Plant Pathology Course:

Plant Form and Function:

Plants (kingdom Plantae) are **autotrophs**; they make their own organic nutrients. The term "organic" refers to compounds that contain carbon. Organic nutrients such as sugars are made by photosynthesis.

Plants are adapted to living on land. For example, the above-ground parts of most plants are covered by a waxy layer called a cuticle to prevent water loss.

Aquatic plants are secondarily adapted to living in water.

Some evidence that suggests that plants evolved from the green algae is:

they both use chlorophyll a, chlorophyll b, and carotenoid pigments during photosynthesis.

the primary food reserve of both is starch.

they both have cellulose cell walls.

There are two major groups of plants, **lower ad higher** plants.

Lower plants' is a collective term for three mains groups of plants, mosses, liverworts and lichens which do not have roots and produce spores to reproduce, rather than flowers. Mosses and liverworts have stems and leaves and attach themselves to rocks, soil or trees using modified stems called rhizoids.
They live on mild damp conditions as most of the species have limited ability to retain water.

Lichens are two kinds of plants, a fungus and an algae, which grow together in close association (symbiosis). Lichens tend to grow more profusely in areas which are more open to sunlight than is the case with mosses and liverworts, but are highly sensitive to atmospheric pollution.

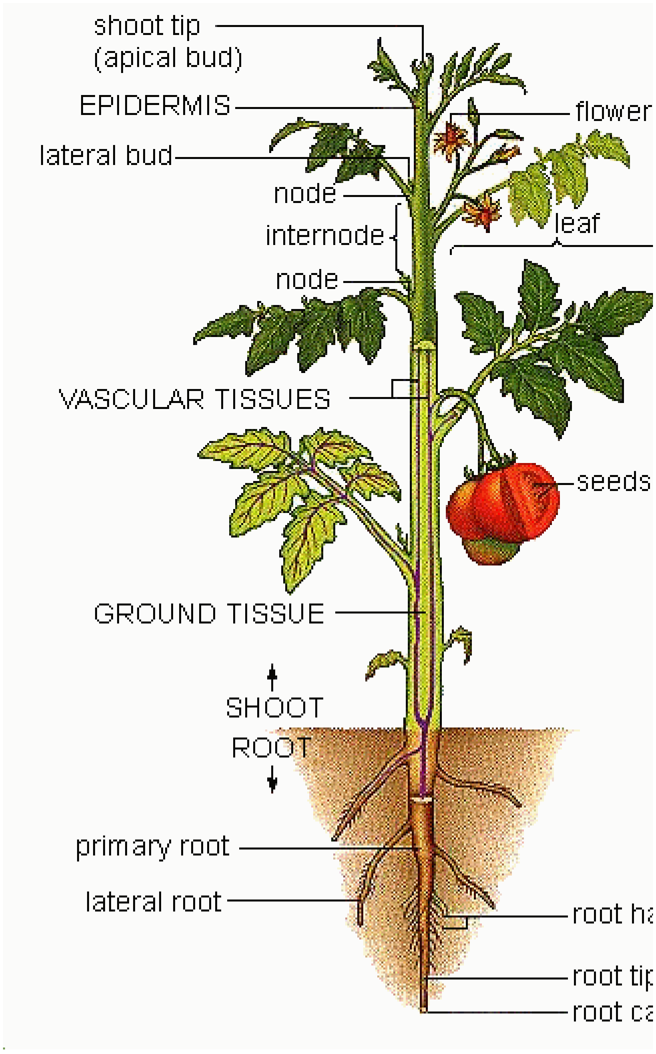
Vascular plants:
Name of vascular plants is derived from Latin vasculum which means duct. They also called higher plants because they have specialized vascular conducting tissues including xylem and phloem tissues. They

form a large group of plants that are defined as those land plants that have lignified tissues called the xylem, for conducting water and nutrient minerals throughout the plant. They also have a specialized non-lignified tissue, the phloem, to conduct products of photosynthesis.

Vascular plants can be divided according to the seed production into two major groups: seedless vascular plants and seed plants. The seed plants are divided into gymnosperms (naked seeds) and angiosperms (covered seeds).

Angiosperms, also called flowering plants, have seeds that are enclosed within an ovary (usually a fruit), while gymnosperms have no flowers or fruits, and have unenclosed or “naked” seeds on the surface of scales or leaves. Gymnosperm seeds are often configured as cones. The characteristics that differentiate angiosperms from gymnosperms include flowers, fruits, and endosperm in the seeds.

Since the goal of this course is to study plant disease, it is necessary to review and focus on the plant structure as a morphology and basic anatomy of higher plants (vascular plants). The morphology deals with the external (forms and location) and internal structural (tissues and cells types) parts of the plants. The angiosperms or flowering plants are the main group will be studied in this course since most of the economically important crops necessary for our daily life are produced by them.



The "Typical" Plant Body

The Root System

- Underground (usually)
- Anchor the plant in the soil
- Absorb water and nutrients
- Conduct water and nutrients
- Food Storage

The Shoot System

- Above ground (usually)
- Elevates the plant above the soil
- Many functions including:
  - photosynthesis
  - reproduction & dispersal
  - food and water conduction
- Note: the shoot system includes the leaves and the reproductive organs, although these will be covered in more detail separately

It is necessary to understand plant morphology before studying the plant anatomy. Angiosperms (flowering plants) are by far the most diverse group of plants known (over 275,000 named species and thought to be at least that many more unknown to science).

Within the Angiosperms, there are two plant groups, the **Monocots** and the **Dicots**. The distinction between these two groups is not always clear, but some general characteristics are outlined below:

Plant Features	**Monocots**	**Dicots**
Floral Arrangement	3's	4's and 5's
Leaf Venation	Parallel	Net
Vascular bundles	Scattered	Ring
Habit	Herbaceous	Herbaceous + Woody
Roots	Fibrous	Taproot
Growth	Primary only	Primary and Secondary
Examples:	Grass, wheat, corn, barley, date Palm	Oaks, Roses, Sunflowers, beans

Tissues and Cell Types in the Plant Body:

<u>Parenchyma Cells</u>

- Least specialized plant cells
- Thin and somewhat flexible cell walls
- Living at maturity
- Carry on most of the plant's metabolic functions
- Generally have a large central vacuole
- Most parenchyma cells have the ability to differentiate into other cell types under special conditions
    - During repair and replacement of organs after injury

Collenchyma Cells

- Thicker primary cells walls (usually with uneven thickness)
- Living at maturity
- Role in support of herbaceous plants
    - *Example* - the "strings" of celery

Schlerenchyma Cells

- Thick secondary cell walls
- Dead at functional maturity
- Cannot increase in length - occur in parts of the plant which have quit growing in length
- Two types - fibers and schlerids
    - <u>Fibers</u> - long, slender cells with a more or less regular secondary cell wall
        - *Example* - hemp fibers for making rope
    - <u>Schlerids</u> - shorter cells with an irregular shape
        - *Example* - stone cells in pears and hard nut and seed shells

Xylem

- Thick secondary cell walls, often deposited unevenly in a coil-like pattern so that they may stretch
- Dead at functionally maturity.
- Involved in conduct of water and ions in the plant
- Two types - tracheids and vessels
    - <u>Tracheids</u> - long, slender cells connected to each other by pits. Found in all vascular plants
    - <u>Vessels</u> - shorter, larger diameter cells with completely perforated cell wall ends. Found only in Angiosperms

Phloem

- Involved in transport of sucrose, other organic compounds, and some ions
- Living at functional maturity
    - Protoplast may lack organelles and nucleus, though
- End walls <u>connect to</u> each other via sieve-plates
- Two types of cells in the phloem - sieve-tube members and companion cells
    - Sieve-tube members - actual conduit for sucrose transport

    - Companion cells - has a nucleus that may also control the sieve-tube element and may aid in sucrose loading.

Tissue Organization in Angiosperms

Dermal Tissue

- Generally a single layer of cells
- The "skin" of the plant
- Primarily parenchyma cells
- Main role is protection of the plant

Ground Tissue

- Makes up the bulk of the plant
- Predominately parenchyma, but collenchyma and schlerenchyma cells are found
- Diverse functions including photosynthesis, storage, and support

Vascular Tissue

- Involved in the transport of water, ions, minerals, and food
- Also has a secondary role in support
- Composed of xylem, phloem, parenchyma, schlerenchyma

Plant Growth

Plant growth is a phenomenon different from animal growth.
Animals exhibit a growth pattern called **determinate growth**.

- After fertilization, the zygote cells are rapidly dividing, undifferentiated cells
- However, after a certain critical stage, the cells differentiate and form tissues.
    - From this point onward, their developmental fate is sealed
    - There are exceptions to this (i.e. stem cells in bone marrow)
- Most animals have a pre-programmed body plan (i.e. barring mutation or accident, most humans have 10 fingers and toes, two eyes, a heart with four chambers, etc..)
- Most animals quit growing after a certain age

Plants, however, exhibit a growth pattern called **indeterminate growth**

- The plant retains areas where rapidly dividing, undifferentiated cells remain all through the life of the plant
- These areas are called **meristems**
    - Meristematic tissue continues to rapidly divide producing undifferentiated cells which may eventually differentiate to form the tissue and cell types discussed above
- Plants do not have a pre-programmed body plan
    - There are constants like leaf shape and branching patters (opposite, alternate, etc.) but you can never predict where a new branch will come about on a tree...
- Plants continue to grow throughout their life

Meristems

The pattern of plant growth depends upon the location of meristems according to their location in the plant.

Apical meristems

- located at the tips of roots and shoots
- supply cells for the plant to increase in length (grow up for shoots and down for roots)
    - growth in this direction is known as **primary growth**
    - primary growth found in herbaceous and woody plants
    - primary growth found in monocots and dicots

Lateral meristems

- located near the periphery of the plant, usually in a cylinder
- supply cells for the plant to increase in girth
    - growth in this direction is known as secondary growth
    - found in all woody and some herbaceous plants
    - lateral meristems and secondary growth found only in dicots

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Primary Growth in the Root

- **Root Cap**
    - Thimble-like covering which protects the delicate apical meristem
    - Produced from cells derived from the root apical meristem
    - Secretes polysaccharide slime that lubricates the soil

    - Constantly sloughed off and replaced
- **Apical Meristem**
    - Region of rapid cell division of undifferentiated cells
    - Most cell division is directed away from the root cap
- **Quiescent Center**
    - Populations of cells in apical meristem which reproduce much more slowly than other meristematic cells
    - Resistant to radiation and chemical damage
    - Possibly a reserve which can be called into action if the apical meristem becomes damaged
- **The Zone of Cell Division - Primary Meristems**
    - Three areas just above the apical meristem that continue to divide for some time
    - **Protoderm** - outermost primary meristem - produces cells which will become dermal tissue
    - **Ground meristem** - central primary meristem - produces cells which will become ground tissue
    - **Procambium -** innermost primary meristem - produces cells which will become vascular tissue
- **The Zone of Elongation**
    - Cells elongate up to ten times their original length
    - This growth pushes the root further downward into the soil
- **The Zone of Maturation**
    - Region of the root where completely functional cells are found

Root Anatomy for dicot and monocot plants:

Root Anatomy - Dicot Roots

Epidermis

- Dermal tissue
- Protection of the root

Cortex

- Ground tissue
- Storage of photosynthetic products
- Active in the uptake of water and minerals

Endodermis

- cylinder once cell thick that forms a boundary between the cortex and the stele
- contains the **casparian strip**, which will be explained later when we discuss water uptake

Pericycle

- found just inside of the endodermis
- may become meristematic
- responsible for the formation of <u>lateral roots</u>

Vascular Tissue

- Xylem and Phloem
- Forms an X-shaped pattern in very center of root

<u>Root Anatomy - Monocot Roots</u>

Epidermis

- Dermal tissue
- Protection of the root

Cortex

- Ground tissue
- Storage of photosynthetic products
- Active in the uptake of water and minerals

Endodermis

- cylinder once cell thick that forms a boundary between the cortex and the stele
- even more distinct than dicot counterpart
- contains the **casparian strip**, which will be explained later when we discuss water uptake

Vascular Tissue

- Xylem and Phloem
- Forms a ring near center of plant

Pith

- Center most region of root

Primary Growth of Shoots

Apical Meristem

- Dome-shaped mass of dividing cells at tip of terminal bud
- Gives rise to three primary mersitems: protoderm, ground meristem, and procambium just as root apical meristem
- Leaves arise as leaf primordia on the flanks of apical meristem

Axillary Meristems

- Regions of meristematic tissue left behind from apical meristem
- Dormant, but have the ability to become activated and form a branch (i.e. becomes the branch's apical meristem)
  - Note difference between how shoots forms a branch versus how a root forms a branch
  - This is do to the position of the vascular tissue in a root vs. the vascular tissue in a shoot
- Subtended by a leaf

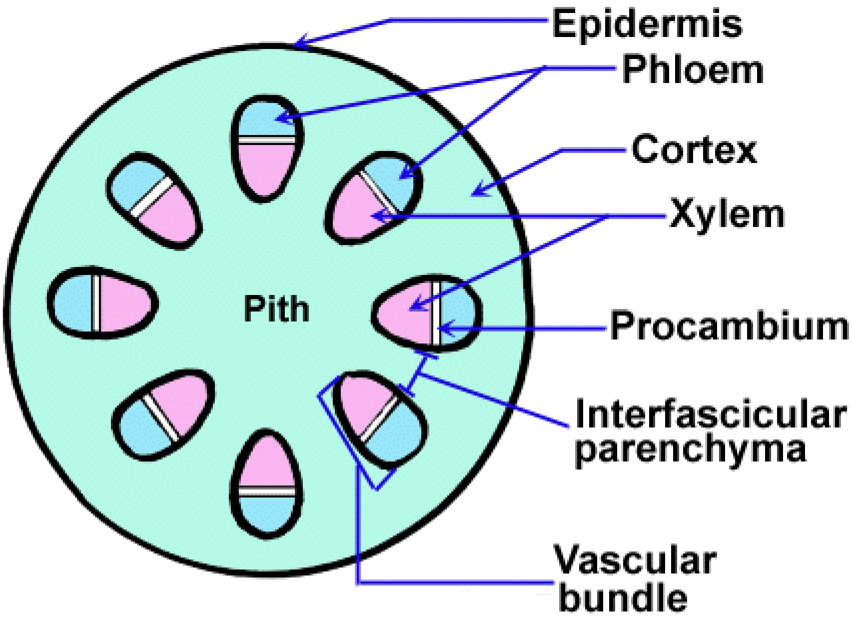
Secondary Growth

Lateral Meristems add girth by producing secondary vascular tissue and periderm

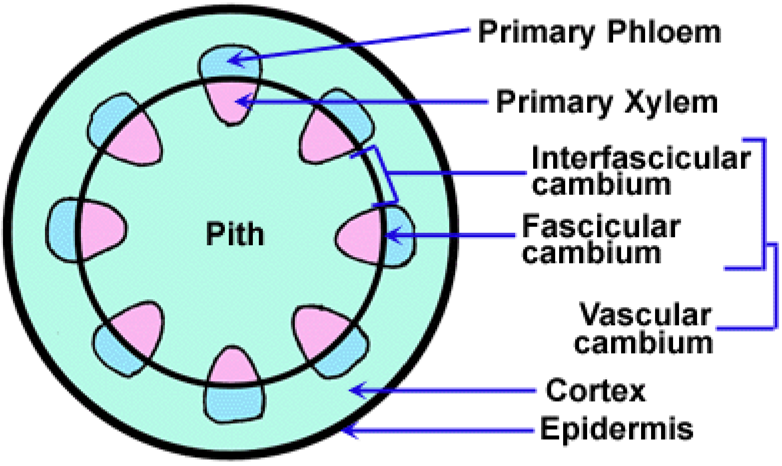
- **Secondary Plant Body** - tissue produced mersitems involved in secondary growth
- **Vascular Cambium** - secondary growth meristem which produces xylem and phloem
- **Cork Cambium** - secondary growth meristem which produces cork, a tough substance that replaces the epidermis

Vascular Cambium

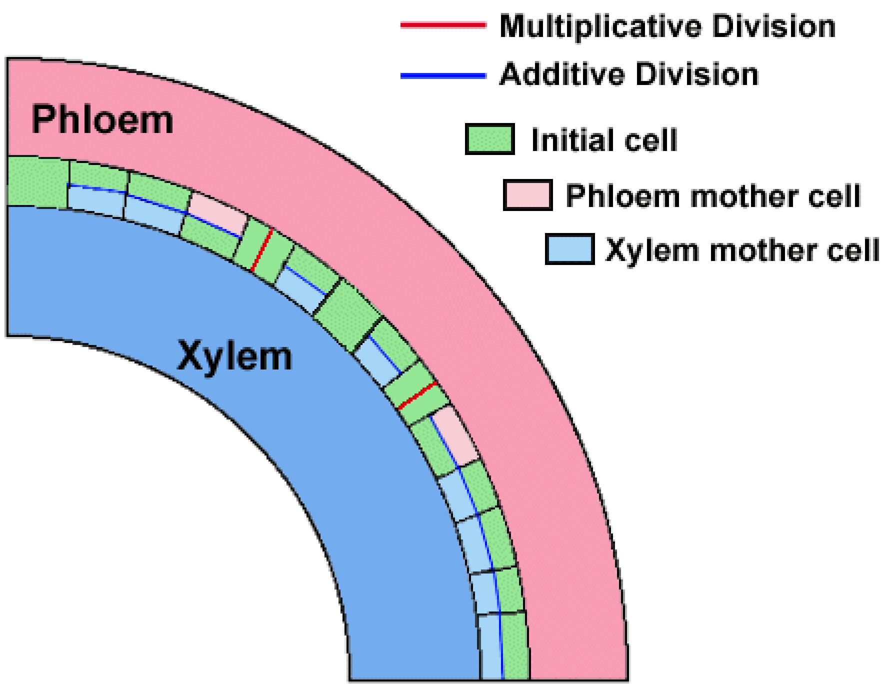
Secondary growth begins with the initiation of the vascular cambium, a cylinder of meristematic tissue that produces additional xylic and phloic tissues. The cells that eventually form the vascular cambium come from two sources, the procambium in the vascular bundles and the interfascicular parenchyma cells between vascular bundles. The diagram below shows the positions of these two populations of cells in a stem with only primary growth.



The two populations of dividing cells unite to form a continuous ring of dividing cells, the vascular cambium.



If we look closely at the cells of the vascular cambium we see two patterns of division. Initial cells can undergo multiplicative divisions (red line in the following diagram) or they can undergo additive divisions (blue line). Multiplicative divisions produce more initial cells and result in the increased circumference of the vascular cambium. Of the two cells produced from an additive division one is retained as an initial cell that will divide again, and the other will become a phloem mother cell or a xylem mother cell. These mother cells will differentiate into their respective cell types.



Secondary Growth in Dicots - Herbaceous and Woody

- Both herbaceous and woody dicots exhibit secondary growth.
- In herbaceous dicots, secondary xylem and phloem are in a single ring of discrete bundles which form
- In woody dicots, the secondary xylem forms a continuous cylinder

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The Cork Cambium and the Production of Periderm

During secondary growth, the epidermis produced by primary growth splits and falls off the stem
It is replaced by a new protective tissues produced by the **cork cambium**

- A cylinder meristematic tissue that initially forms from the outer cortex of the stem
- Cork cambium produces cork cells, which form exterior to the cork cambium
- As cork cells mature, they secrete suberin (a waxy substance) in their cell walls and then die
- Cork cells function as a barrier to protect the stem from physical damage and from pathogens

The cork cambium + the cork are known as the **periderm**
The "**bark**" of the tree consists of the periderm + the phloem

- What would happen if you removed a large ring of bark from a tree?

Unlike the vascular cambium which can grow in diameter via multiplicative growth, the cork cambium is fixed in size.

- After a few weeks, the cork cambium loses meristematic ability
- Expansion splits the original periderm
- New cork cambium then forms deeper in the cortex of the stem
- Eventually no more cortex remains, so the cork cambium then forms from parenchyma cells of the secondary xylem.

The Monocot Stem - A Stem Lacking Secondary Growth

Monocot stems differ from dicot stems in that they lack secondary growth

- No vascular cambium nor cork cambium
- Stems usually uniform in diameter
- Scattered vascular bundles (not in a ring like dicot stems)