Introduction: *Extreme Tree Climbing*

- Some plants, such as coast redwoods, are among the largest and oldest organisms on earth

- Coast redwoods are gymnosperms, a kind of plant that bears seeds on cones

- Angiosperms, or flowering plants, bear seeds in fruits

- Most plants are angiosperms, which will be the focus of this unit on plant structure
PLANT STRUCTURE
AND FUNCTION
31.1 CONNECTION: People have manipulated plant genetics since prehistoric times

- Humans have engaged in agriculture for about 10,000 years

- Genetic manipulation of crop plants such as wheat began with cross pollination of plants to produce desirable traits

- Today many crop plants are genetically modified using DNA technology
31.2 The two main groups of angiosperms are the monocots and the eudicots

- Monocots and eudicots differ in
  - Number of **cotyledons** (seed leaves)
  - Pattern of leaf venation
  - Arrangement of stem vascular tissue
  - Number of flower parts
  - Root structure
31.2 The two main groups of angiosperms are the monocots and the eudicots

- **Monocots**
  - One cotyledon
  - Parallel leaf venation
  - Scattered vascular bundles
  - Flower parts in 3s or multiples of 3
  - Fibrous roots
31.2 The two main groups of angiosperms are the monocots and the eudicots

- **Eudicots**—most plants are eudicots
  - Two cotyledons
  - Branched leaf venation
  - Ring of vascular bundles
  - Flower parts in 4s or 5s (or multiples)
  - Taproot system
MONOCOTS

Seed leaves: One cotyledon
Leaf veins: Veins usually parallel
Stems: Vascular bundles in complex arrangement
Flowers: Floral parts usually in multiples of three
Roots: Fibrous root system

EUDICOTS

Seed leaves: Two cotyledons
Leaf veins: Veins usually branched
Stems: Vascular bundles arranged in ring
Flowers: Floral parts usually in multiples of four or five
Roots: Taproot usually present
31.3 A typical plant body contains three basic organs: roots, stems, and leaves

- Plants absorb water and minerals from soil through **roots**

- Plants absorb the sun’s energy and carbon dioxide from the air through **shoots** (**stems** and **leaves**)

- Plant roots depend on shoots for carbohydrates produced via photosynthesis

- Plant shoots depend on roots for water and minerals
31.3 A typical plant body contains three basic organs: roots, stems, and leaves

- **Plant roots**
  - Anchor plant
  - Absorb water and nutrients
  - Store food

- **Plant shoots**
  - Stems, leaves, and reproductive structures
  - Stems provide support
  - Leaves carry out photosynthesis
Shoot system

Leaf
- Blade
- Petiole
- Axillary bud

Stem
- Node
- Internode

Root system
- Taproot

Terminal bud

Flower

Root hairs

Epidermal cell

Root hair
31.4 Many plants have modified roots, stems, and leaves

- Modifications of plant parts are adaptations for various functions
  - Food or water storage
  - Asexual reproduction
  - Protection
  - Climbing
  - Photosynthesis
31.4 Many plants have modified roots, stems, and leaves

- Root modifications
  - Food storage
    - Large taproots store starches
      - Examples include carrots, turnips, sugar beets, sweet potatoes
31.4 Many plants have modified roots, stems, and leaves

- **Stem modifications**
  - Stolon—asexual reproduction
  - Rhizomes—storage, asexual reproduction
  - Tubers—storage, asexual reproduction
  - Cactus stem—water storage and photosynthesis
Strawberry plant

Potato plant

Stolon (runner)

Ginger plant

Taproot

Rhizome

Tuber

Rhizome
Potato plant

- Taproot
- Rhizome
- Tuber
Ginger plant

Rhizome
31.4 Many plants have modified roots, stems, and leaves

- Leaf modifications
  - Protection
    - Cactus spine
  - Climbing
    - Pea plant tendril
31.5 Three tissue systems make up the plant body

- **Dermal tissue**
  - Outer protective covering

- **Vascular tissue**
  - Support and long-distance transport

- **Ground tissue**
  - Bulk of the plant body
  - Food production, storage, support
31.5 Three tissue systems make up the plant body

- **Dermal tissue**
  - Layer of tightly packed cells called the epidermis
  - First line of defense against damage and infection
  - Waxy layer called cuticle reduces water loss
31.5 Three tissue systems make up the plant body

- **Vascular tissue**
  - Composed of xylem and phloem
  - Arranged in bundles

- **Ground tissue**
  - Lies between dermal and vascular tissue
  - Eudicot stem ground tissue is divided into pith and cortex
  - Leaf ground tissue is called mesophyll
31.6 Plant cells and tissues are diverse in structure and function

- Plants cells have three structures that distinguish them from animals cells
  - Chloroplasts used in photosynthesis
  - A large, fluid-filled vacuole
  - A cell wall composed of cellulose
31.6 Plant cells and tissues are diverse in structure and function

- **Plant cell wall**
  - Some plant cell walls have two layers
    - Primary cell wall—outermost layer
    - Secondary cell wall—tough layer inside primary wall
  - A sticky layer called the middle lamella lies between adjacent plant cells
  - Openings in cell walls called plasmodesmata allow cells to communicate and exchange materials easily
31.6 Plant cells and tissues are diverse in structure and function

- Plant cell structure is related to function
- There are five major types of plant cells
  - Parenchyma cells
  - Collenchyma cells
  - Sclerenchyma cells
  - Water-conducting cells
  - Food-conducting cells
31.6 Plant cells and tissues are diverse in structure and function

- Parenchyma cells
  - Most abundant cell type
  - Thin primary cell wall
  - Lack secondary cell wall
  - Alive at maturity
  - Function in photosynthesis, food and water storage
Starch-storing vesicles

Primary cell wall (thin)

Pit
31.6 Plant cells and tissues are diverse in structure and function

- **Collenchyma cells**
  - Unevenly thickened primary cell wall
  - Lack secondary cell wall
  - Alive at maturity
  - Provide flexible support
Primary cell wall (thick)
31.6 Plant cells and tissues are diverse in structure and function

- **Sclerenchyma cells**
  - Thick secondary cell wall containing lignin
    - Lignin is a main component of wood
  - Dead at maturity
  - Rigid support
  - Two types of sclerenchyma cells are fibers and sclereids
    - Fibers—long and thin, arranged in bundles
    - Sclereids—shorter than fibers, present in nut shells and pear tissue
Secondary cell wall
Pits
Primary cell wall
Fiber cells
Fiber
Primary cell wall

Secondary cell wall

Sclereid cells

Sclereid

Pits
31.6 Plant cells and tissues are diverse in structure and function

- Water conducting cells—tracheids and vessel elements
  - Both have thick secondary cell walls
  - Both are dead at maturity
  - Chains of tracheids and vessel elements form tubes that make up the vascular tissue called **xylem**
31.6 Plant cells and tissues are diverse in structure and function

- **Food-conducting cells**—*sieve tube members*
  - No secondary cell wall
  - Alive at maturity but lack most organelles

- **Companion cells**
  - Contain organelles
  - Control operations of sieve tube members

- Chains of sieve tube members, separated by porous *sieve plates*, form the vascular tissue called *phloem*
Cytoplasm
Primary cell wall
Companion cell
Sieve plate
Cytoplasm
PLANT GROWTH
Plant growth is **indeterminate**

- Growth occurs throughout a plant’s life
- Plants are categorized based on how long they live
  - **Annuals** complete their life cycle in one year
  - **Biennials** complete their life cycle in two years
  - **Perennials** live for many years

Animal growth is **determinate**

- Growth stops after a certain size is reached
31.7 Primary growth lengthens roots and shoots

- Plant growth occurs in specialized tissues called meristems

- **Meristems** are regions of active cell division

- **Apical meristems** are found at the tips of roots and shoots

- **Primary growth** occurs at apical meristems

- Primary growth allows roots to push downward through the soil and shoots to grow upward toward the sun

Video: Root Growth in a Radish Seed (time lapse)
31.7 Primary growth lengthens roots and shoots

- The apical meristems of root tips are covered by a root cap.

- Root growth occurs behind the root cap in 3 zones:
  - Zone of cell division—the apical meristem
  - Zone of cell elongation—cells lengthen by as much as 10 times
  - Zone of maturation—cells differentiate into dermal, vascular, and ground tissues
31.7 Primary growth lengthens roots and shoots

- The apical meristems of shoot tips occur as buds at the stem tip and at the base of leaves.
- Cells produced in the shoot apical meristem differentiate into dermal, vascular, and ground tissues.
- Vascular tissue produced from the apical meristem is called primary vascular tissue.
  - Primary xylem
  - Primary phloem
Leaves

Apical meristem

Axillary bud meristems
31.8 Secondary growth increases the girth of woody plants

- **Secondary growth** occurs at lateral meristems.

- **Lateral meristems** are areas of active cell division that exist in two cylinders that extend along the length of roots and shoots.

- **Vascular cambium** is a lateral meristem that lies between primary xylem and phloem.

- **Cork cambium** is a lateral meristem that lies at the outer edge of the stem cortex.
31.8 Secondary growth increases the girth of woody plants

- Vascular cambium produces cells in two directions
  - *Secondary xylem* produces *wood* toward the interior of the stem
  - *Secondary phloem* produces the inner bark toward the exterior of the stem

- Cork cambium produces cells in one direction
  - Cork cambium produces the outer *bark*, which is composed of cork cells
Year 1
Late Summer

Key
- Dermal tissue system
- Ground tissue system
- Vascular tissue system

Shed epidermis

Secondary xylem (wood)
Cork cambium
Secondary phloem
Cork
Bark

Growth
Key
- Dermal tissue system
- Ground tissue system
- Vascular tissue system

Year 2
Late Summer

Secondary xylem
(2 years’ growth)
31.8 Secondary growth increases the girth of woody plants

- Wood annual rings show layers of secondary xylem
  - In temperate regions, periods of dormancy stop growth of secondary xylem
  - Rings occur in areas when new growth starts each year

- The bark (secondary phloem and cork) is sloughed off over time
31.8 Secondary growth increases the girth of woody plants

- Wood rays are parenchyma tissue that radiate from the stem’s center
  - Wood rays function in lateral transport and storage

- Most transport occurs near the vascular cambium
  - **Sapwood** near the vascular cambium transports water
  - Heartwood stores resins and wastes
  - Transport of sugars occurs in the secondary phloem near the vascular cambium
Bark
Rings
Wood rays
Heartwood
Sapwood
Vascular cambium
Secondary phloem
Cork cambium
Cork
REPRODUCTION OF FLOWERING PLANTS
31.9 The flower is the organ of sexual reproduction in angiosperms

- Flowers typically contain four types of highly modified leaves called floral organs
  - **Sepals**—enclose and protect flower bud
  - **Petals**—showy; attract pollinators
  - **Stamens**—male reproductive structures
  - **Carpels**—female reproductive structures
31.9 The flower is the organ of sexual reproduction in angiosperms

- A stamen has two parts
  - **Anther**—produces pollen, which house cells which develop into sperm
  - Filament—elevates anther

- A carpel has three parts
  - **Stigma**—site of pollination
  - **Style**—“neck” that leads to ovary
  - **Ovary**—houses **ovules**, which contain developing egg
31.9 The flower is the organ of sexual reproduction in angiosperms

- Angiosperm life cycle overview
  - Fertilization occurs in the ovule; the fertilized egg develops into an embryo encased in a seed
  - The ovary develops into a fruit, which protects the seed and aids in dispersal
  - The seed **germinates** under suitable conditions to produce a seedling, which grows into a mature plant

Video: Flowering Plant Life (time lapse)
Ovary, containing ovule

Mature plant with flowers, where fertilization occurs
Ovary, containing ovule

Mature plant with flowers, where fertilization occurs

Fruit (mature ovary), containing seed

Embryo

Seed
Mature plant with flowers, where fertilization occurs

Ovary, containing ovule

Fruit (mature ovary), containing seed

Seed

Embryo

Germinating seed
Ovary, containing ovule

Mature plant with flowers, where fertilization occurs

Fruit (mature ovary), containing seed

Embryo

Seed

Seedling

Germinating seed
31.10 The development of pollen and ovules culminates in fertilization

- Plant life cycles involve alternating diploid ($2n$) and haploid ($n$) generations
  - The diploid generation is called the sporophyte
    - Specialized diploid cells in anthers and ovules undergo meiosis to produce haploid spores
    - The haploid spores undergo mitosis and produce the haploid generation
  - The haploid generation is called the **gametophyte**
    - Gametophytes produce gametes via mitosis
31.10 The development of pollen and ovules culminates in fertilization

- The male gametophyte is a pollen grain
  - A cell in the anther undergoes meiosis to produce four haploid spores
  - Each spore divides via mitosis to produce two cells called the tube cell and generative cell
  - A tough wall forms around the cells to produce a pollen grain
  - Pollen grains are released from the anther
The female gametophyte is an embryo sac

- A cell in the ovule undergoes meiosis to produce four haploid spores
- Three of the spores degenerate
- The surviving spore undergoes a series of mitotic divisions to produce the embryo sac
- One cell within the embryo sac is an egg ready for fertilization
- One central cell within the embryo sac has two nuclei and will produce endosperm
31.10 The development of pollen and ovules culminates in fertilization

- **Pollination**
  - Transfer of pollen from anther to stigma
  - Pollen is carried by wind, water, and animals

- **Pollen grain germination**
  - Tube nucleus produces pollen tube, which grows down through the style to the ovary
  - Generative nucleus divides to produce two sperm
31.10 The development of pollen and ovules culminates in fertilization

- Double fertilization
  - One sperm fertilizes the egg to produce a zygote
  - One sperm fuses with the central cell nuclei to produce $3n$ endosperm
  - Endosperm nourishes the developing embryo

[Video: Bat Pollinating Agave Plant]
[Video: Bee Pollinating]
[Animation: Plant Fertilization]
Development of male gametophyte (pollen grain)

- Anther
- Cell within anther
- Meiosis
- Four haploid spores
- Single spore
- Wall forms
- Pollen germinates
- Pollination

Development of female gametophyte (embryo sac)

- Ovary
- Ovule
- Meiosis
- Surviving cell (haploid spore)

Surviving cell (haploid spore)

- Meiosis

- Mitosis (of each spore)
- Two cells
- Two sperm in pollen tube
- Pollen grain released from anther
- Two sperm discharged

Mitosis

- Two cells
- Egg cell
- Embryo sac

Double fertilization occurs

- Pollen tube enters embryo sac
- Two sperm discharged
- Triploid (3n) endosperm nucleus
- Diploid (2n) zygote (egg plus sperm)

Diploid (2n) zygote (egg plus sperm)

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Development of male gametophyte (pollen grain)

Development of female gametophyte (embryo sac)

Anther

Cell within anther

Meiosis
Four haploid spores

Single spore

Wall forms
Mitosis (of each spore)

Two cells
Pollen grain released from anther

Ovary

Meiosis
Surviving cell (haploid spore)

Mitosis

Two cells
Egg cell

Embryo sac

Ovule

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Pollination

Pollen germinates

Wall forms

Two cells

Pollen grain released from anther

Two sperm in pollen tube

Embryo sac

Egg cell

Pollen tube enters embryo sac

Two sperm discharged

Double fertilization occurs

Triploid (3n) endosperm nucleus

Diploid (2n) zygote (egg plus sperm)
31.11 The ovule develops into a seed

- The zygote divides many times via mitosis to produce the embryo

- The embryo consists of tiny root and shoot apical meristems and one or two cotyledons

- A tough **seed coat** develops

- **Seed dormancy**
  - Embryo growth and development are suspended
  - Allows delay of germination until conditions are favorable
31.11 The ovule develops into a seed

- **Eudicot seeds**
  - Two cotyledons
  - Apical meristems lack protective sheaths
  - Endosperm absorbed by cotyledons

- **Monocot seeds**
  - Single cotyledon
  - Apical meristems have a protective sheaths
  - Endosperm is present
31.12 The ovary develops into a fruit

- Hormonal changes induced by fertilization trigger the ovary to develop into a **fruit**
- Fruits protect the seed and aid in dispersal
- Mature fruits may be fleshy or dry
  - Fleshy fruits—oranges, tomatoes, grapes
  - Dry fruits—beans, nuts, grains

Animation: Fruit Development
31.13 Seed germination continues the life cycle

- Germination breaks seed dormancy
- Germination begins when water is taken up
- Eudicot seedling shoots emerge from the soil with the apical meristem “hooked” downward to protect it
- Monocot seedling shoots are covered by a protective sheath and emerge straight from the soil
Cotyledon

Foliage leaves

Protective sheath enclosing shoot

Embryonic root

Cotyledon
31.15 EVOLUTION CONNECTION:
Evolutionary adaptations allow some trees to live very long lives

- The oldest organism on earth is thought to be a 4,600 year old bristlecone pine (*Pinus longaeva*) named Methuselah

- Several adaptations allow some plants to live much longer than animals
  - Constant cell division in meristems can repair damage
  - Plants produce defensive compounds that protect them
You should now be able to

1. Describe two main kinds of flowering plants and how they differ in number of seed leaves and in structures such as stems, roots, leaves, and flowers

2. Name the three tissue systems that make up the plant body and the functions of each

3. Describe the structure and function of five types of cells found in the plant body

4. Give the name and location of the specialized areas where most plant growth occurs
You should now be able to

5. Explain the difference between primary and secondary growth

6. Describe the source and pattern of secondary plant growth

7. Describe the structure of an angiosperm flower and the function of each part

8. Explain the difference between the angiosperm sporophyte and gametophyte
You should now be able to

9. Describe the series of events that occur in the angiosperm life cycle from spore production to seed germination

10. Describe some modes of plant asexual reproduction and conditions that favor asexual reproduction

11. Identify evolutionary adaptations that allow plants to live very long lives