Plant Growth: An Overview

- Most plants demonstrate ***indeterminate growth***, growing as long as the plant lives.
- Certain plant organs, such as flowers and leaves, undergo ***determinate growth***, ceasing to grow after they reach a certain size.
- **Annual** plants complete their life cycle - from germination through flowering and seed production to death - in a single year or less.
  - Many wildflowers and important food crops, such as cereals and legumes, are annuals.
- The life of a **biennial** plant spans two years.
  - Often, there is an intervening cold period between the vegetative growth season and the flowering season.
- Plants that live many years, including trees, shrubs, and some grasses, are **perennials**.
  - These often die not from old age, but from an infection or some environmental trauma.
- A plant is capable of indeterminate growth because it has perpetually embryonic tissues called **meristems** in its regions of growth.
- These cells divide to generate additional cells, some of which remain in the meristematic region while others become
specialized and incorporated into the tissues and organs
of the growing plant.
- The pattern of plant growth depends on the location of meristems.
- **Apical meristems**, located at the tips of roots and in the buds of shoots, supply cells for the plant to grow in length.
  - This elongation, **primary growth**, enables roots to spread through the soil and shoots to extend their exposure to light and carbon dioxide.
  - Woody plants also show **secondary growth**, progressive thickening of roots and shoots.
    - Secondary growth is the product of **lateral meristems**, cylinders of dividing cells extending along the length of roots and shoots.
- Each growing season, primary growth produces young extensions of roots and shoots, while secondary growth thickens and strengthens the older part of the plant.

Winter Twig Anatomy

- At the tip of a winter twig of a deciduous tree is the dormant terminal bud, enclosed by scales that protect its apical meristem.
  - In the spring, the bud will shed its scales and begin a new spurt of primary growth.
  - Along each growth segment, nodes are marked by scars left when leaves fell in autumn.
  - Above each leaf scar is either an axillary bud or a branch twig.
  - Farther down the twig are whorls of scars left by the scales that enclosed the terminal bud during the previous winter.
  - Each spring and summer, as the primary growth extends the shoot, secondary growth thickens the parts of the shoot that formed in previous years.

Primary growth: Apical meristems extend roots and shoots by giving rise to the primary plant body

- Primary growth produces the **primary plant body** - the parts of the root and shoot systems produced by apical meristems.

GROWTH IN ROOTS

- The root tip is covered by a thimble like **root cap**, which protects the meristem as the root pushes through the soil during primary growth.
- Growth in length is concentrated near the root's tip, where three zones of cells at successive stages of primary growth
  are located: the zone of cell division, the zone of elongation, and the zone of maturation.
- The **zone of cell division** includes the apical meristem and its derivatives, the primary meristems.
  - These primary meristems: the **protoderm**, **procambium**, and **ground meristem** will produce the three primary tissue systems of the ***root***: dermal, vascular, and ground tissues.
- The zone of cell division blends into the **zone of elongation** where cells elongate, sometimes to more than ten times their original length.
  - It is this elongation of cells that is mainly responsible for pushing the root tip, including the meristem, ahead.
- In the **zone of maturation**, cells begin to specialize in structure and function.
  - In this root region, the three tissue systems produced by primary growth complete their differentiation, their cells becoming functionally mature.
- The protoderm, the outermost primary meristem, produces the single cell layer of the epidermis.
  - Water and minerals absorbed by the plant must enter through the epidermis.
  - Root hairs enhance absorption by greatly increasing the surface area.
- The procambium gives rise to the **stele**, which in roots is a central cylinder of vascular tissue where both xylem and phloem develop.
- The ground tissue between the protoderm and procambium gives rise to the ground tissue system.
  - These are mostly parenchyma cells between the stele and epidermis.
  - They store food and are active in the uptake of minerals that enter the root with the soil solution.
- The innermost layer of the cortex, the **endodermis**, is a cylinder one cell thick that forms a boundary between the cortex and stele.

GROWTH IN SHOOTS

- The apical meristem of a shoot is a dome-shaped mass of dividing cells at the terminal bud.
  - It forms the primary meristems - protoderm, procambium and ground meristem.
  - Leaves arise as ***leaf primordia*** on the flanks of the apical meristem.
  - ***Axillary buds*** develop from islands of meristematic cells left by apical meristems at the leaf primordia base. They have the potential of forming branches.

- The leaf epidermis is composed of cells tightly locked together like pieces of a puzzle.
- The leaf epidermis is a first line of defense against physical damage and pathogenic organisms and the waxy cuticle is a barrier to water loss from the plant.
- The epidermal barrier is interrupted only by the **stomata**, tiny pores flanked by specialized epidermal cells called **guard cells**.
  - Each stoma is a gap between a pair of guard cells.
  - The stomata allow gas exchange between the surrounding air and the photosynthetic cells inside the leaf.
  - They are also the major avenue of evaporative water loss from the plant - a process called ***transpiration***.
- The ground tissue of the leaf, the **mesophyll**, is sandwiched between the upper and lower epidermis.
  - It consists mainly of parenchyma cells equipped with chloroplasts and specialized for photosynthesis.
- The vascular tissue of a leaf is continuous with the xylem and phloem of the stem.
  - Within a leaf, veins subdivide repeatedly and branch throughout the mesophyll.
    - The xylem brings water and minerals to the photosynthetic tissues and the phloem carries its sugars and other organic products to other parts of the plant.
    - The vascular infrastructure also reinforces the shape of the leaf.

Secondary growth:

Lateral meristems add girth by producing secondary vascular tissue and periderm

- The stems and roots, but not the leaves, of most dicots increase in girth by secondary growth.
  - The **vascular cambium** acts as a meristem for the production of secondary xylem and secondary phloem.
  - The **cork cambium** acts as a meristem for a tough thick covering for stems and roots that replaces the epidermis.
- ***Vascular cambium*** is a cylinder of meristematic cells that forms secondary vascular tissue.
  - The accumulation of this tissue over the years accounts for most of the increase in diameter of a woody plant.
  - Secondary xylem forms to the interior and secondary phloem to the exterior of the vascular cambium.
- As secondary growth continues over the years, layer upon layer of secondary xylem accumulates, producing the tissue we call wood.
- Early in secondary growth, the epidermis produced by primary growth splits, dries, and falls.
- It is replaced by new protective tissues produced by ***cork cambium,*** a meristematic cylinder that first forms in the outer cortex of the stem and later in secondary phloem.
- Cork cambium produces cork cells, which accumulate at the cambium's exterior.
  - Waxy material deposited in the cell walls of cork cells before they die acts as a barrier against water loss, physical damage, and pathogens.
- The cork plus the cork cambium forms the **periderm**, a protective layer that replaces the epidermis.
- In areas called **lenticels**, splits develop in the periderm because of higher local activity of the cork cambium.
- These areas within the trunk facilitate gas exchange with the outside air.

- **Bark** refers to all tissues external to the vascular cambium, including secondary phloem, cork cambium, and cork.
- After several years of secondary growth, several zones are visible in a stem.
  - These include two zones of secondary xylem (***heartwood and sapwood***), the vascular cambium, living secondary phloem, cork cambium, and cork.
- The ***heartwood*** no longer conducts water but its lignified walls of its dead cells form a central column that supports the tree.
  - These cells are clogged with resins and other compounds that help protect the core from fungi and wood-boring insects.
- The ***sapwood*** functions in the upward transport of water and minerals, called the xylem sap.
  - Because each new layer of secondary xylem has a larger circumference, secondary growth enables the xylem to transport more sap each year, providing water and minerals to an increasing number of leaves.