

PLANT STRUCTURE

The structure and morphology of plants as they relate to function and utility of horticultural crops will be discussed. Topics covered in this lecture will be 1) the cell and its components, 2) tissue and its systems, 3) anatomical regions, 4) morphological structures of roots, shoots, leaves, flowers and seeds.

I. THE CELL

Cell - the structural unit of plants

Cytology - the study of cells concerning their organization, structure, and function. Plant cells vary in shape and measure between 0.025 mm and 0.25 mm (24μ - 250μ) in size. Some cells (long tubular fibers) are as much as 2 feet long.

Cytoplasm (protoplasm) - all the living unit of a protoplast outside the nucleus in the cell.

Plasma membrane - the membrane that surrounds the cytoplasm. It is semipermeable to solutes, while cell wall is some degree permeable to all solutes and solvents. It is composed of **lipoproteins**.

Endoplasmic reticulum (ER) - paired membranes within the cytoplasm closely associated with the outer membrane of nuclear envelop.

Nucleus - the dense protoplasmic body essential in cellular synthetic and developmental activities; present in all living plant cells except mature sieve-tube elements. The control center of the cell which contains chromosomes. Chromosome contains DNA.

Ribosomes - small particles (100-200 A) which are actual sites of protein synthesis by RNA.

Cell wall - the structure made of polysaccharides (long-chain units of simple sugars such as glucose), lignin and pectin. The principal polysaccharide is **cellulose**, which is unbranched polymer of **glucose** molecules. The branched polysaccharides are **hemicelluloses**, branched chain polysaccharides containing a variety of monosaccharide units, only one of which is glucose, as well as non-sugar components such as protein.

Lignin - polymers of phenolic acid which makes the cell wall inelastic and enduring material resistant to microbial decomposition. (lignin must be removed to prevent yellowing in paper making)

Pectins - acidic polysaccharides, specifically water-soluble polymers of galacturonic acid that forms sols and gels with water (solidifying agent for jams and jellies).

All cell wall in plants is not continuous. It appears to be pierced by cytoplasmic strand (**plasmodesmata**) that provide a living connection between cells.

Plastids - specialized disk-like bodies in the cytoplasm (only in plant cells). They can be leucoplasts (colorless) or chromoplasts (colored). **Chloroplasts** are chromoplasts which contain chlorophyll. There are about 20-100 chloroplasts in each chlorophyllous cell of a typical green leaf (mature leaf cells of spinach may contain 500 chloroplasts).

Chloroplasts - contain **grana** which are structural units resembling stacked coins. Grana contain the **chlorophyll**, a pigment system which is the receptor of light. The actual carbon dioxide fixation into carbohydrate compounds occurs in the surrounding material called **stroma**.

Chloroplasts have their own DNA and self-replicating under the influence of nuclear genes.

Mitochondria - a small cytoplasmic particle associated with intercellular respiration. A power center of the cell, mitochondria are made up of proteins and phospholipids. It carries out the enzymatic activity of oxidative respiration. This activity occurs through the formation of the energy-carrying substance called ATP. Mitochondria contains DNA for self replication.

Vacuoles - membrane-lined cavities located within the cytoplasm. They are filled with a watery substance known as the cell sap, which contains a number of dissolved materials-salts, pigments, and various organic metabolic substances. They are small and numerous in actively dividing cells; they coalesce into one large vacuole that occupies the center of the cell, pushing the cytoplasm and the nucleus next to the cell wall.

Other components of cytoplasm: crystals, starch grains, oil droplets, silica, resins, gums alkaloids, and many organic substances, many of these are reserve or waste products.

II. TISSUES AND TISSUE SYSTEMS

Although the plant ultimately originates from a single cell (the fertilized egg), the marvels of cell division and differentiation produce an organism composed of many kinds of cells that are structurally and physiologically diverse. It is this difference in cell morphology and cell arrangement that results in the complex variation between plants and within an individual plant. Plants can be shown to be made up of groups of similar types of cells that are organized in a definite pattern. Continuous, organized masses of similar cells are known as **tissues**.

Tissues - Continuous, organized masses of similar cells

Meristematic tissue - actively dividing undifferentiated cells

Permanent tissues - nondividing differentiated cells

Simple tissues - composed of one type of cell

Parenchyma - simple thin-walled cells

Collenchyma - thicker-walled "parenchyma"

Sclerenchyma - thick-walled supporting cells

Complex tissues - composed of more than one type of cell

Xylem - water-conducting tissue

Phloem - food-conducting tissue

1. Meristematic Tissues

Meristematic tissue is composed of cells actively or potentially involved in cell division and growth. Meristem not only perpetuates the formation of new tissue but also perpetuates itself.

- a. **Apical meristem** - meristems at the tips of shoots and roots. They are known horticulturally as the **growing point**.
- b. **Cambium -lateral meristems** responsible for the increase in girth of woody stems; actively dividing and expanding as a result of increase in stem diameter.
- c. **Intercalary meristems** - (in grass) isolated meristematic regions near the nodes. The mowing of lawns does not interfere with the growth of the grass plant from the growing points are not damaged by mowing.
- d. **Primary tissues** - tissues differentiated from the apical meristems
- e. **Secondary tissues** - tissues formed from the cambium

2. Permanent Tissues

Permanent tissues are made up of nondividing differentiated cells derived directly from meristems. They are referred to as **simple tissues** when they are composed of one type of cell and as **complex tissues** when they are mixtures of cell types.

a. *Simple tissues*

Parenchyma -relatively undifferentiated, unspecialized vegetative tissue. (It makes up a large portion of many plants, such as the fleshy portion of fruit, roots, and tubers)

Collenchyma - tissue characterized by elongated cells with thickened primary walls composed of cellulose and pectic compounds. (Thick-walled parenchyma). This tissue functions largely as mechanical support in early growth. (The strands at the outer edge of a celery stalk are collenchyma)

Sclerenchyma -tissue composed of especially thick-walled cells that are often lignified. When these cells are long and tapered they are usually referred as **fibers**. Others are **sclereids**. Clusters of these sclereids, or "stone cells," are responsible for the gritty texture of pears. In masses, sclereids are responsible for the hardness of walnut shells and of peach and cherry pits. Unlike parenchyma and collenchyma, sclerenchyma cells are nonliving when mature.

b. *Complex tissues*

Xylem -the principal water-conducting tissue consisted of living and non-living cells. **Wood** is largely xylem. (Herbaceous plants also contain xylem but the volume is much less). Xylem is composed of **tracheids** (elongated tapered cells with walls that are hard and usually lignified, although not especially thick) and **vessels** (formed from meristematic cells from which the cell contents and end walls have been dissolved). The water moves readily through the empty tracheid, flowing from cell to cell through the numerous pits between them. Vessel cells are lined up end to end and the series may be many feet long. Xylem is formed by differentiation of the apical meristems of root and shoot. In perennial woody plants, secondary xylem is also formed in the familiar annual rings. The spring wood consists of larger cells with thinner walls and appears lighter, or less dense than the summer wood.

Phloem: the principal food-conducting tissue. They are made up of specialized cells called **sieve elements**. Sieve elements are elongated living cells with thin cellulose walls through which the food is conducted from one part of the plant to another. The nucleus of the sieve cell disappears. Sieve cells are physically associated with **companion cells** which have the nucleus. In addition to sieve and companion cells, fibers and sclereids may be present in phloem. The fibers of hemp and flax are derived from the phloem tissue.

The phloem is not enduring, and the old phloem disintegrates in woody stems. The phloem is protected by special meristematic tissues (cork cambium) that produce parenchymatous tissue. Bark is composed of the phloem, corky tissue and other incidental tissues.

III. ANATOMICAL REGIONS

1. *The Vascular System*

Horticultural plants are grossly divided into the vascular system (plumbing), the cortex (frame and insulation), and the epidermis (siding, floor, and roof). The pith, pericycle, endodermis, and secretory glands are one or more of these regions.

Vascular system = xylem + phloem

= the conduction system of the plant.

Since it also supports the plant, it may be compared to both the circulatory and skeletal systems of animals. Vascular system forms a continuous ring in the stem, in which the inner portion is xylem, surrounding an area of parenchymatous tissue known as **pith**. The vascular system may be continuous and may appear as a series of strands in longitudinal section and bundles in cross section (as in potato, and monocotyledonous plants).

Pith is absent in roots. In roots, the vascular system is separated from the cortex by specialized tissues called the **pericycle** and the **endodermis**. **Pericycle** is composed of parenchymatous tissue and is the source of the branch roots and stems that arise from the root. **Endodermis** is commonly a single sheet of cells separating the vascular system from the cortex. It has a protective function. The pericycle and endodermis are absent in the stem.

2. **Cortex**

Tissue between the vascular system and the epidermis. It is made up of primary tissues, predominantly parenchyma. **Cork** is formed when mature tissue is infiltrated by a waxy substance known as **suberin** (which waterproofs the cell walls, or suberization). **Periderm** is the corky protective sheath produced by suberization. The cork industry is developed based on this tissue (as in *Quercus suber*).

3. **Epidermis**

The continuous cell layer that envelops the plant. **Root hairs** are tube-like extensions that absorb nutrients and water.

Stomata-epidermal structure composed of two guard cells that form a pore. Gases such as oxygen and carbon dioxide are introduced into plant via **stomata**.

Cuticle - a waxy layer formed (by **cutin**) on the surface of the epidermis (as in apple).

4. **Secretory Glands**

Glands are the complex secretory structures that produce fragrance (from flowers), essential oils, resins, gums, mucilages. **Trichomes** are the multicelled, hairlike epidermal appendages.

IV. MORPHOLOGICAL STRUCTURES

1. Roots

The **primary** root - the original seedling root. It becomes the **taproot** of the plant root system.

The **fibrous** root system...thin lateral roots (as in the grass) thick function as feeder roots.

Root Modifications -Roots **swollen** and **fleshy** with stored food in the form of starches and sugars. (Carrot, sweet potato, turnip, radish, sugarbeet, dahlia)

2. Shoots

a. The stem:

The **shoot** - a central axis with appendages. The central axis, the **stem**, supports the food-producing leaves and connects them with the nutrient-gathering roots.

b. The buds:

Bud - an embryonic stem.

All buds do not grow actively; many exhibit arrested development or dormancy but are potential sources of further growth.

The bud types

Terminal buds - buds borne on the tip of stem

Lateral buds (axillary buds) - borne on the leaf axis

Adventitious buds - buds formed in internodal regions of the stem, leaves or roots often as a result of injury.

By what they contain:

Leaf buds - buds that produce leaves

Flower buds - buds that produce flowers

Mixed buds - buds that produce leaves and flowers

Accessory buds - buds other than the central bud

The bud arrangements:

Opposite - borne in an opposite position

Alternate - borne alternately

Whorled - borne in a whorled position

The **phyllotaxy** - the spiral pattern of leaf arrangement expressed as a fraction ($1/2$, $1/3$, $2/5$, $3/8$), where the number of turns to get to a leaf directly above another and denominator is the number of buds passed.

c. Stem modifications

Above-ground stem modifications:

The **crown** - the junction of stem at the ground level that connects the root (Crown in forestry refers to the branched top of a tree). The crown is the "**compressed stem**" since GA application elongates it as seen in strawberries. **Crown division** is used in propagation in herbaceous perennials as in asparagus and day lilies.

Off-shoots - short, many-noded, horizontal branches growing out of the crown.

Stolons - stems that grow horizontally along the ground. A **runner** is a stolon with long internodes originating at the crown.

Spurs - stems of woody plants whose growth is restricted. Spurs are the sites on which flowers of apples, pear and quince are borne.

Below-ground stem modifications:

Bulb - a compressed modification of the shoot. It consists of a short, flattened or disk-like stem surrounded by fleshy leaf-like structures called **scales**

Corms - short, fleshy underground stems (gladiolus, crocus)

Rhizomes - horizontal underground stems. They may be compressed and fleshy (iris) or slender with elongated internodes (turfgrass).

Tubers - the greatly enlarged fleshy portions of underground stems (as in potato).

3. The Leaf

Leaves are the flat appendages of the stem where photosynthesis occurs. The leaf **blade** is borne on a stalk called **petiole**. The **stipules** are the leaf-like outgrowths of petioles

a. **Veins** - the vascular system branched through the leaf tissue. The veining is typically netlike in dicots and parallel in monocots. The leaf blade is commonly bilaterally symmetrical but not radially symmetrical, since it has distinct upper and lower side.

b. **Palisade** cells - elongated closely packed cells (containing a large quantity of chloroplasts) located underneath the upper surface (adaxial) of the leaf. Most of the photosynthetic activities occur in these **palisade parenchyma cells**.

c. **Spongy mesophyll** cells - the loosely arranged cells in the sponge-like region of the leaf tissue between the palisade layer and the lower (abaxial) epidermis. These tissues allow gaseous exchange needed for photosynthesis and transpiration.

4. The Flower

- a. **Sepals** (collectively, the **calyx**) - small, green leaflike structures that enclose or support the petals in a flower.
- b. **Petals** (collectively, the **corolla**) - the conspicuous portion of most flowers. They often are highly colored and may contain perfume glands.
- c. **Stamens** - the male part of the flowers. The stamen is composed of a pollen-bearing **anther** and a **filament**.
- d. The **pistil** - the female part of the flower. It is consisted of an **ovule**-bearing **ovary**, **style** and **stigma**. The ovule gives rise to the seed and the mature ovary becomes the fruit. The flower parts are often borne on an enlarged portion of the flower-supporting stem called the **receptacle**.
- e. **Complete** flower - the flower containing sepals, petals, stamens and pistils.
Incomplete flower - the flower lacking one or more of the flower parts
Pistillate flower (female flower) - lacking stamens
Staminate flower (male flower) - lacking pistils
The **perfect** flower- **hermaphroditic** flower that has both stamens and pistils
- f. Plant types by flowers:
Monoecious - bearing both staminate and pistillate flowers on the same plant (cucumber, maize)
Dioecious - species in which the plants are separated into staminate (male) and pistillate (female) plants (date palm, papaya, spinach, asparagus, hemp)
Andromonoecious - bearing perfect flowers and staminate flowers on the same plant (as in muskmelon)
Gynomonoecious - bearing perfect flowers and pistillate flowers on the same plant (as in cucurbits)
Trimonoecious -bearing male, female and perfect flowers on the same plant. (as in some cucurbit species)
- g. Common **Inflorescence** (the flower clusters)
Head (Asteraceae, sunflower)
Spike (wheat)
Raceme (radish)
Corymb (cherry)
Panicle (rice)
Cyme (simple dichasium or compound dichasium; i.e., strawberry)
Simple umbel [Apiaceae (formerly Umbelliferae), onion]
Compound umbel (Apiaceae, carrot)

5. The Fruit

Botanically the **fruit** refers to the mature ovary and other flower parts associated with it.

- a. **Simple** fruits (composed of a single ovary):
Dry (made up of nonliving sclerenchyma cells with lignified or suberized walls)
Flesh (made up of large portions of living succulent parenchyma tissues)
Pericarp (the ovary wall) is consisted of **exocarp**, **mesocarp** and **endocarp**
Berry - the entire pericarp is flesh (as tomato, grape, pepper)
Pepo - berry fruit (as in muskmelon) made up of a hard rind (exocarp, receptacle tissue), mesocarp (the edible flesh)
Drupes (stone fruits) - simple flesh fruits having a stony endocarp (as in cherry, plum, peach, olive). A drupe is composed of stone (endocarp), skin (exocarp) and fleshy edible portion

(mesocarp).

Pomes - simple flesh fruits in which the inner portion of the **pericarp** forms a dry paperlike "core" (as in apple, pear, quince)

Dry fruits - **Pods** (pea), **follicles** (milk weed), **capsules** (jimson weed), **siliques** (crucifers) are dehiscent fruits

Achenes (sunflower), **caryopses** (maize), **samaras** (maple), **schizocarps** (carrot), **nuts** (walnut) are non-dehiscent.

- b. **Aggregate** fruits (each aggregate fruit is derived from a flower having many pistils on a common receptacle).

Blackberry - individual fruits of the aggregate are **drupes** (stony).

Strawberry - individual fruits of the aggregate are achenes (one-seeded, dry fruits attached to the receptacle at a single point) (the edible portion is the **receptacle**)

- c. **Multiple** fruits (derived from many separate but closely clustered flowers)
Pineapples, fig and mulberry are multiple fruits.

6. The Seed

A seed is a miniature plant in an arrested state of development. Structurally the seed is a matured ovule.

- a. **Seed coat** - matured (dried) skin of the ovule
- b. The seed **embryo** is differentiated into a rudimentary shoot (**plumule**), a root (**radicle**), and seed leaves (**cotyledons**). **Hypocotyl** is the transition zone between the rudimentary root and shoot.
- c. **Endosperm** - food storage tissues within a seed
Albuminous seed - endosperm forms a specialized region in the seed (maize).
Exalbuminous seed - endosperm is absorbed by the developing embryo (beans, walnuts).