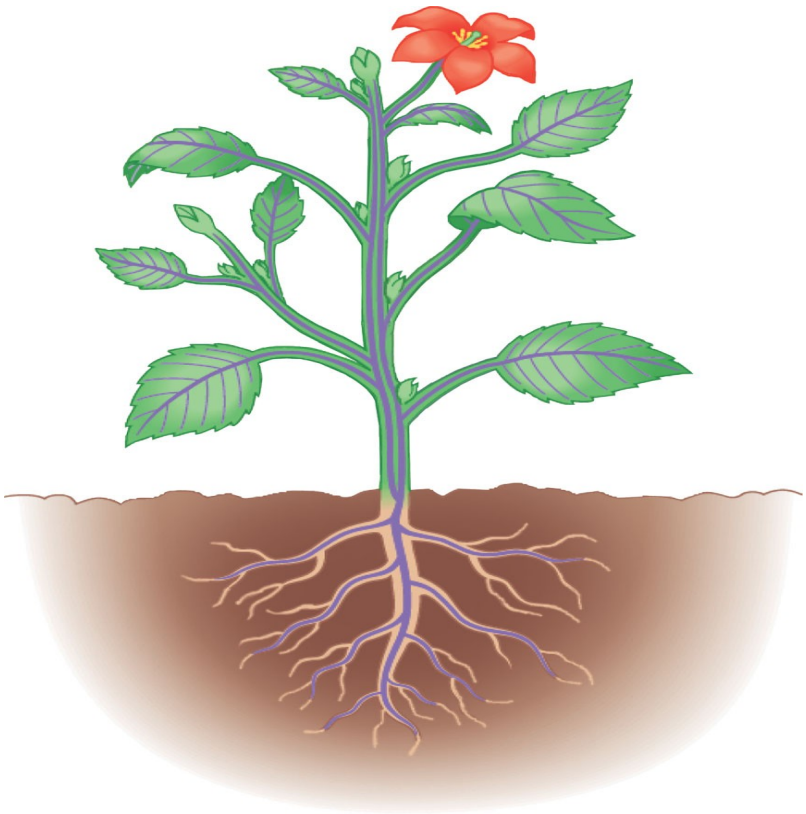
C. Vascular plants have a modular body plan (redundancy of units, general ability to replace units)

II. ORGANIZATION OF THE VASCULAR PLANT BODY

A. Vascular plants have a root system and a shoot system
   1. **root system**
      - penetrates the soil/substrate and anchors the plant
      - absorbs water and ions for plant to use

   2. **shoot system**
      - **stems**: serve as framework and support to position leaves
      - **leaves**: primary location for photosynthesis
      - structures that serve reproductive functions (cones, flowers, fruits, seeds, etc.)
      -

B. **meristem**
   1. give rise to all other cells of plant
   2. composed of small, unspecialized cells that divide continually
      - after division, one cell remains meristematic
      - other cell becomes part of plant body; may or may not go through more mitosis before differentiating



C. **primary growth**

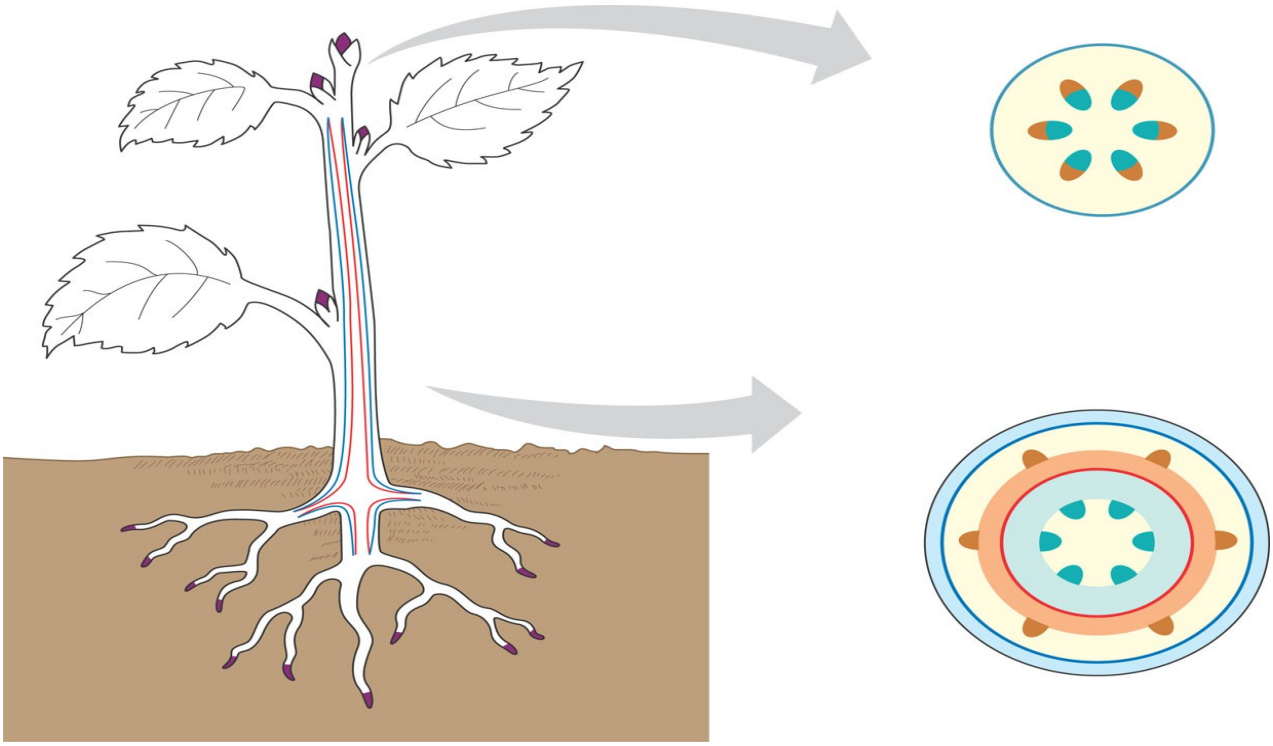
1. initiated by **apical meristems** near tips of roots, shoots
2. lengthening of primary plant body results
3. produces "primary" tissues that are partially differentiated
   - **ground meristem** – produces ground tissue
   - **protoderm** – produces epidermis
   - **procambium** – produces primary vascular tissue

D. **secondary growth**

1. initiated by **lateral meristems** – internal meristematic cylinders
2. expand girth of plant (thickening of plant body)
3. produces "secondary" tissues; allows thick, woody trunk in some plants
   - **cork cambium** – cork cells in bark of woody plants (outer bark)
   - **vascular cambium**: secondary vascular tissue
     - secondary phloem – closest to cork

- secondary xylem – internal; main component of wood

4. appears to have evolved independently in different plant groups



PLANT TISSUES AND CELL TYPES

E. 3 basic tissues: dermal tissue, ground tissue, vascular tissue

F. **dermal tissue**, or **epidermis**

1. protective outermost cells, cover all parts of primary plant body
2. usually only one cell thick
3. cells usually flattened
4. covered on outside by waxy **cuticle** layer that varies in thickness (depending on the species, plant region, and environmental conditions
5. most lack chloroplasts
6. includes some specialized cell types for protection or absorption: guard cells, trichomes, root hairs

7. **guard cells** – paired cells flanking a stoma
    - control opening of stoma
    - have chloroplasts
    - stoma openings allow passage of gases, mainly CO_2, O_2, H_2O vapor
    - stomata occur on leaf epidermis, occasionally on stems and fruit
    - stomata usually more numerous on underside of leaves
8. **trichomes** – hair like epidermal outgrowths
    - occur on stems, leaves and reproductive organs
    - give surface a "woolly" or "fuzzy" appearance
    - keep surface cool
    - reduce evaporation rate
    - help protect from predators/pathogens
        - physical separation
        - glandular trichomes may secrete sticky or toxic substances
9. **root hairs** – single cells found near root tips
    - tubular extensions of individual epidermal cells
    - intimate contact with soil/substrate
    - responsible for all absorption in herbaceous plants (water, minerals, nutrients)

G. **ground tissue** – primarily parenchyma cells

1. **parenchyma cells** – most abundant cells of primary tissues
    - initially spherical, get compressed and flattened by neighbors
    - least specialized cell type (other than meristem)
    - usually capable of further division
    - typically have thin walls (usually only primary wall)
    - large vacuoles and usually about 14 sides at maturity
    - usually remain alive after maturity; some over 100 years old
    - function in storage, photosynthesis (**chlorenchyma**), secretion
2. **collenchyma**
    - living at maturity (usually long-lived)
    - flexible, often in strands, forming support for organs (bend without breaking)
    - elongated cells with unevenly thickened primary cell walls

- example: celery "strings"

3. **sclerenchyma**
   - thick, tough secondary walls
   - usually lack living protoplasts at maturity
   - secondary walls often **lignified** (contain lignin); sometimes primary cell walls are lignified
     - **lignin** – highly branched polymer that reinforces structure
     - common in cells that have a supporting or mechanical function in body structure
   - two types: fibers and sclereids
     - **fibers** – long, slender, usually grouped in strands
       example: strands of flax, woven to make linen
     - **sclereids** – variable in shape; often branched; single or in groups
       example: gritty "stone cells" of pears

H. **vascular tissue**

1. **xylem**
   - principle water conducting tissue
     - contains various dissolved minerals and ions
     - conducts water in unbroken stream from roots to leaves
     - evaporation of water at leaves (**transpiration**) pulls water upward
   - provides structural support for plant body
   - conducting elements: tracheids and vessels
     - both not living at maturity
     - both are elongated cells with thick, lignified secondary walls
     - **tracheids**
       i. taper at ends and overlap one another
       ii. water flows from tracheid to tracheid through pits in secondary cell walls
     - **vessels**
       i. continuous hollow tubes (linked row)
       ii. ends may be almost completely open
       iii. more efficient than tracheids (higher flow rate)
       iv. almost exclusively in angiosperms
     - vessels evolved from tracheids independently in several groups
     - some fibers evolved from tracheids are specialized for support

- also includes fibers and parenchyma cells
- **primary xylem** from procambium (from apical meristem)
- **secondary xylem** from vascular cambium (from lateral meristem) – can form wood

2. **phloem**
   - principle food conducting tissue – carbohydrates (sucrose mainly); also amino acids, hormones
   - found in outer parts of roots and stems
   - girdling kills trees (remove bark in ring down to vascular cambium; prevents transport of food to or from roots)
   - conducting cells: sieve cells and sieve-tube members
     - both possess clusters of pores called sieve areas
     - both are elongated, living cells without a nucleus
   - **sieve cells**
     - more primitive (found in all vascular plant phyla)
     - pores all same size
   - **sieve-tube members**
     - only found in angiosperms
     - pores may be larger, called sieve plates
     - occur end-to-end, forming sieve tube
     - associated with **companion cells**
       i. specialized parenchyma cells
       ii. carry out metabolic functions to maintain sieve-tube members
       iii. possess normal parenchyma cell components (nuclei)
       iv. connected to sieve-tube member via **plasmodesmata**
   - also includes fibers and parenchyma cells
   - **primary phloem** from procambium
   - **secondary phloem** from vascular cambium

III. <u>ROOTS</u>

A. **root cap** – parenchyma at tip
   1. protection
   2. **Golgi complexes** produce mucous for lubrication
   3. **amyloplasts** (plastids with starch grains) used to perceive gravity

B. **zone of cell division** – apical meristem, cells divide every 12-36 hours
   1. after division, some daughter cells remain as meristem
   2. others soon subdivide into protoderm, procambium, and ground meristem

C. **zone of elongation** – cells get longer
   1. **vacuoles** fuse to make large central vacuole
   2. flexible cell wall until final size is reached in the zone; after this, cells can grow no more

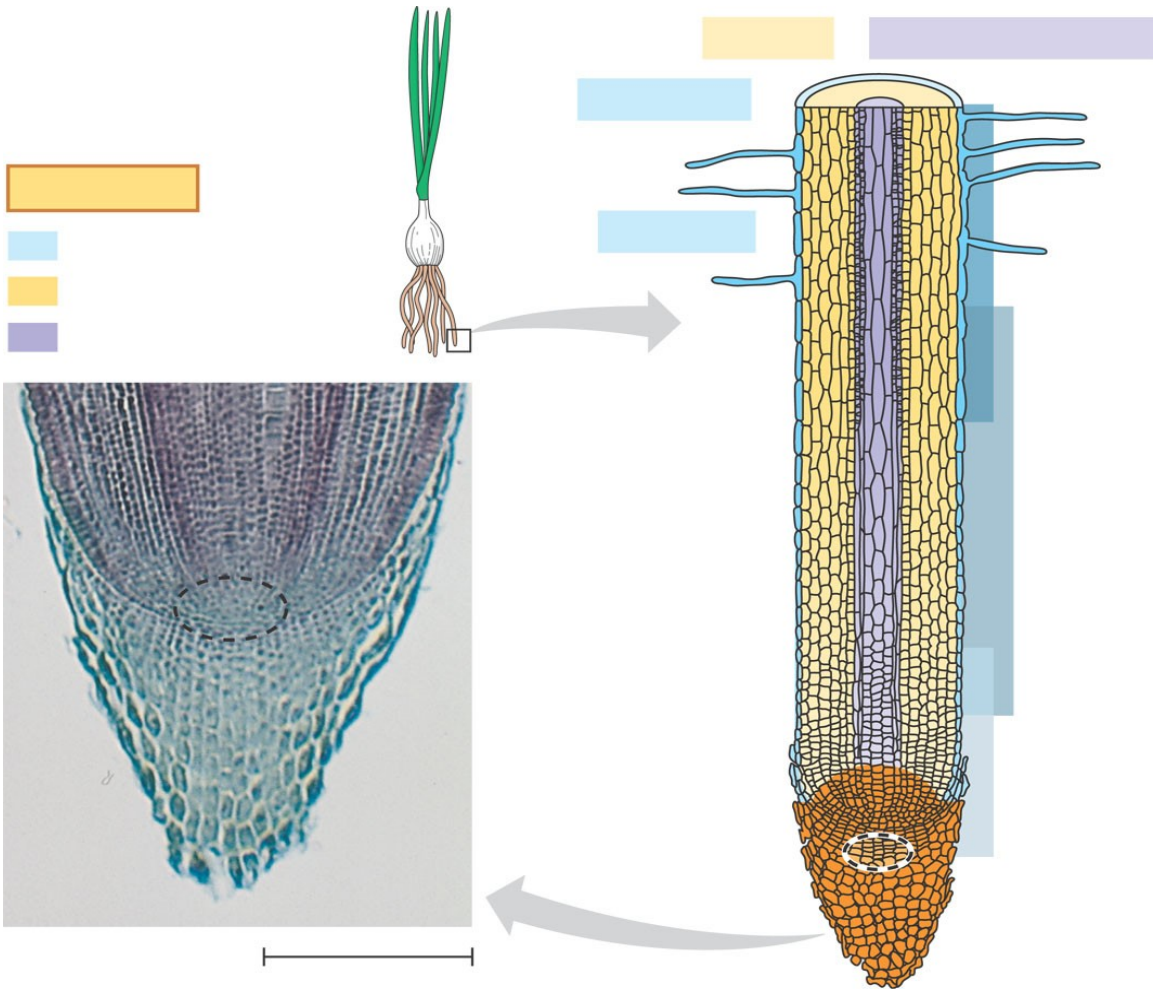
D. **zone of maturation** – become specific cell types
   1. **epidermal cells**
      - thin cuticle
      - develop **root hairs**, where absorption occurs
      - roots hairs usually last a few days; new ones continually made
   2. **cortex** – parenchyma below epidermis
      - may function in food storage
      - inner boundary becomes single-layered cylinder (**endodermis**)
      - primary walls of endodermis impregnated with **suberin** (fatty substance, impervious to moisture)
        - forms **Casparian strips**
        - water getting to center of root (where conducting tissues occur) must pass through interior of endodermal cells (never between them)
      - **stele** – all tissues interior to endodermis
        - **pericycle** – parenchymal layer just inside endodermis
          i. may give rise to lateral or branch roots
          ii. may become part of vascular cambium in dicots
        - **primary xylem**
          i. forms star in core in most dicots
          ii. in monocots and some dicots, forms vascular bundles in ring, with a parenchymal pith in center of root
        - **primary phloem** – between arms or bundles of xylem

E. **primary growth** – just behind root cap

F. **secondary growth** – after formation of lateral meristems (cambia)

G. modified roots
   1. most vascular plants make either a **taproot system** (one main root with branches) or **fibrous root system** (many roots of similar diameter); there are several modified root types

2. **aerial roots** – may be photosynthetic (some epiphytes), prop roots (like corn) branch near soil for support, adventitious roots – leave plant other than at base
3. **pneumatophores** – rise above water in aquatic trees; can function for gas exchange (mangroves, probably bald cypress)
4. **contractile roots** – pull plant deeper (lilies)
5. **parasitic roots** – penetrate host, **haustoria** for feeding from host
6. **food storage roots** – extra parenchyma cells (sweet potatoes; part root/part stem for carrots, beets, radishes, parsnips, turnips)
7. **water storage roots** – in some members of pumpkin family in arid regions; some over 100 lbs.
8. **buttress roots** – extra support (some figs and tropical trees)



IV. STEMS

A. **axis** – where leaves attach in spirals, whorls of 3+, or opposite pairs

B. **node** –where leaf is attached

C. **internode** – area between nodes

D. **axillary bud** – between leaf and stem, may form new stem or flowers

E. **terminal bud** – extend length of stem

F. herbaceous stems – don't form cork cambium; usually green, photosynthetic, and have stomata

G. **apical meristems** at tips

1. growth from apical meristem lengthens stem
2. bud scales fall off, revealing leaf and bud primordia during growing season
3. epidermis forms from protoderm
4. procambial strands form cylinders of primary xylem and primary phloem
5. ground meristem forms parenchyma cells
6. parenchyma in center = **pith**

H. **vascular cambium** divides to form secondary vascular tissues, increasing girth

I. **cork cambium** in woody stems –

1. arises from outer cortex; cork cells are boxlike, become impregnated with suberin and then die, form outer bark
2. **lenticels** – some cells from cork cambium unsuberized, permit gas exchange

J. monocot stems – herbaceous, vascular bundles dispersed

K. herbaceous dicots – vascular bundles arranged in ring

L. woody dicots

1. secondary xylem = wood
2. **annual rings** – growth confined to warm weather and/or rainy season {can give an idea of growing seasons over time (larger = better year)}
3. **rays** – parenchymal cells that run perpendicular to xylem vessels or tracheids; function in the lateral transmission of water and dissolved minerals
4. **heartwood** –vessels become blocked and waste accumulates, making wood darker in center
5. **sapwood** – light, functioning conductive wood outside to heartwood
6. **bark** – outer bark from cork cambium, inner bark is phloem
7. hardwood = dicot wood; softwood = conifer wood

M. modified stems

1. **bulbs** – swollen, knoblike underground stems with fleshy leaves attached (onions, lilies, tulips)
2. **corms** – like bulbs but with no fleshy leaves attached
3. **rhizomes** – horizontal underground stems (ferns, irises, perennial grasses)
4. **runners** and **stolons** – horizontal stems above ground (strawberries); definition of stolon varies
5. **tuber** – carbohydrates concentrated at tip of stolons, which swell (example: potato); "eyes" are axillary buds that can form new plants
6. **tendrils** – twine around a support and help plant to climb (grapes, ivy) – some tendrils are actually modified leaves (peas, pumpkins)
7. **cladophylls** – flattened, photosynthetic stems that resemble leaves (found in cacti and some other plants; cactus leaves are modified into spines)

V. <u>LEAVES</u>

A. develop from **primordia** laid down by meristems

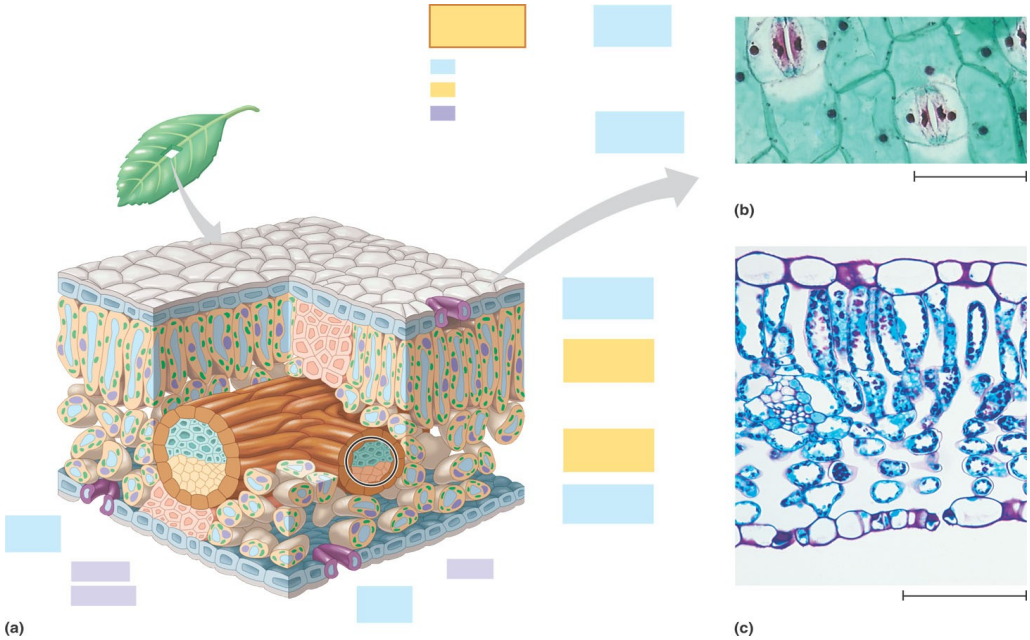
B. external structure

1. dicot – flattened blade and slender stalk (**petiole**)
2. monocot – no petiole; blade usually sheaths stem (ex.: onion)
3. veins – vascular tissue pattern
   - monocot – parallel
   - dicot – intricate network
4. **axillary bud** – at base of leaf
5. simple vs. compound leaves
   - **simple leaves** – undivided (may have teeth or indentations)
   - **compound leaves** – each blade divided into leaflets, leaflets don't have axillary buds (compound leaf has one bud at base)
     - **pinnately compound** – leaflets in pairs along common axis
     - **palmately compound** – leaflets radiate from common point on petiole (examples – marijuana)
6. alternate vs. opposite arrangement
   - **alternate** – single leaves occur on alternating sides, usually in a spiral
   - **opposite** – leaves occur in pairs on opposite sides of stem
7. **whorls** and rosettes
   - circle of 3+ leaves at a node on stem

- **rosette** is a whorl at essentially ground level

C. internal structure

1. **epidermis** – transparent, most cells with no chloroplasts
   - upper and lower surfaces of leaf
   - **cuticle** – waxy layer of variable thickness
   - may have glands and trichomes
   - usually, stomata mainly on lower epidermis (underside of leaf)
2. **mesophyll** – between upper and lower epidermis
   - interspersed with veins (vascular bundles)
   - **palisade mesophyll** – chlorenchyma in tightly packed rows close to the upper epidermis
   - **spongy mesophyll** – loosely packed chlorenchyma nearer lower epidermis
   - many air spaces, especially in spongy mesophyll (for gas exchange)
   - monocot mesophyll not differentiated into palisade and spongy layers



D. **leaf abscission** – all plants lose leaves

1. **abscission zone** at base of petiole
2. young leaves make hormones that inhibit specialization in abscission zone

3. hormonal changes during aging allow two layers of differentiation
   - protective layer – on stem side; up to several cells wide, may become impregnated with suberin
   - separation layer – on leaf side; eventually weakens connection between leaf and stem
4. as abscission zone develops, chlorophyll in leaves breaks down; other colors may be revealed (cause of fall colors)
   - carotenoids – yellows and oranges; present all the time
   - anthocyanins and betacyanins – water-soluble red and blue pigments that may be present to some degree all the time, but often accumulate in leaf cell vacuoles as chlorophyll is lost
5. weather/wind eventually knocks most leaves off
6. "evergreens" lose and replace their leaves continuously in small numbers; deciduous plants lose and replace all leaves together in response to seasons

E. modified leaves

1. **bracts** (floral leaves) – large, colorful leaves functionally act as petals; flowers usually inconspicuous (poinsettias, dogwoods)
2. **spines** – cacti and others – reduction in leaves reduces water loss and protects from predators
3. **reproductive leaves** – as in maternity plant, walking fern
4. **window leaves** – cone-shaped leaves with a transparent tip; allows light into hollow interior, thus allowing some buried plant parts to have photosynthesis below ground
5. **shade leaves** – leaves in shady areas have larger surface area and are thinner compared to leaves that receive more direct light
6. **carnivorous leaves** – designed to capture animals (mainly insects) to provide a nutrient supplement (common in swampy areas with sandy soil and high amounts of sunlight, where nitrogen and/or phosphorous may be limiting – example: southeastern U.S.)