Fundamental Biology
BI 1101

an interdisciplinary approach to introductory biology

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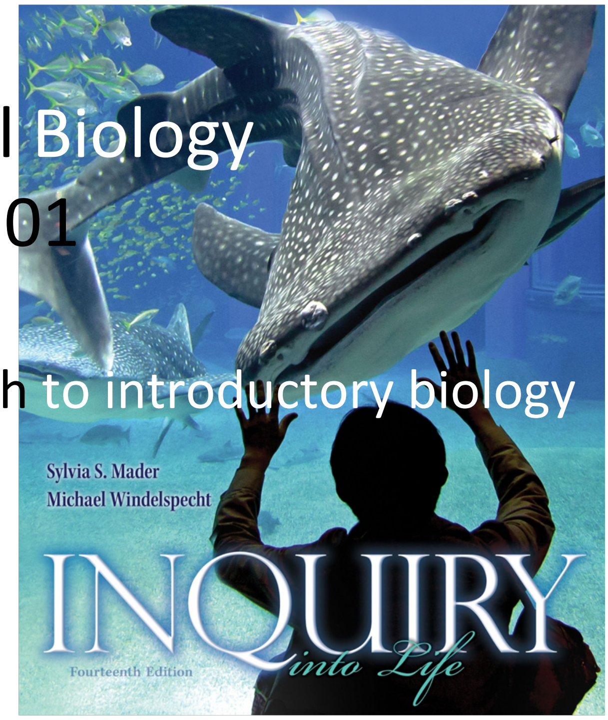
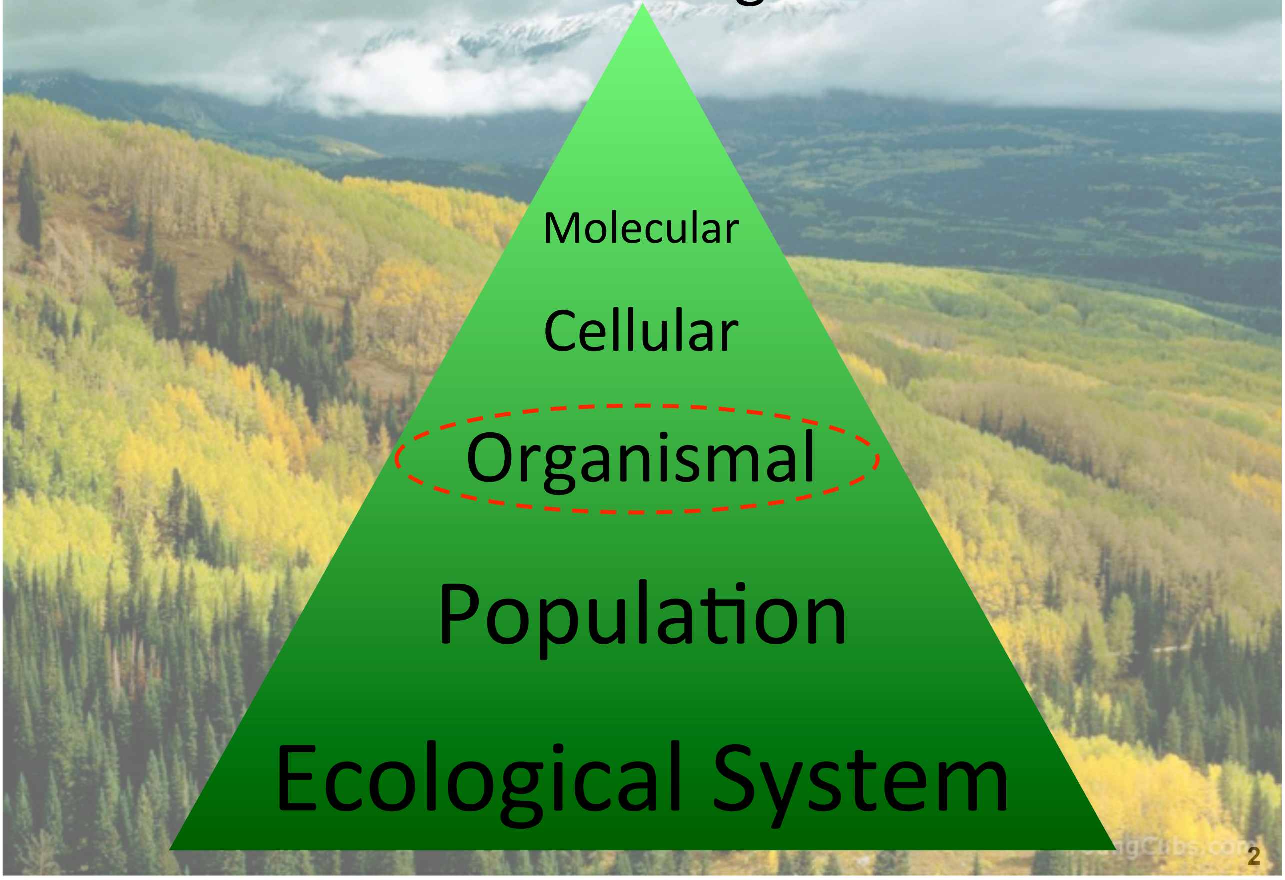
SITH-ITB



Five Levels of Organization



PLANT STRUCTURE AND FUNCTION

Learning outcomes

After this chapter, students are able to:

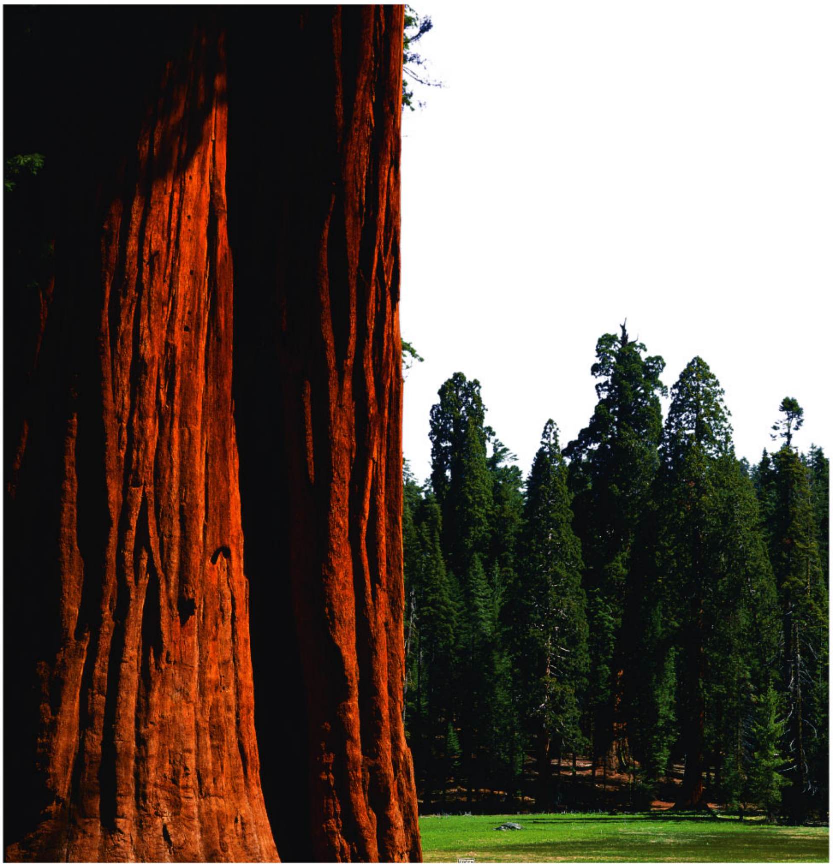
1. Explain basic structure and function of plant cells and tissues
2. Explain how growth and development occurred in plants
3. Describe plant reproduction through vegetative and generative system
4. Explain what happens to the materials that plants take up from the air and soil.
5. Compare the intracellular and extracellular movements of material into root xylem.
6. Explain how, when, and where phloem conducts sap.
7. Explain how hydroponics helps to determine which plant nutrients are essential.

You should now be able to

8. Distinguish between micronutrients and macronutrients and note examples of each.
9. Explain how fertilizers can prevent nutrient deficiencies in plants.
10. Explain how irrigation and the use of fertilizers affect agriculture.
11. Compare the processes and products of organic and conventional agriculture.
12. Explain how and why most plants depend upon bacteria to supply nitrogen.
13. Explain how fungi help most plants absorb nutrients from the soil.
14. Describe examples of parasitic and carnivorous plants.

PLANT GROWTH AND REPRODUCTION

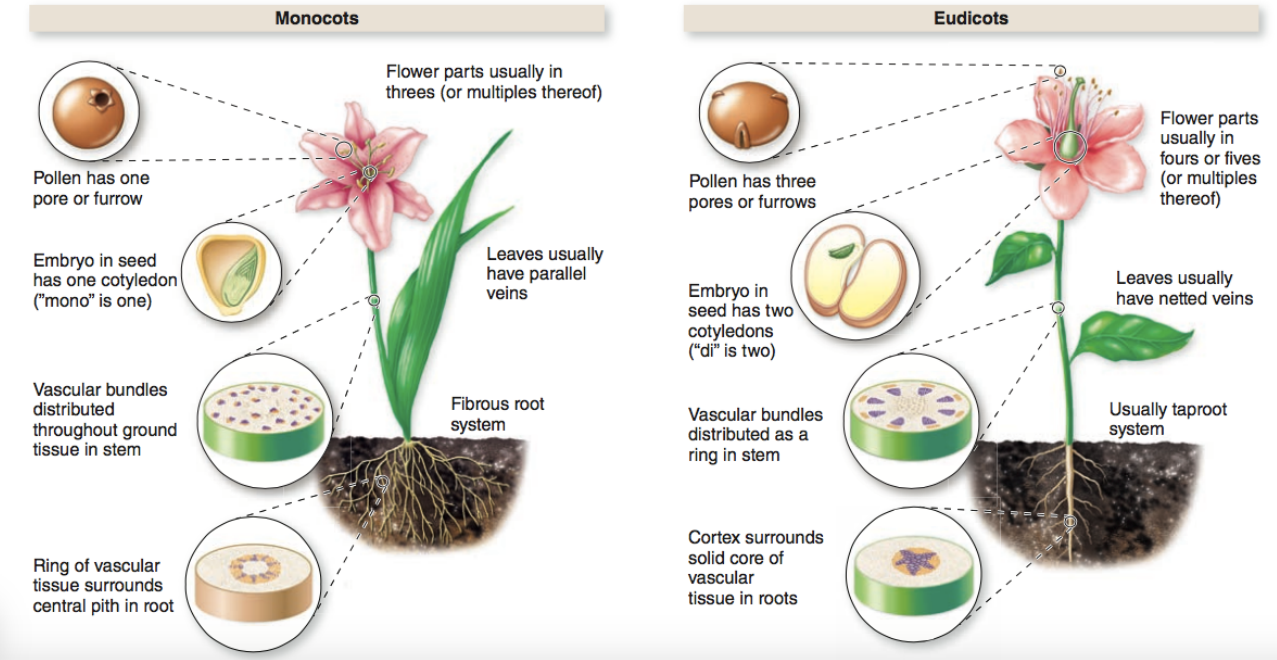
- The General Sherman - giant sequoia is the largest plant on Earth
  - 2,500 years old
  - 84-m tall
  - 1,400-ton trunk
  - A gymnosperm, bearing seeds in cones
- Angiosperms, bearing seeds in flowers, make up more than 90% of the plant kingdom



TALKING ABOUT SCIENCE

Plant scientist Natasha Raikhel studies the *Arabidopsis* plant as a model biological system

- Natasha Raikhel is one of America's most prominent plant biologists
- Dr. Raikhel uses *Arabidopsis* (mustard plant) to study
  - Biological systems
  - Structure–function relationship in plants

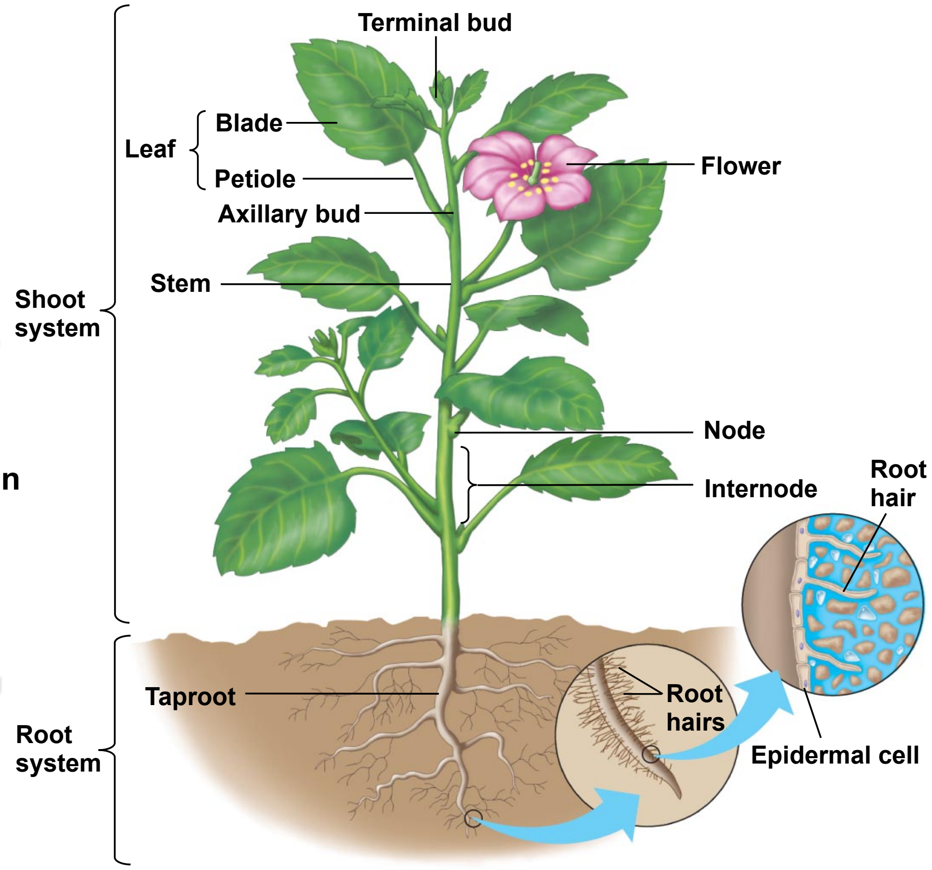

Monocots
Flower parts usually in threes (or multiples thereof)
Pollen has one pore or furrow
Embryo in seed has one cotyledon ("mono" is one)
Leaves usually have parallel veins
Vascular bundles distributed throughout ground tissue in stem
Fibrous root system
Ring of vascular tissue surrounds central pith in root
Eudicots
Flower parts usually in fours or fives (or multiples thereof)
Pollen has three pores or furrows
Embryo in seed has two cotyledons ("di" is two)
Leaves usually have netted veins
Vascular bundles distributed as a ring in stem
Usually taproot system
Cortex surrounds solid core of vascular tissue in roots

A typical plant body consists of roots and shoots

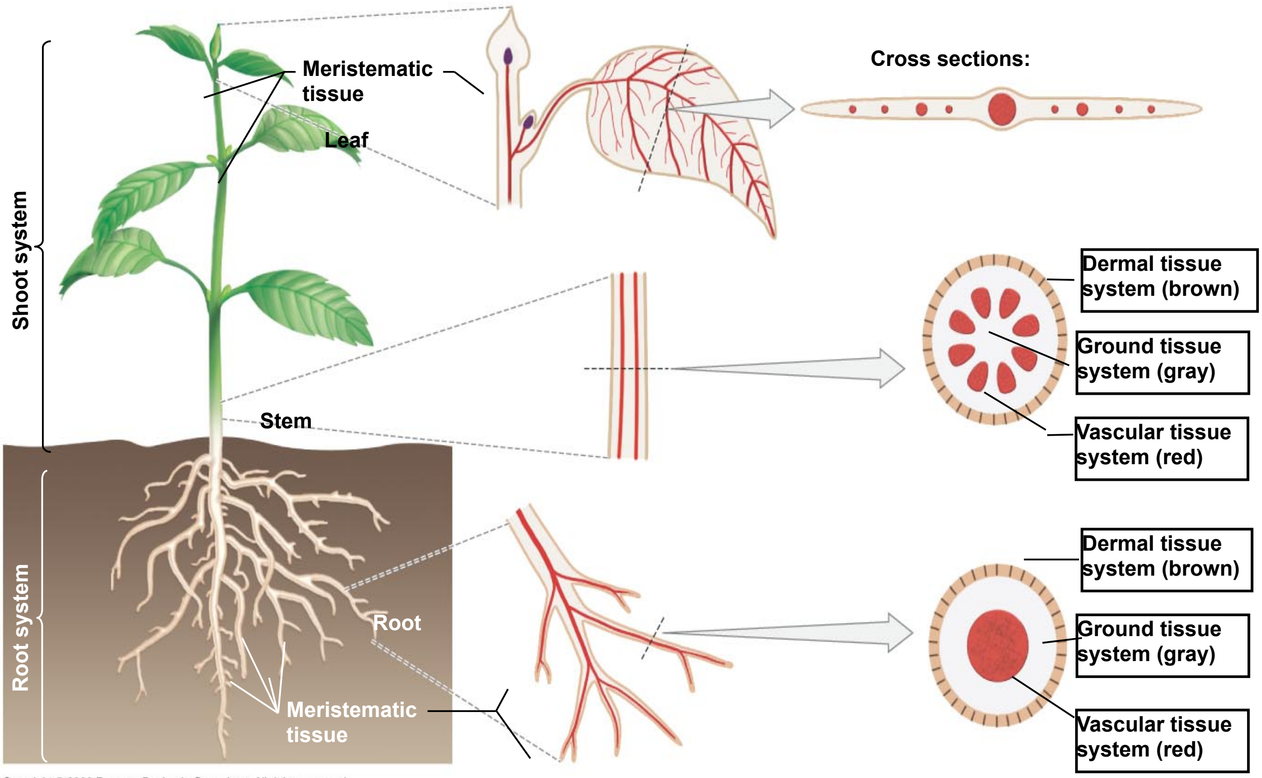
- A plant is adapted to draw resources from two different environments
- Root system
  - Anchors plant in the soil
  - Absorbs and transports minerals and water
    - Root hairs increase absorptive surface
  - Stores food

- Shoot system
  - Obtains CO_2 and light from air
  - Stem, with nodes and internodes, supports leaves and flowers
  - Leaves are main photosynthetic organs
  - Flowers are reproductive organs
    - Terminal and axillary buds
- Apical dominance is an evolutionary adaptation that increases the plant's exposure to light

Organ system in plants

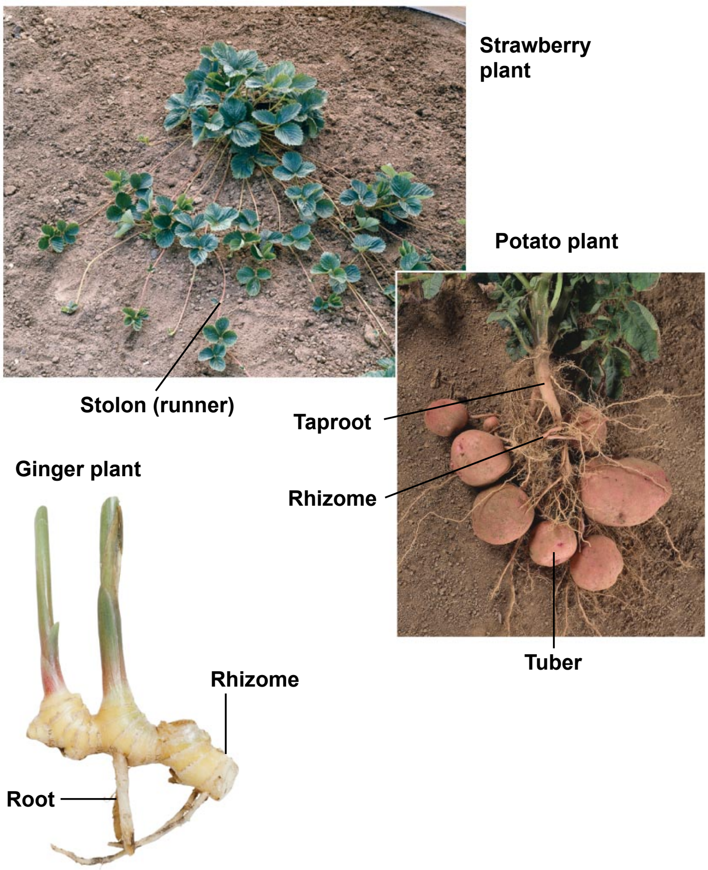


Three tissue systems in plants



Many plants have modified roots, stems, and leaves

- Roots, stems, and leaves are adapted for a variety of functions
  - Modified roots store sugar
  - Modified stems
    - Stolons enable a plant to reproduce asexually
    - Rhizomes store food and can form new plants
    - Tubers are structures specialized for storage

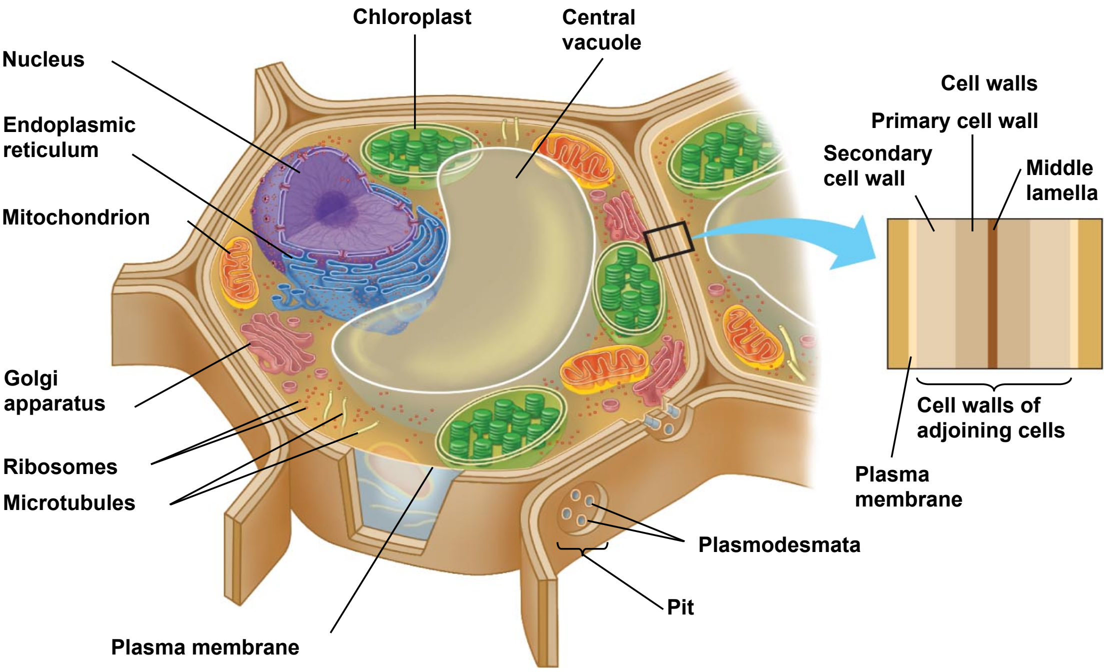


Modified leaves

– Store food or water
– Function in protection of plant
– Aid in climbing (tendrils)

Plant cells and tissues are diverse in structure and function

– Most plant cells have three unique structures
  - Chloroplasts, the sites of photosynthesis
  - A central vacuole containing fluid
  - A cell wall that surrounds the plasma membrane



– Plants have five major types of cells
  - Parenchyma: perform most of the plant's metabolic functions
  - Collenchyma: provide support
  - Sclerenchyma: form a rigid skeleton that supports the plant; the main component of wood
    - Fibers: long cells arranged in bundles
    - Sclereids: shorter, have very hard secondary walls

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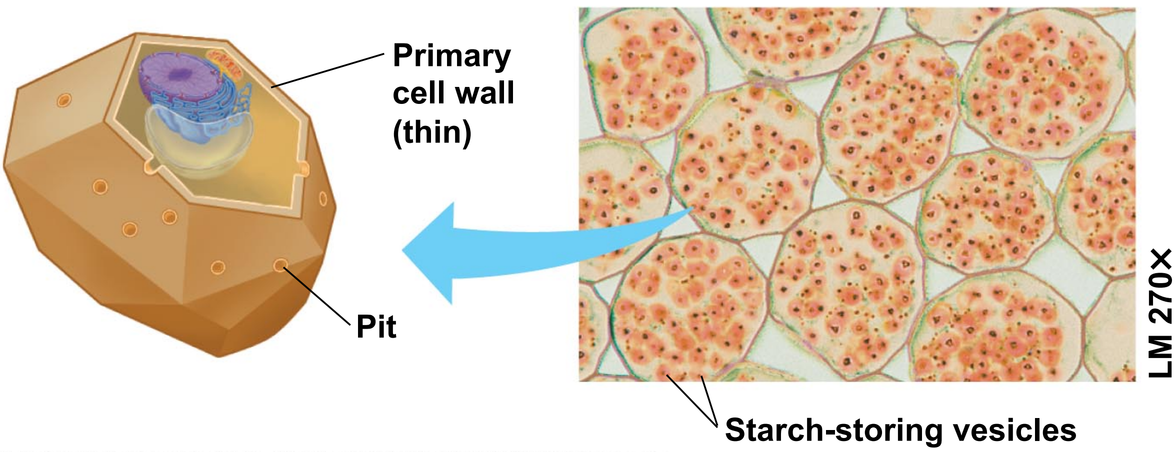

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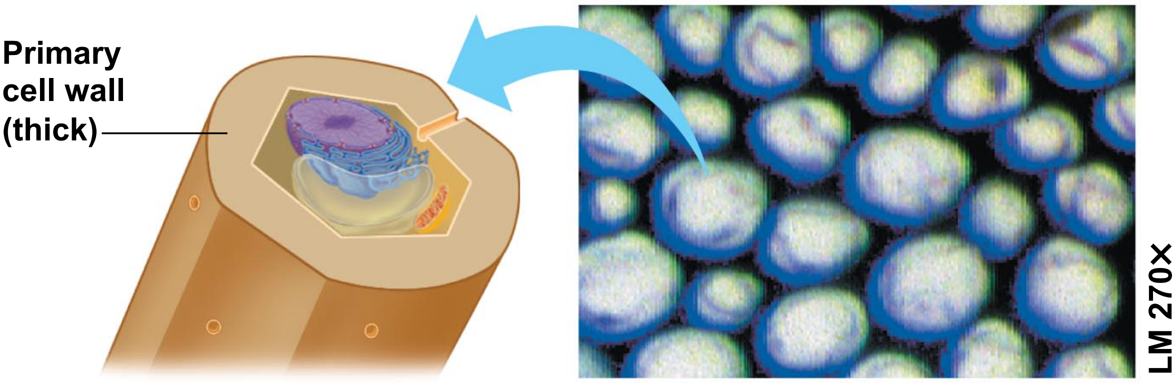

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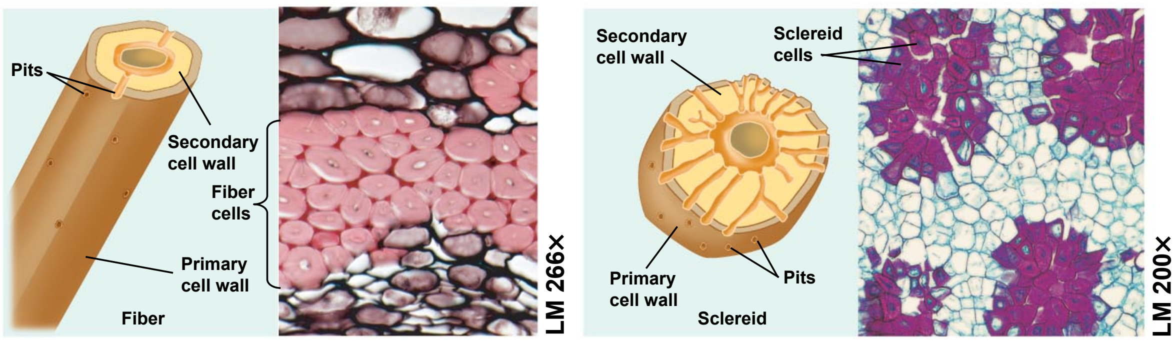
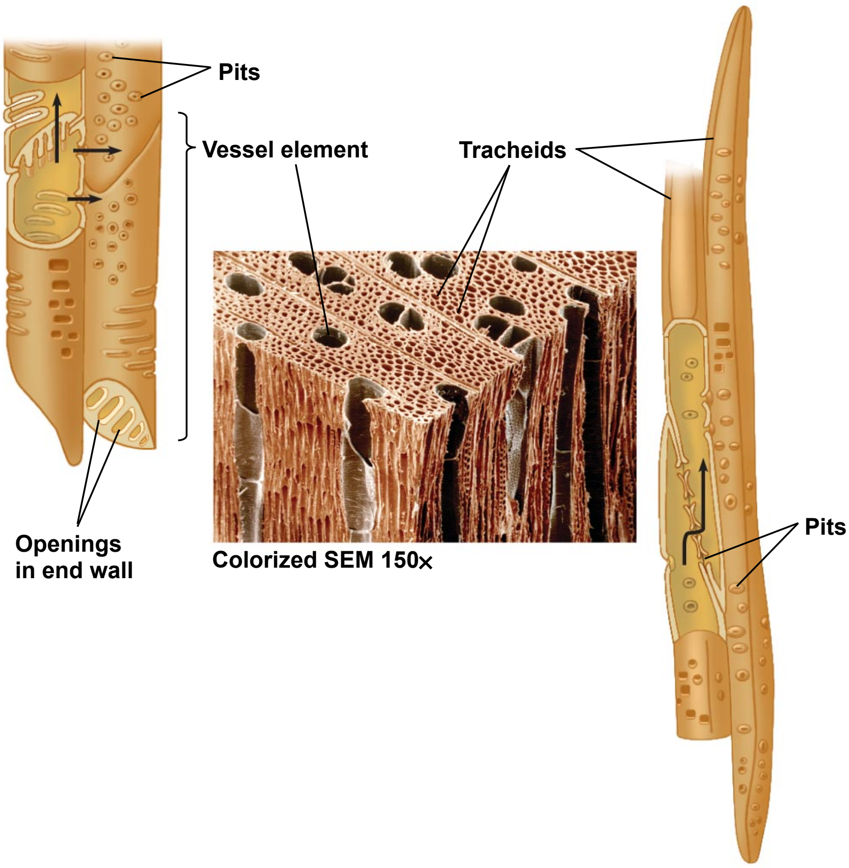


- Water-conducting cells in angiosperms
  - Tracheids and vessel elements
  - Hollow tubes of dead cell walls
- Food-conducting cells
  - Sieve-tube members separated by sieve plates
  - Companion cells
- Vascular tissue
  - Xylem: conveys water and minerals
  - Phloem: transports sugars

LE 31-05e



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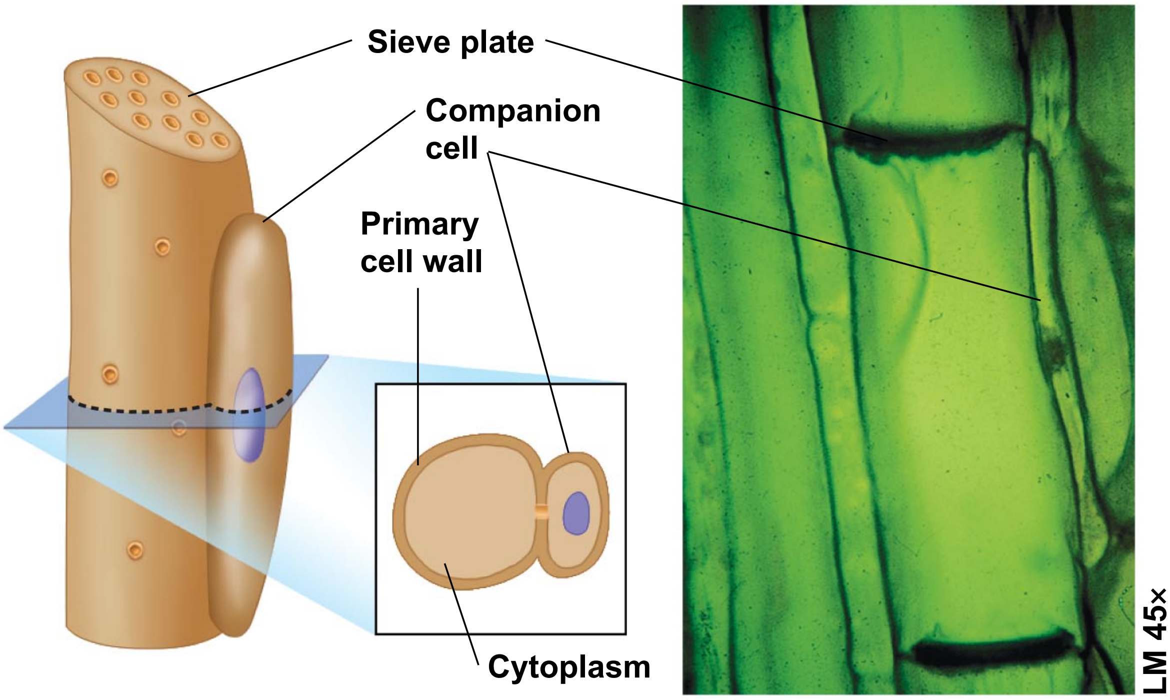


- Three tissue systems make up the plant body
  - A tissue system consists of one or more tissues organized into a functional unit
  - Dermal tissue system forms outer protective covering of the plant
    - Epidermis
    - Cuticle

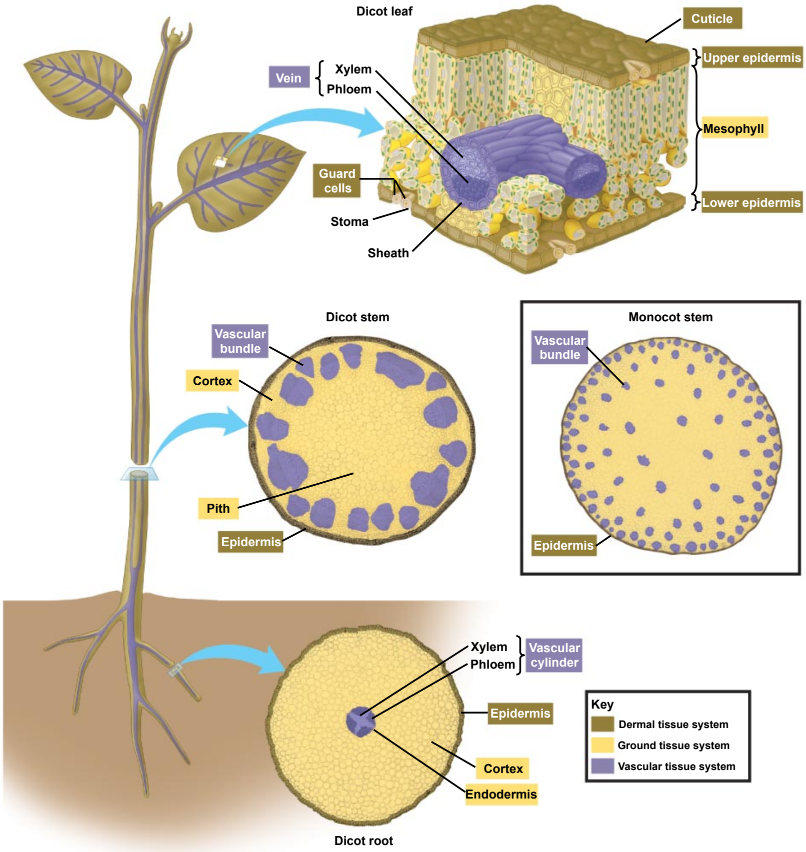
- Vascular tissue system
  - Contains xylem and phloem
  - Provides long-distance transport and support
- Ground tissue system
  - Most of the bulk of young plants
  - Pith: internal to vascular tissue
  - Cortex: external to vascular tissue

- Arrangement of tissue systems in root
  - Vascular cylinder is in center
    - Xylem radiates out
    - Phloem fills in spaces
  - Ground tissue system consists entirely of cortex
    - Endodermis is one-cell-thick innermost layer

– Arrangement of tissue systems in stem
  - Vascular tissue in vascular bundles
    – Dicot: arranged in a ring
    – Monocot: scattered throughout ground tissue
  - Ground tissue
    – Dicot: has both cortex and pith regions
    – Monocot: Not divided into regions

– Arrangement of tissue systems in leaf
  - Epidermis interrupted by stomata flanked by guard cells
  - Mesophyll ground tissue sandwiched between lower and upper epidermis
  - Vascular system made up of network of veins

LE 31-06



Plant Growth

Classification of shoot growth

- **Determinate** – flower buds initiate terminally; shoot elongation stops; e.g. bush snap beans
- **Indeterminate** – flower buds born laterally; shoot terminals remain vegetative; e.g. pole beans

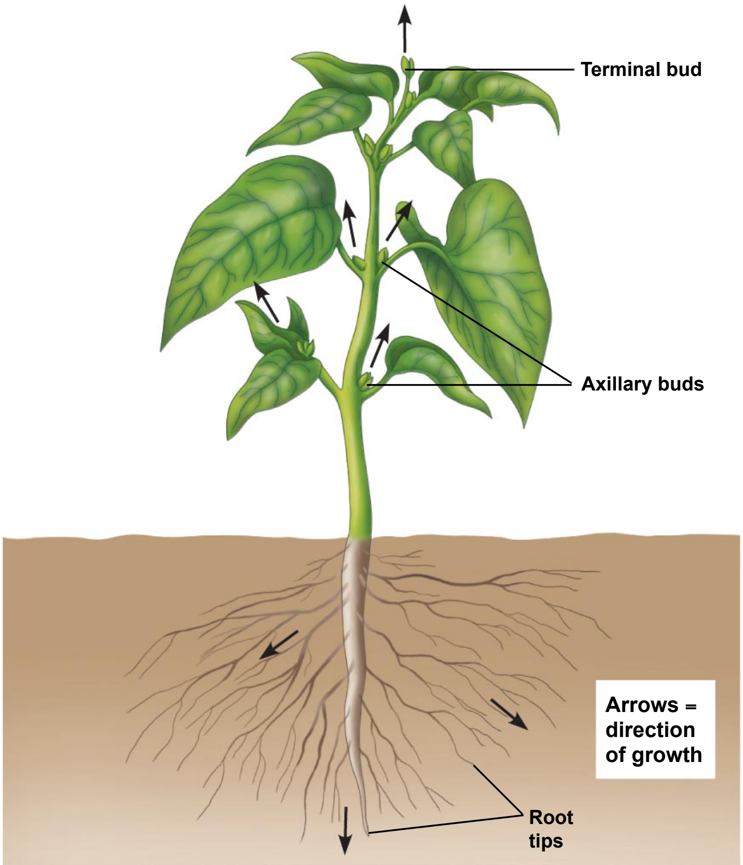
Dua contoh tumbuhan yang tumbuh dan berkembang dari proses pertumbuhan yang tidak terbatas (‘indeterminate growth processes’)

***PLANT PHYSIOLOGY,* 5e, Figure 16.1**

PLANT GROWTH

Primary growth lengthens roots and shoots

- Plants undergo indeterminate growth but are not immortal
- Flowering plants are categorized based on length of life cycle
  - Annuals: complete life cycle in a single year or less
  - Biennials: complete life cycle in two years
  - Perennials: live and reproduce for many years
- Primary growth enables a plant to grow in length
  - Apical meristems are unspecialized cells that continue to give rise to new cells
    - Located in the tips of roots and the terminal and axillary buds of shoots
    - Covered by a protective root cap that is sloughed off during growth



Secondary growth increases the girth of woody plants

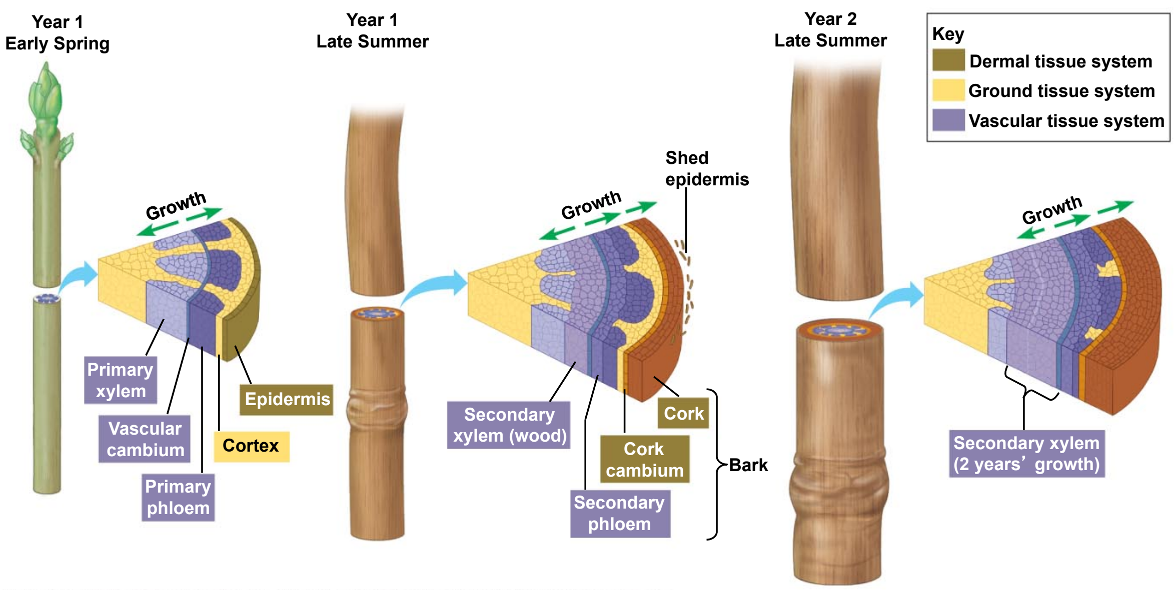
- Secondary growth is produced by lateral meristems, two cylinders of dividing cells
  - Vascular cambium
    - Lies between primary xylem and primary phloem
    - Thickens a stem by adding secondary xylem and phloem on both sides
  - Cork cambium
    - Makes cork, a new outer layer of epidermis

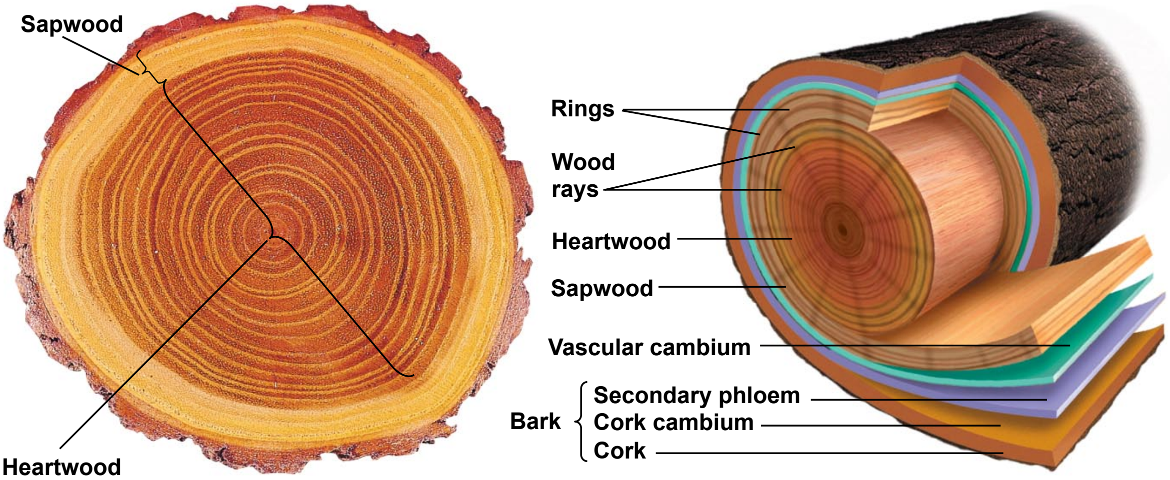
– Bark comprises everything external to the vascular cambium

- Layers sloughed off as secondary xylem expands outward

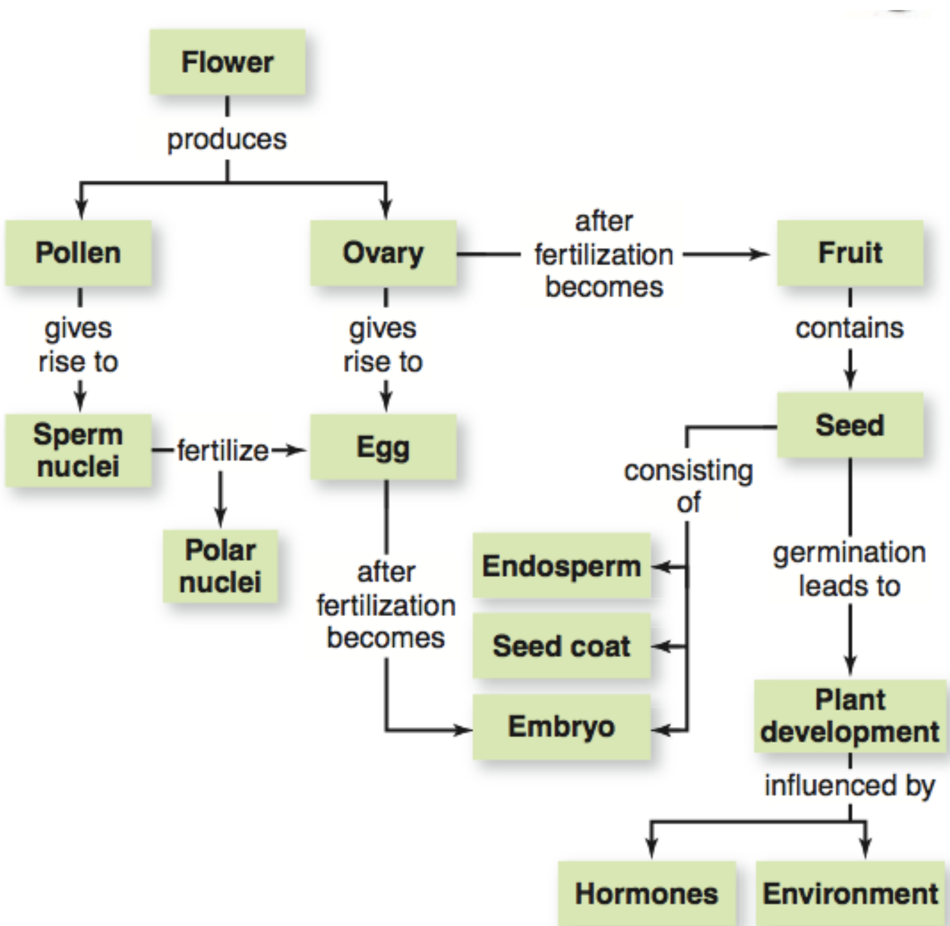
– Wood is made of secondary xylem

- Heartwood: older layers of secondary growth in center of tree that no longer function in transport
- Sapwood: younger secondary xylem that conducts xylem sap
- Wood rays: parenchyma cells that transport water to outer living tissue





Sapwood
Heartwood
Rings
Wood
rays
Heartwood
Sapwood
Vascular cambium
Bark
Secondary phloem
Cork cambium
Cork

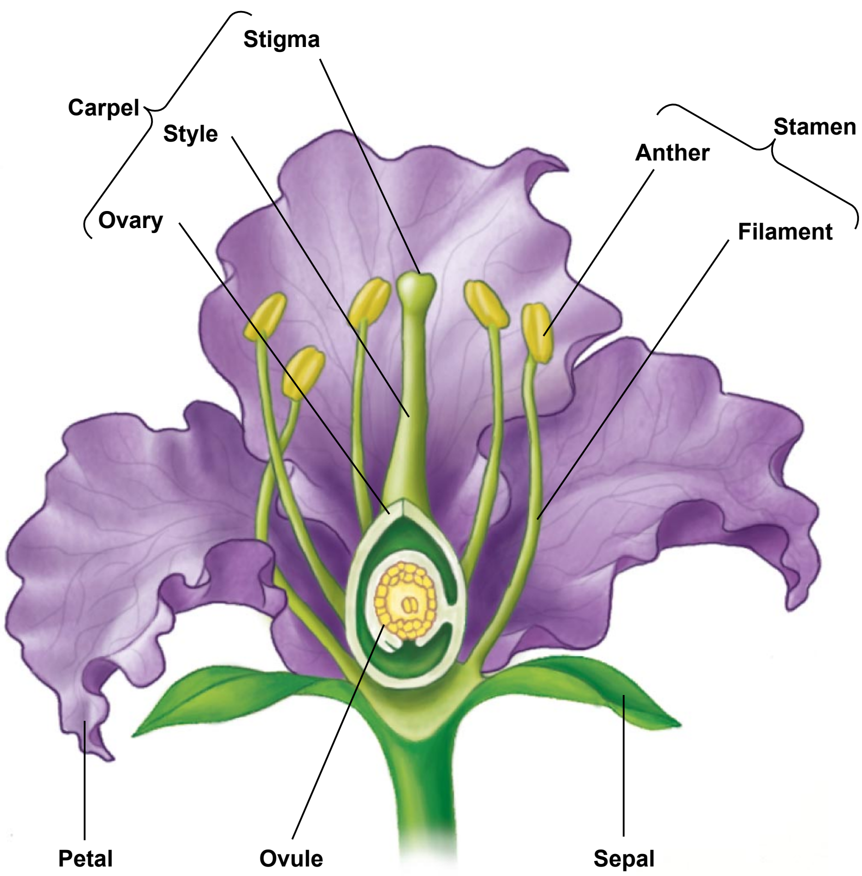


Flower
produces
Pollen
Ovary
after fertilization becomes
Fruit
gives rise to
gives rise to
contains
Sperm nuclei
fertilize
Egg
Seed
consisting of
Polar nuclei
Endosperm
germination leads to
after fertilization becomes
Seed coat
Embryo
Plant development
influenced by
Hormones
Environment

REPRODUCTION OF FLOWERING PLANTS

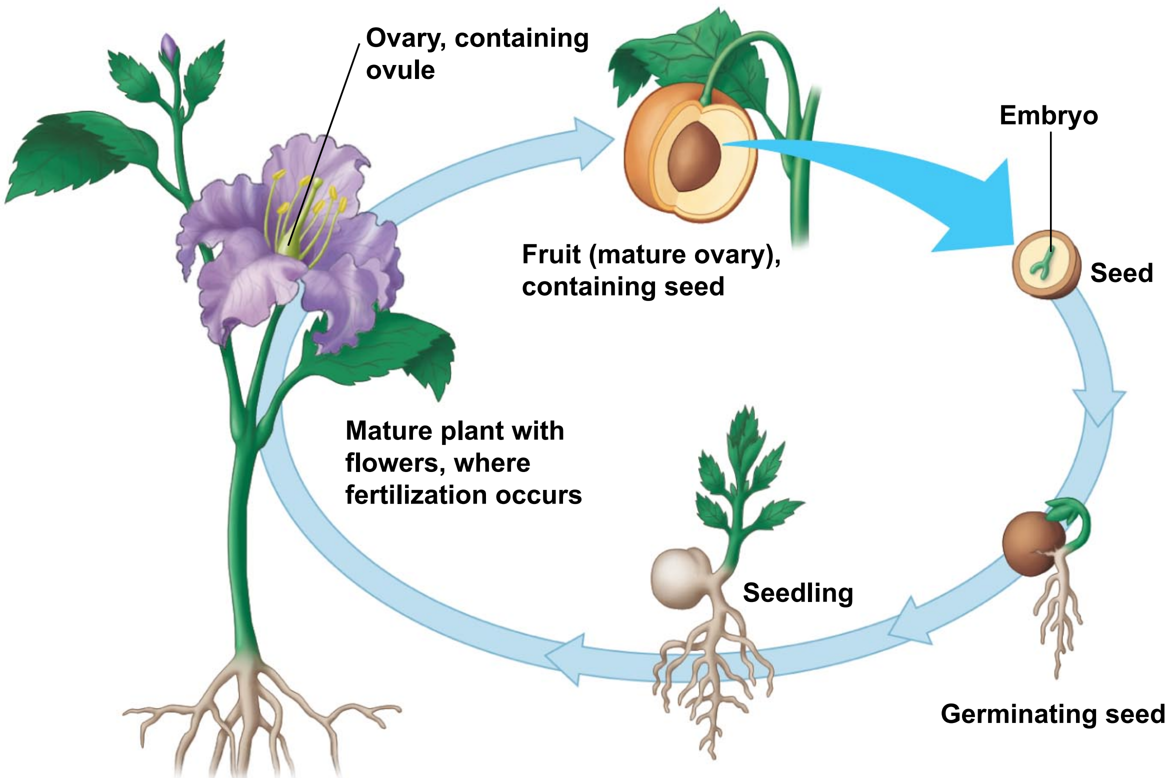
Overview: The sexual life cycle of a flowering plant

- The angiosperm flower consists of four types of modified leaves
  - Sepals enclose and protect bud
  - Petals advertise flower to pollinators
  - Stamen: male reproductive organ
    - Pollen grains develop in anther at tip of filament
- Carpel: female reproductive organ
    - Stigma, at tip of style, receives pollen grains
    - Ovary at base of carpel houses ovules
      - » Contain developing egg and supporting structures



– Life cycle of an angiosperm

- Fertilization occurs in ovule
- Ovule develops into seed containing embryo
- Ovary develops into fruit
- Seed germinates
- Embryo develops into seedling
- Seedling grows into mature plant



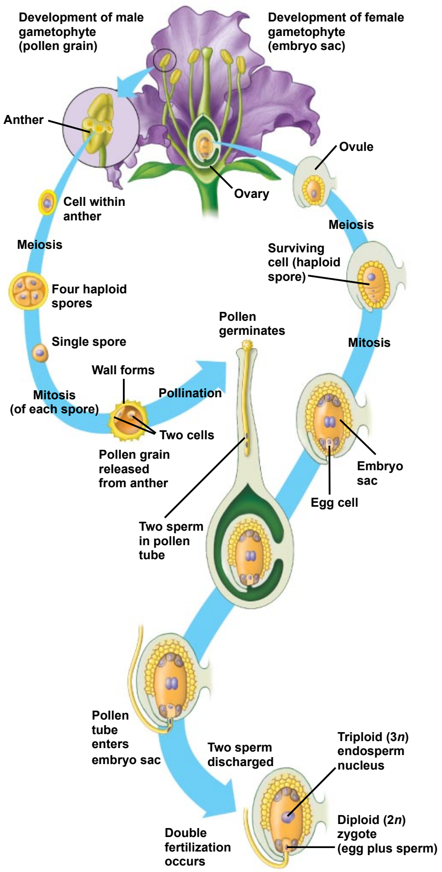
The development of pollen and ovules culminates in fertilization

- The plant life cycle includes alternation of haploid and diploid generations
  - Diploid sporophyte produces haploid spores by meiosis
  - Spores divide by mitosis, becoming microscopic, multicellular, haploid gametophytes
  - Gametophyte produces gametes by mitosis
  - Fertilization produces diploid zygote
  - Zygote divides by mitosis and develops into a new sporophyte

- Development of male gametophyte
  - Cell in anthers develops into four haploid spores
  - Spores form haploid tube cell and generative cell
  - Wall forms around the cells, resulting in two-cell pollen grain (male gametophyte)

– Development of female gametophyte
  - Ovary contains central cell surrounded by smaller cells
  - Central cell produces four haploid spores
  - Three spores degenerate
  - Surviving spore enlarges and develops into embryo sac (female gametophyte)
    – Contains large central cell and the haploid egg, ready to be fertilized

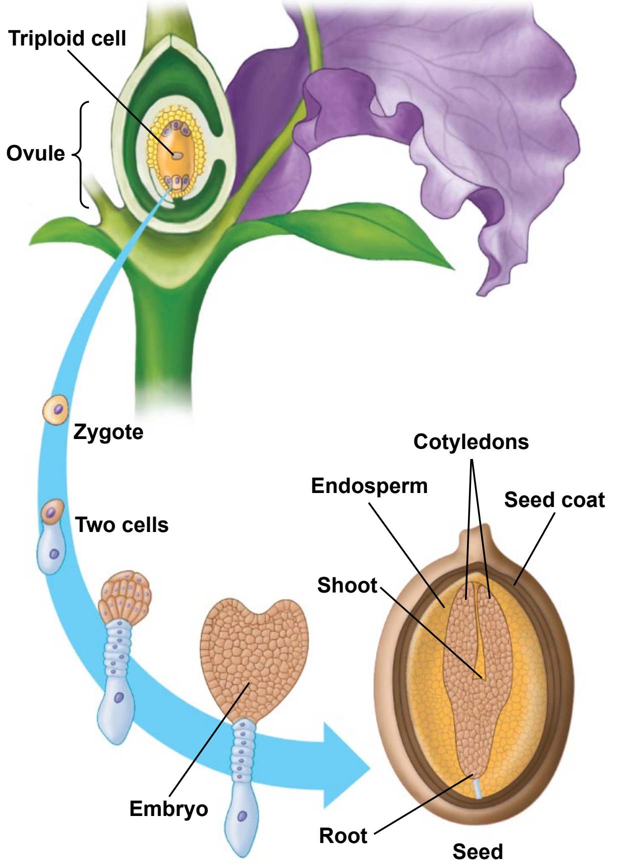
– Double fertilization, a hallmark of angiosperms
  - Pollination
  - Pollen grain germinates on stigma
    – Tube cell gives rise to pollen tube, which grows downward to ovary
    – Generative cell forms two sperm
  - Pollen tube discharges two sperm in ovary
    – One fertilizes egg, forming zygote
    – One contributes haploid nucleus to diploid central cell of embryo sac, giving rise to endosperm

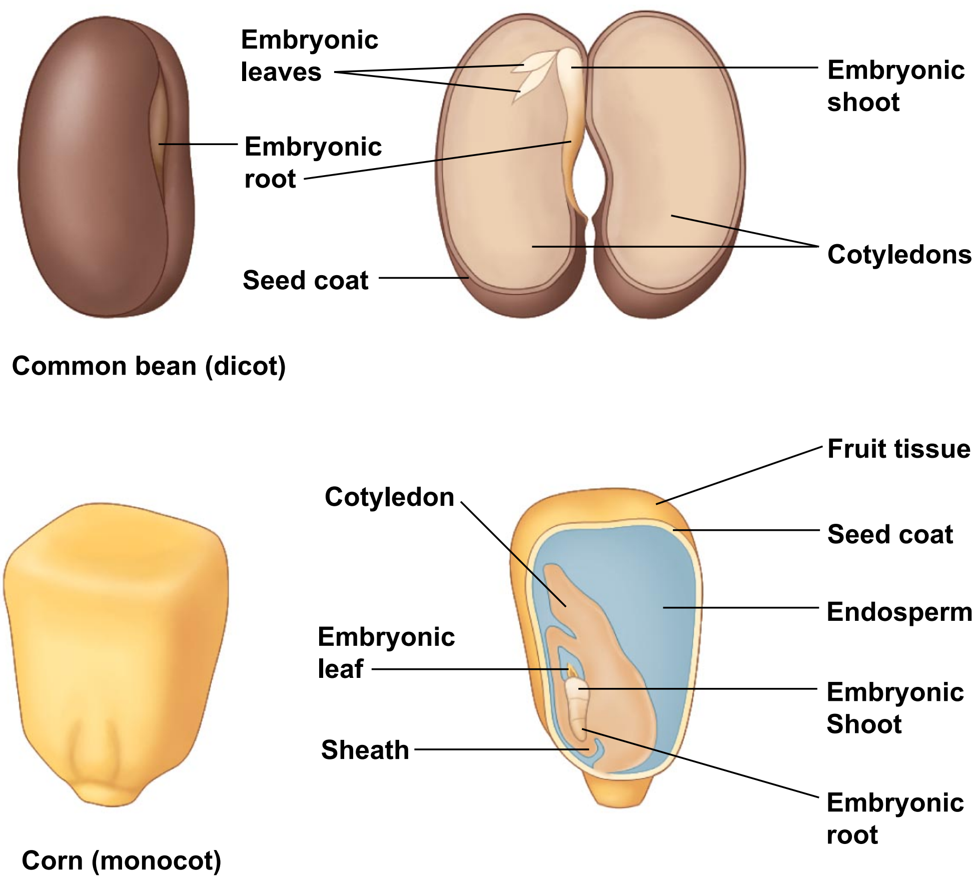


The ovule develops into a seed

- Ovule contains triploid central cell and zygote
- Central cell develops into endosperm that nourishes seedling
- Zygote divides and becomes embryo
- Result of embryonic development is a seed
    - Develops hard seed coat
    - Undergoes seed dormancy
    - Contains embryonic root, shoot, and leaf; cotyledon(s); and endosperm

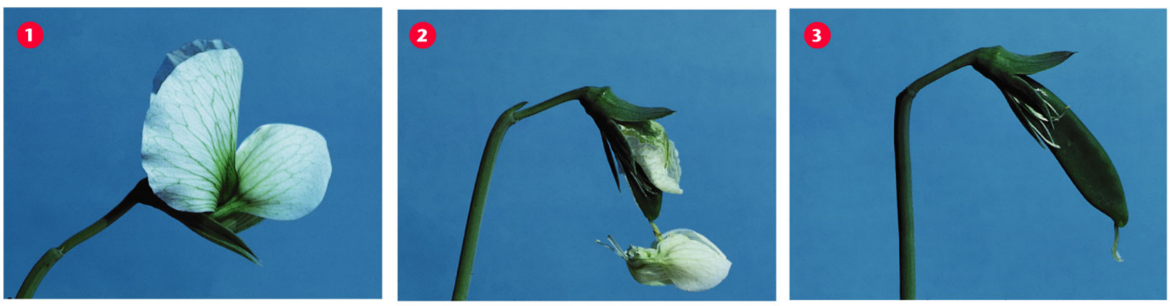
LE 31-11a

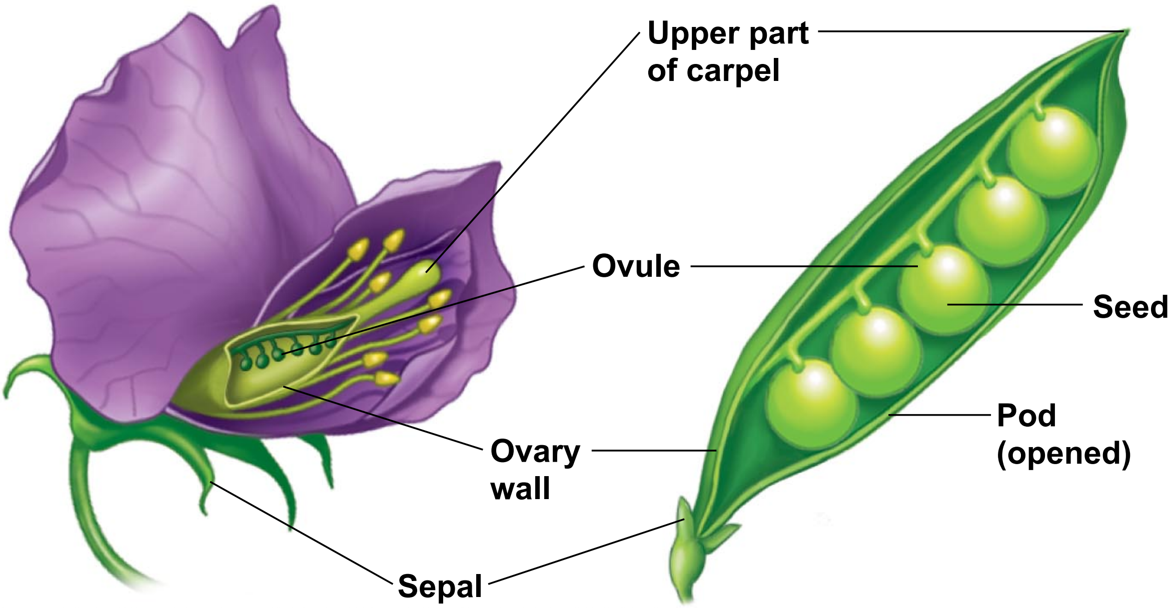

Triploid cell
Ovule
Zygote
Two cells
Embryo
Cotyledons
Endosperm
Seed coat
Shoot
Root
Seed


Embryonic leaves
Embryonic root
Seed coat
Embryonic shoot
Cotyledons
Common bean (dicot)
Fruit tissue
Cotyledon
Seed coat
Endosperm
Embryonic leaf
Embryonic Shoot
Sheath
Embryonic root
Corn (monocot)

The ovary develops into a fruit

– A fruit is a specialized vessel that houses and protects seeds and helps them disperse
– Changes leading to fruit formation
  • Soon after pollination, flower drops petals
  • Ovary expands, walls thicken, forming fruit



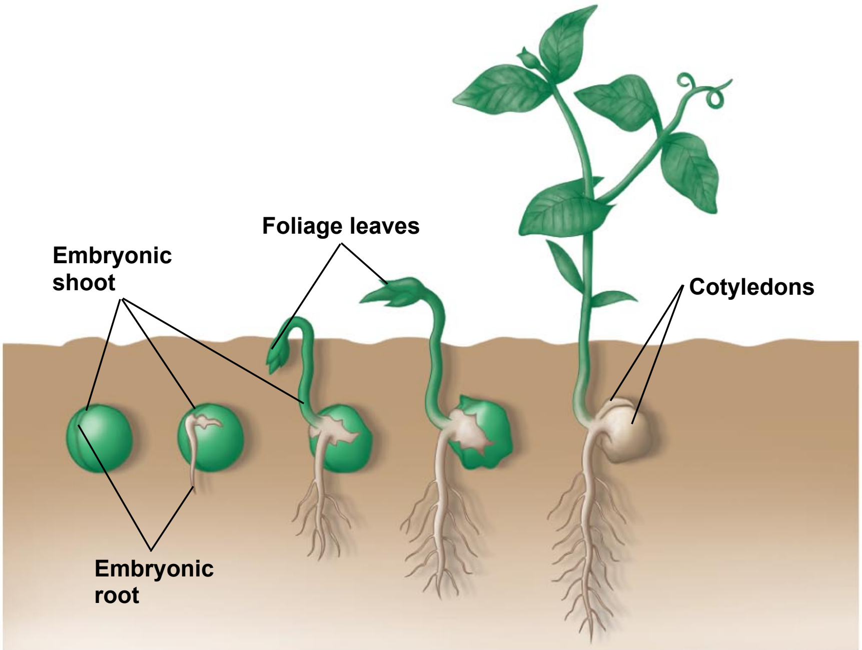


- Fruits are highly varied
  - Simple fruit: derived from a flower with a single carpel (peach, pea, nut)
  - Aggregate fruit: results from a single flower with multiple carpels (raspberry)
  - Multiple fruit: develops from tightly clustered separate flowers (pineapple)

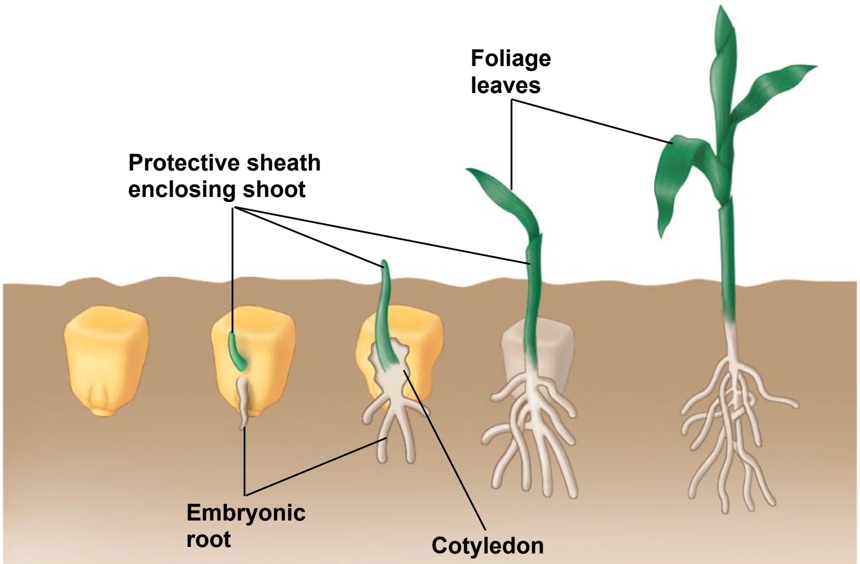
- 31.13 Seed germination continues the life cycle
  - Germination resumes growth and development that was suspended during seed dormancy
    - Seed takes up water and starts to expand
    - Embryo resumes growth and absorbs nutrients from the endosperm

    - In dicots, the root emerges first, followed by the shoot, which is covered by a protective hook
    - In monocots, a protective sheath surrounding the shoot breaks the soil
    - Cotyledons remain in soil

LE 31-13a



LE 31-13b



- Asexual reproduction produces plant clones
  - Asexual or vegetative reproduction is an extension of an angiosperm's indeterminate grown
    - Fragmentation: separation of a parent into parts that develop into whole plants (garlic)
    - Sprouting from roots (redwood trees)
    - Asexual reproduction from roots (creosote bushes)
    - Sprouting shoots or roots from runners (dune grass)

CONNECTION

Asexual reproduction is a mainstay of modern agriculture

- Plants can be propagated asexually from cuttings or bits of tissue
  - Can increase productivity
  - Can reduce genetic diversity
- Most crops today are grown in monocultures

PLANT TRANSPORT AND NUTRITION

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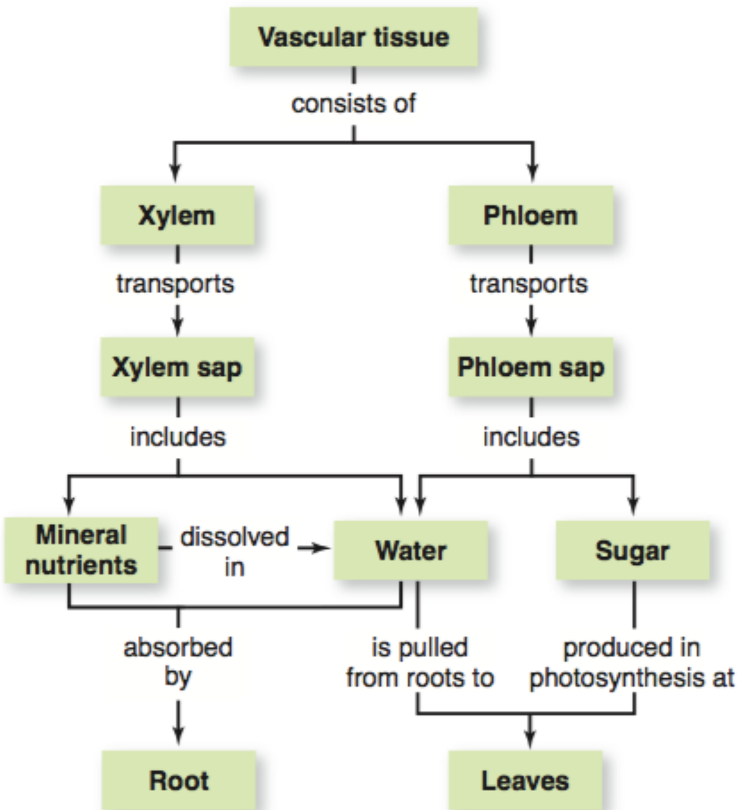

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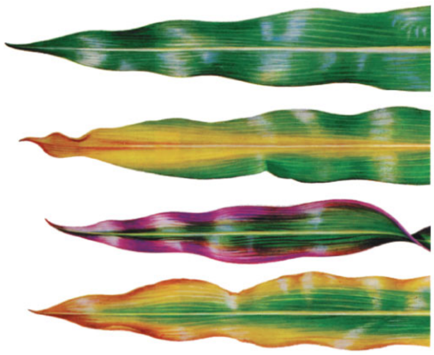
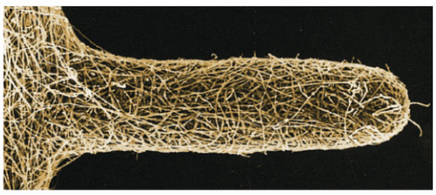
- Many plants can remove toxins such as heavy metals from soils by
  - taking them up with their roots and
  - storing them in their bodies.
- After Hurricane Katrina, sunflowers were used to remove toxins from soils in some parts of New Orleans.

The Uptake and Transport of Plant Nutrients



Plant Nutrients and the Soil



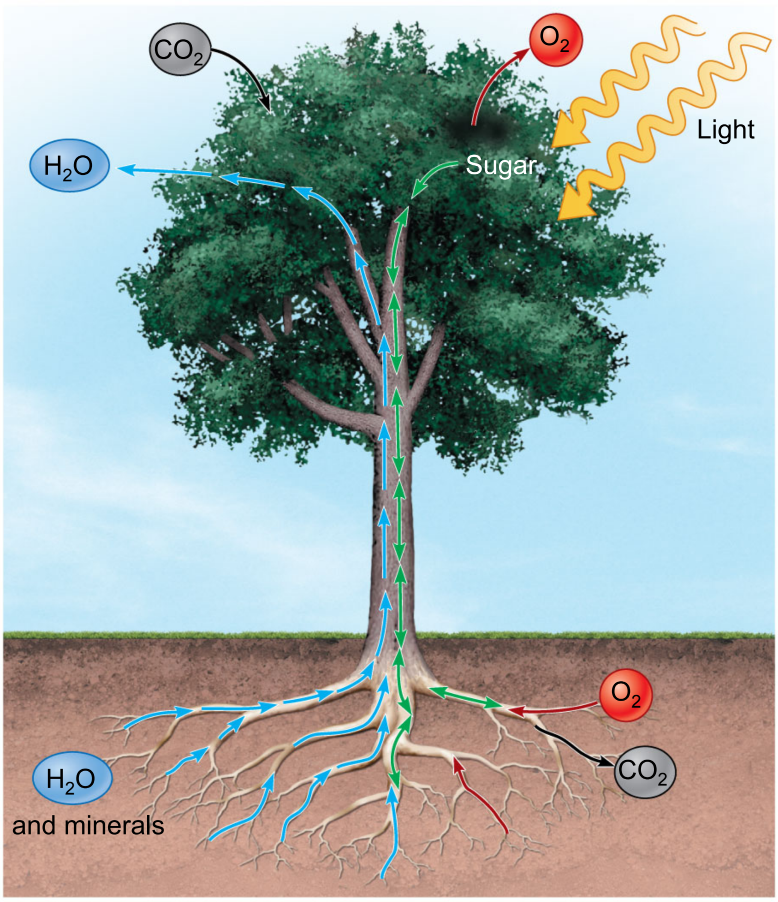
Plant Nutrition and Symbiosis

THE UPTAKE AND TRANSPORT OF PLANT NUTRIENTS

Plants acquire nutrients from air, water, and soil

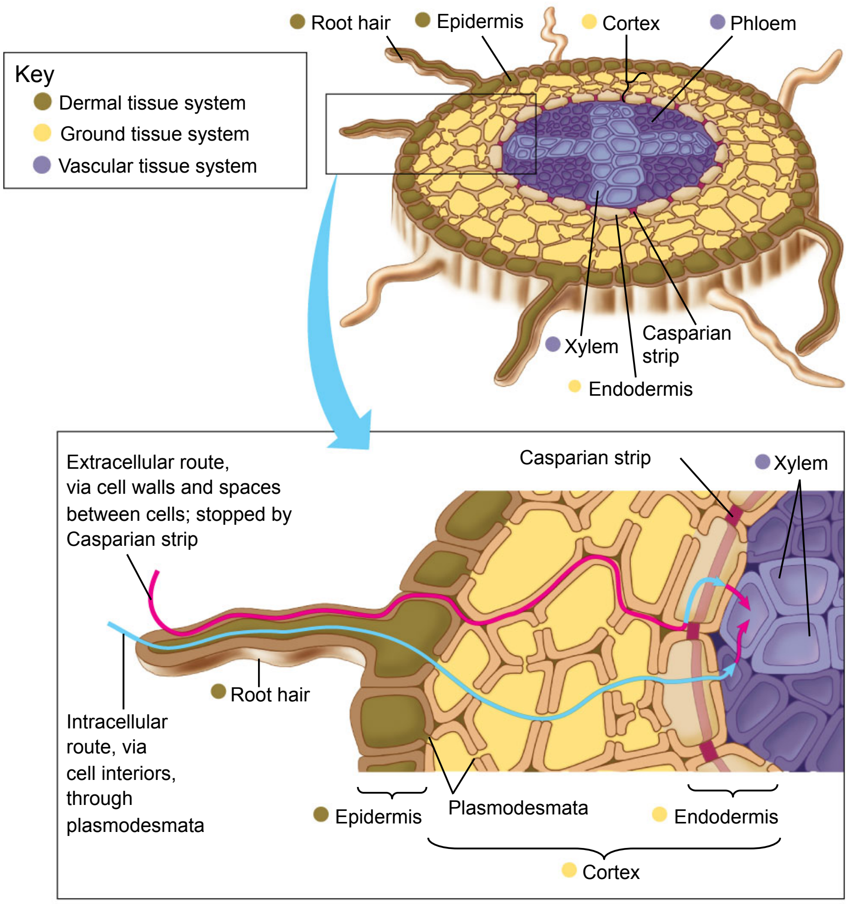
- Plant growth uses
  - air,
  - water, and
  - soil.
- Plants obtain water, minerals, and some oxygen from the soil.
- The sugars made by plants in photosynthesis use
  - carbon and oxygen from the atmosphere and
  - hydrogen from water.

- Plants use cellular respiration to break down some of these sugars
  - obtaining energy and
  - consuming oxygen.
- A plant must
  - move water from its roots to its leaves and
  - deliver sugars to specific areas of its body.



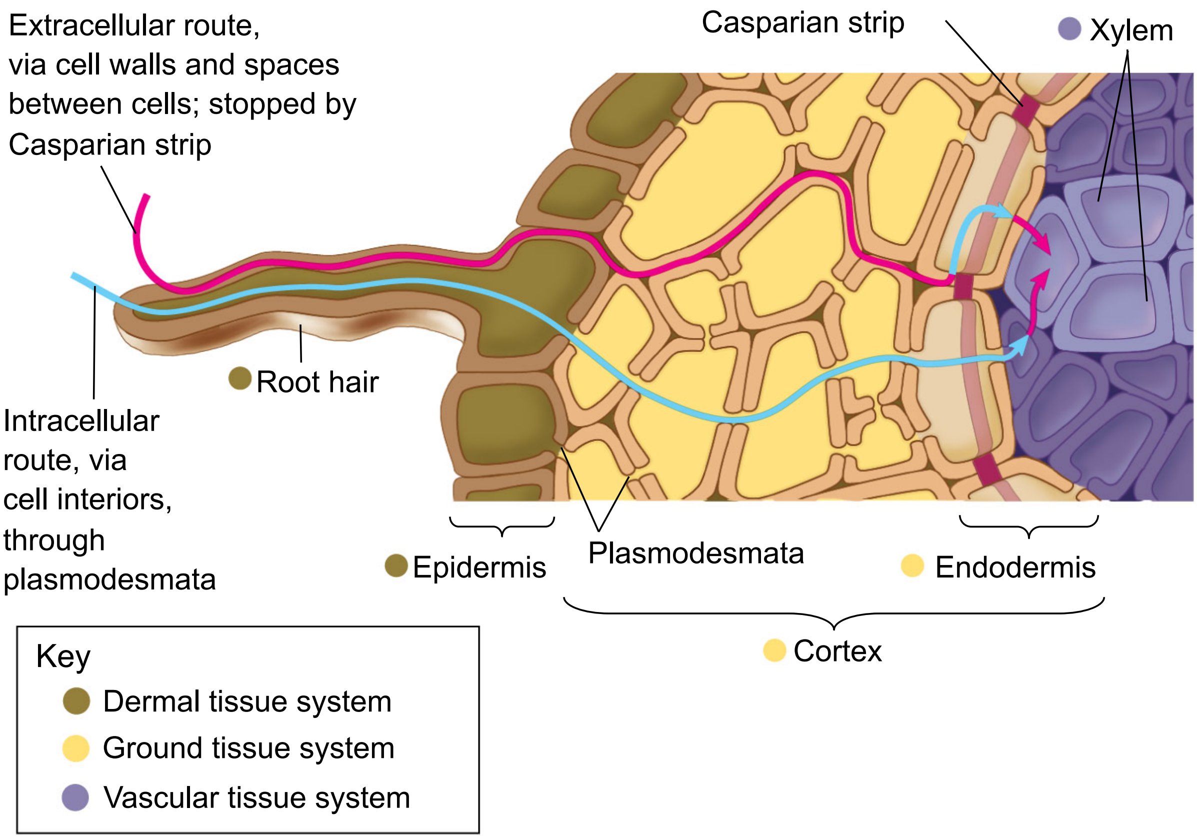
The plasma membranes of root cells control solute uptake

- Root hairs greatly increase a root's absorptive surface.
- Water and solutes can move through the root's epidermis and cortex by going
  - through cells,
  - between cells, or
  - through some combination of these routes.



- Once the water and solutes reach the endodermis, a continuous waxy barrier called the **Casparian strip**
  - stops them from entering the xylem via cell walls and
  - forces them to cross the selectively permeable plasma membrane of an endodermal cell to enter the xylem (water-conducting tissue) for transport upward.

Figure 32.2B_2



Transpiration pulls water up xylem vessels

- **Xylem sap** consists of
  - water and
  - dissolved inorganic nutrients.
- Xylem tissues of angiosperms consist of very thin tubes composed of two types of cells that conduct xylem sap up a plant:
  1. tracheids and
  2. vessel elements.

Transpiration pulls water up xylem vessels

- What force moves xylem sap up against the downward pull of gravity?
  - **Root pressure**, the accumulation of water in roots by osmosis, can push xylem sap up a few meters.
  - **Transpiration**, the loss of water by evaporation from leaves (and other aerial parts of a plant)
    - is regulated by guard cells surrounding stomata and
    - can move xylem sap to the top of the tallest tree.

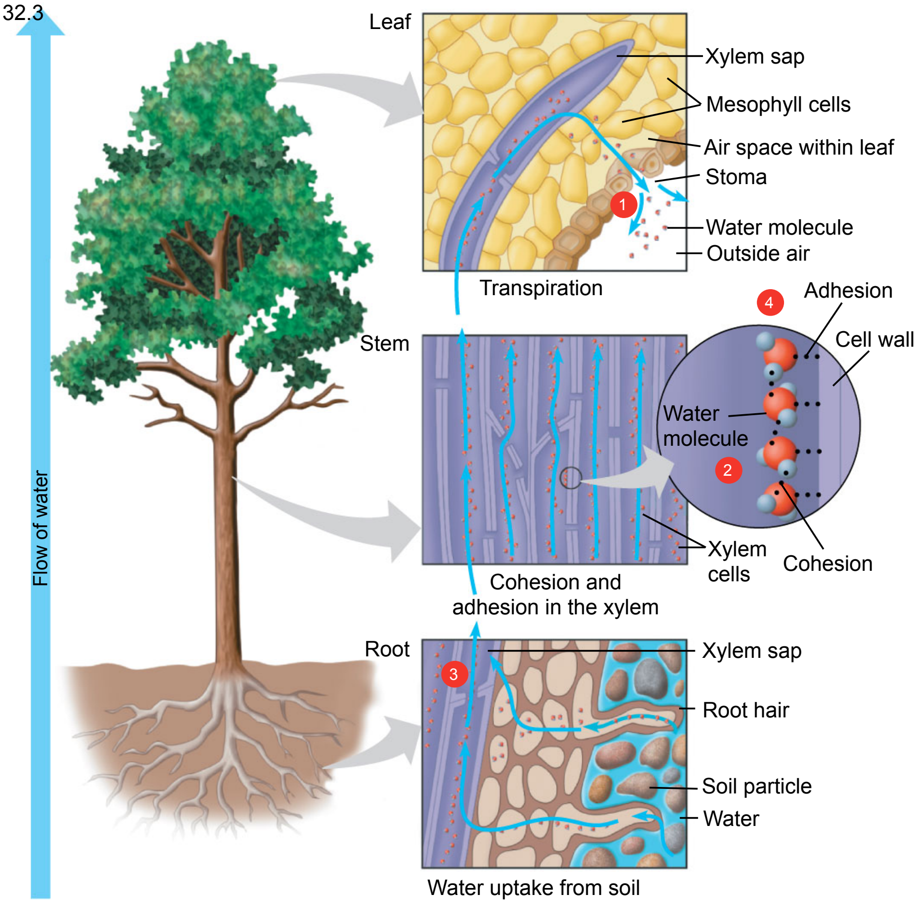
Transpiration pulls water up xylem vessels

- Transpiration can pull xylem sap up a tree because of two special properties of water:
  1. **Cohesion** is the sticking together of molecules of the same kind.
  2. **Adhesion** is the sticking together of molecules of different kinds.

Transpiration pulls water up xylem vessels

- The overall process of this movement of xylem sap is called the **transpiration-cohesion-tension mechanism**. In this process,
  - the air's pull on water creates a tension and
  - that tension pulls on an unbroken chain of water molecules in the xylem
    - held together by cohesion and
    - helped upward by adhesion.
  - Therefore xylem sap moves up without any energy expenditure by the plant.

Figure 32.3

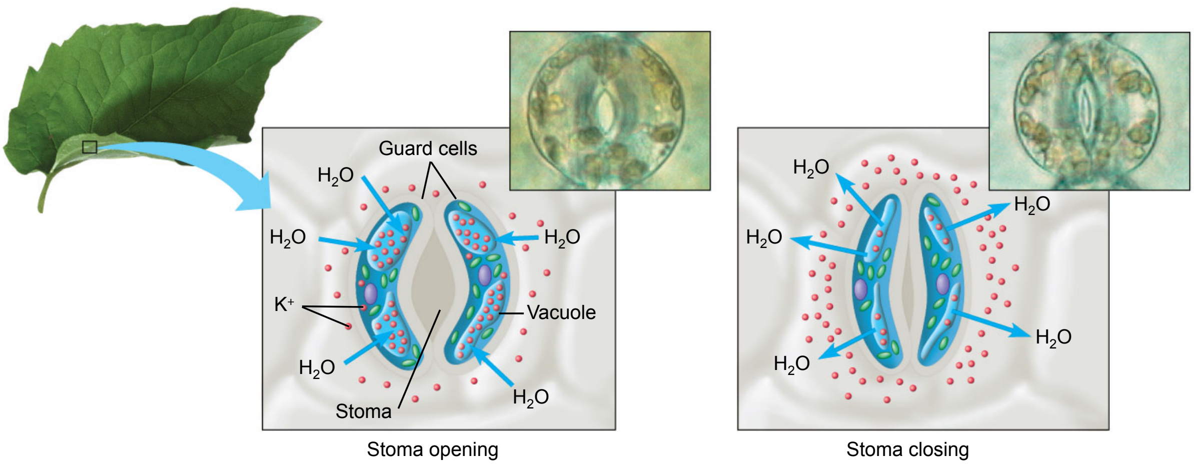


Guard cells control transpiration

- A plant must make a trade-off between its need
  - for water and
  - to make food by photosynthesis.
- Stomata
  - can open and close and
  - help plants adjust their transpiration rates to changing environmental conditions.
  - Guard cells control the opening of a stoma by changing shape.

- Stomata open when guard cells take up water in the following process:
  - Potassium is actively taken up by guard cells from nearby cells.
  - This creates an osmotic gradient and water follows.
  - Uneven cell walls of guard cells cause them to bow when water is taken up.
  - The bowing of the guard cells causes the pore of the stoma to open.
  - When guard cells lose K^+ ions, the guard cells become flaccid and the stoma closes.

Figure 32.4



Guard cells control transpiration

- Several factors influence guard cell activity.
  - In general, stomata are open during the day and closed at night.
  - Sunlight signals guard cells to accumulate K^+ and open stomata.
  - Low CO_2 concentration in leaves also signals guard cells to open stomata.
  - Plants have natural rhythms that help them close stomata at night to conserve water.
  - Plants may also close stomata during the day to conserve water when necessary.

Phloem transports sugars

- **Phloem sap** transports sugars
  - made by photosynthesis and
  - using a pressure flow mechanism.
- At a **sugar source**
  - sugar is loaded into the phloem tube,
  - sugar raises the solute concentration in the tube, and
  - water follows, raising the pressure in the tube.

Phloem transports sugars

- At a **sugar sink**
  - sugar is removed,
  - water follows, and
  - phloem sap flows from source to sink in a process called the **pressure flow mechanism**.

Figure 32.5A

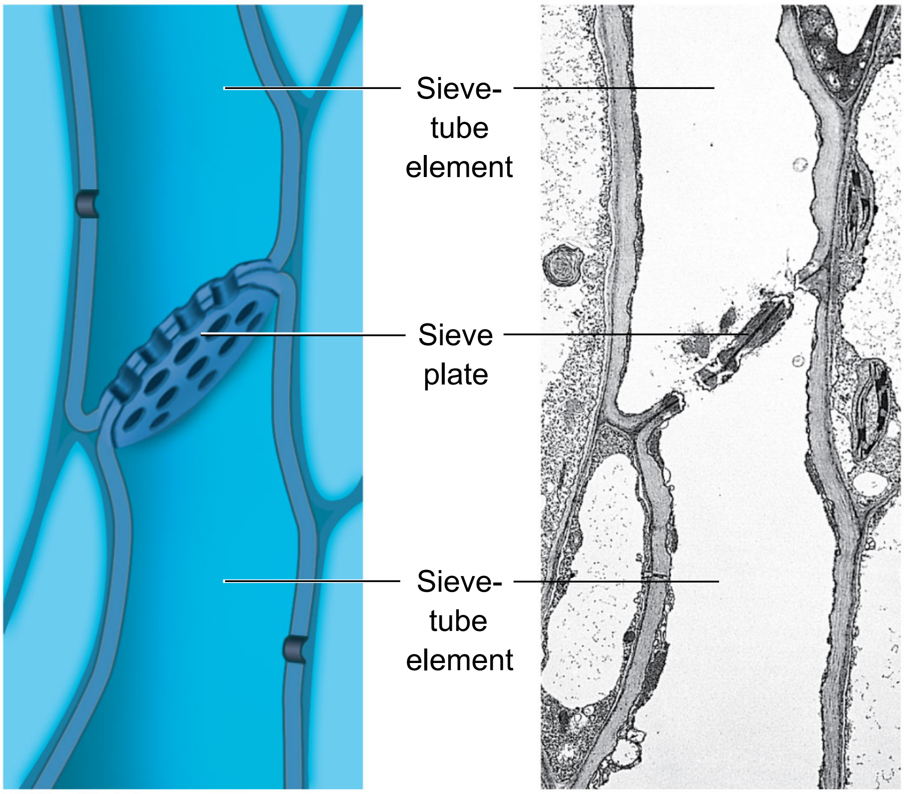
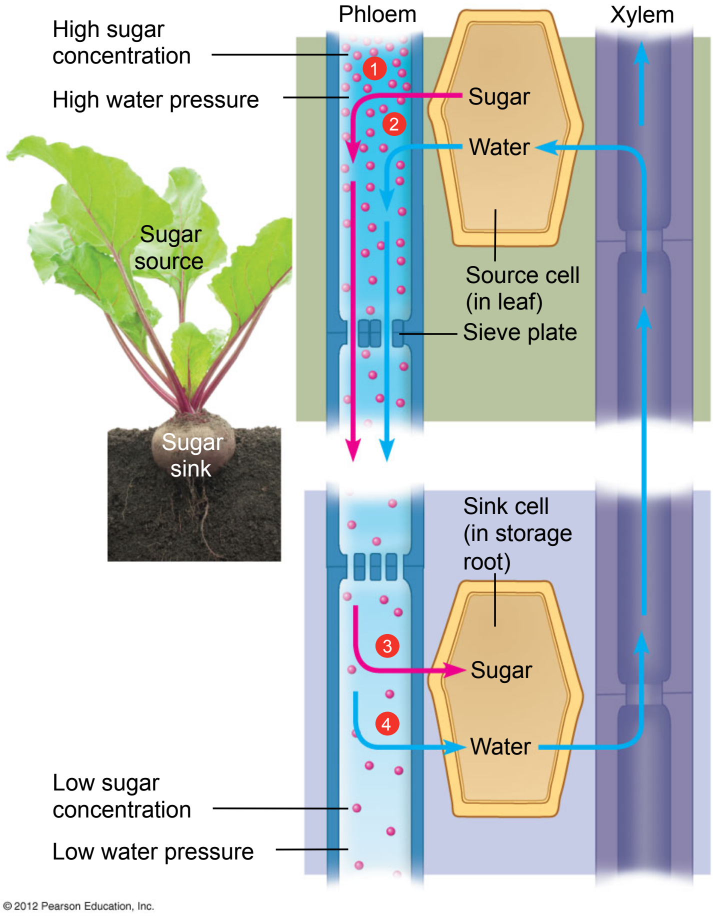


Figure 32.5B



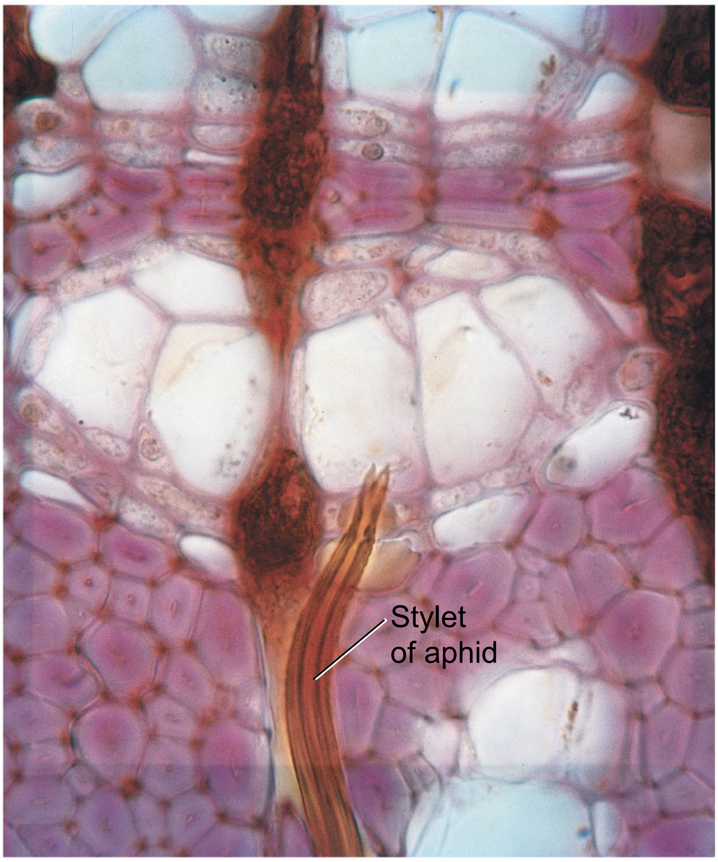
Phloem transports sugars

- Plant biologists use aphids to study phloem sap.
  - Pressure in the phloem sap force-feeds an aphid.
  - If an aphid is severed at the stylet (sucking mouthpart) and only the stylet remains, phloem sap continues to flow into the stylet.

Figure 32.5C_1

Aphids feeding on a branch

Figure 32.5C_2



Aphid's stylet inserted into a phloem cell

Figure 32.5C_3

Aphid with phloem droplet

Figure 32.5C_4

Severed stylet dripping
phloem sap

PLANT NUTRIENTS AND THE SOIL

Plant health depends on a complete diet of essential inorganic nutrients

- A plant must obtain inorganic substances to survive and grow.
- **Essential elements** are those that a plant must obtain to
  - complete its life cycle of growth and
  - have reproductive success.

- There are 17 elements essential to plant growth and reproduction.
  - There are nine **macronutrients** that plants require in relatively large amounts.
  - There are eight **micronutrients** that plants require in relatively small amounts.
- Both types of nutrients have vital functions.

- Macronutrients are components of organic molecules and include
  - carbon,
  - hydrogen,
  - oxygen,
  - nitrogen,
  - sulfur,
  - phosphorus,
  - potassium,
  - calcium, and
  - magnesium.

These six make up 98% of a plant's dry weight.

- **Micronutrients** often act as cofactors and include
  - chlorine,
  - iron,
  - manganese,
  - boron,
  - zinc,
  - copper,
  - nickel, and
  - molybdenum.

Figure 32.6

Complete solution containing all minerals (control)

Solution lacking potassium (experimental)

CONNECTION: Fertilizers can help prevent nutrient deficiencies

- The availability of nutrients in soil affects plant growth and health.
- Growers can often determine which nutrients are missing from soil by looking at plant symptoms.
- Nitrogen shortage is the most common nutritional problem for plants.

CONNECTION: Fertilizers can help prevent nutrient deficiencies

- **Fertilizers** are compounds given to plants to promote growth.
- Nutrient deficiencies can be alleviated by adding to soil
  - inorganic chemical fertilizers or
  - **compost**, a soil-like mixture of decomposed organic matter.

Figure 32.7A

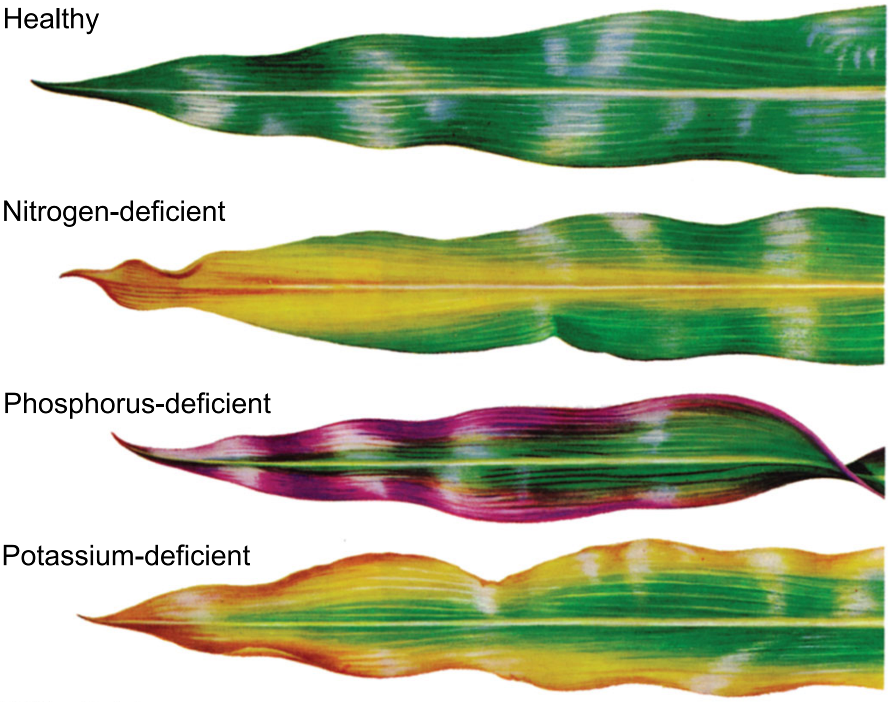
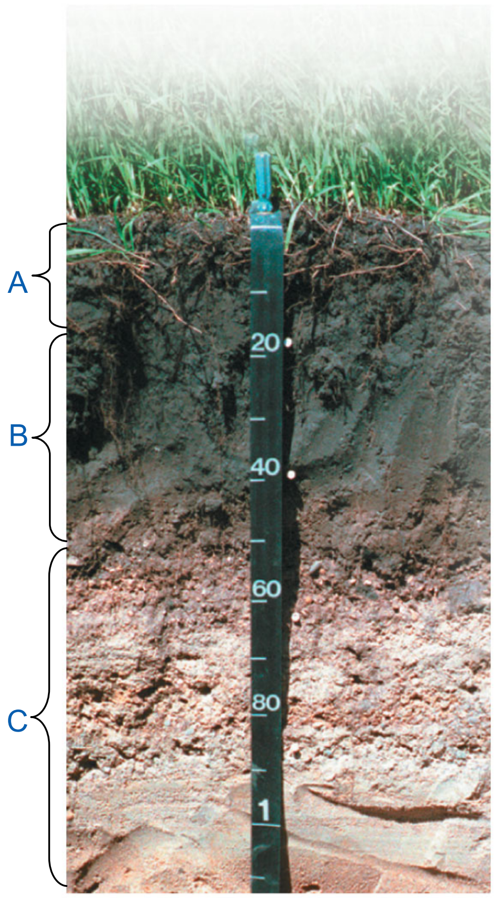


Figure 32.7B

Fertile soil supports plant growth

- Soil horizons are layers of soil with different characteristics.
  - The A horizon, or **topsoil**,
    - is subject to weathering and
    - contains **humus** (decayed organic matter) and many soil organisms.
  - The B horizon primarily consists of
    - clay and
    - dissolved elements.
  - The C horizon consists of rocks of the "parent material" from which soil is formed.



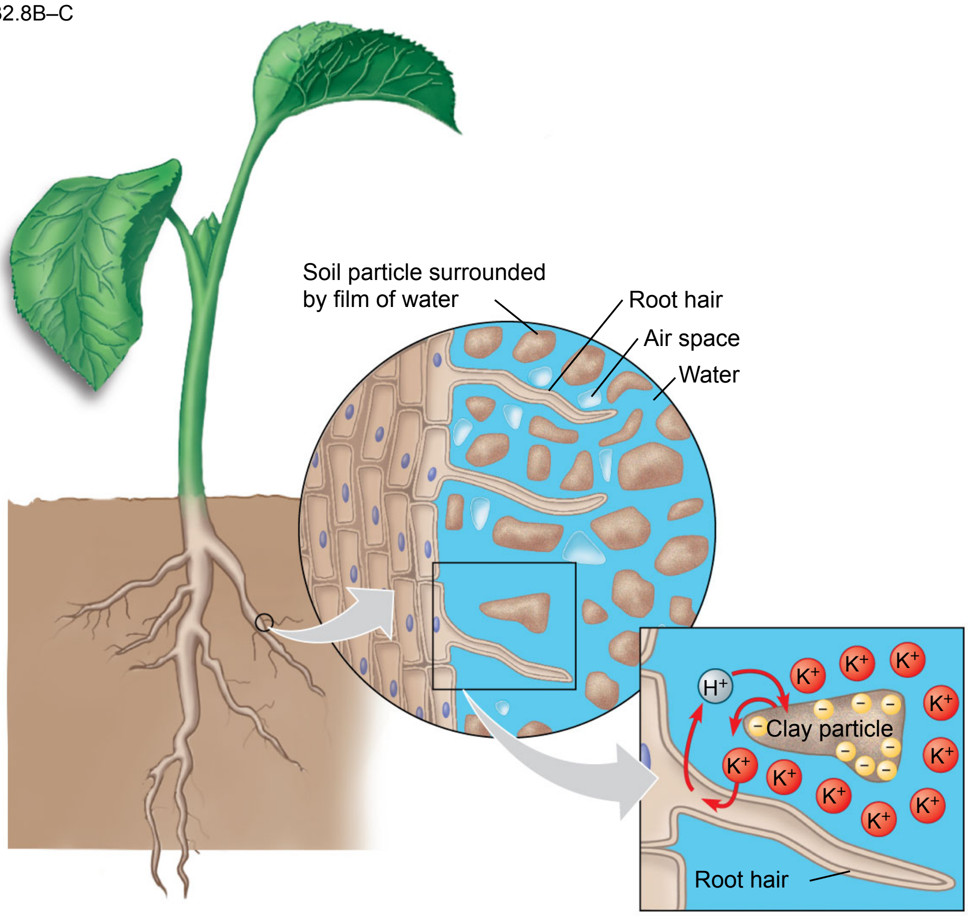
Fertile soil supports plant growth

- A soil's physical and chemical characteristics affect plant growth.
  - Small rock and clay particles
    - hold water and ions and
    - allow oxygen to diffuse into plant roots.
  - Humus
    - provides nutrients and
    - supports the growth of organisms that enhance soil fertility.

Fertile soil supports plant growth

- Anions such as nitrate are readily available to plants because they are not bound to soil particles.
- Cations such as K^+ adhere to soil particles.
- In **cation exchange**, root hairs
  - release H^+ ions, which displace cations from soil particles, and then
  - absorb the free cations.

Figure 32.8B–C



Soil conservation is essential to human life

- Human practices in agriculture have degraded soils.
  - Irrigation can gradually make soil salty.
  - Plowed lands are subject to erosion by wind and rain, which removes topsoil.
  - Chemical fertilizers are costly and may contaminate groundwater.
- Good soil management includes
  - water-conserving irrigation,
  - erosion control, and
  - the prudent use of herbicides and fertilizers.

Figure 32.9A

113

Figure 32.9C

CONNECTION: Organic farmers follow principles of sustainable agriculture

- Organic farming promotes **sustainable agriculture**, a system embracing farming methods that are
  - conservation-minded,
  - environmentally safe, and
  - profitable.
- The USDA has established guidelines for foods labeled "organic."

CONNECTION: Organic farmers follow principles of sustainable agriculture

- Organic farming guidelines are intended to
  - sustain biological diversity,
  - maintain soil quality,
  - reduce or eliminate the use of chemical pesticides,
  - avoid use of genetically modified plants, and
  - reduce or eliminate the use of chemical fertilizers.

CONNECTION: Agricultural research is improving the yields and nutritional values of crops

- Advances in genetic engineering have led to many improvements in crops that
  - are more resistant to disease and insects, reducing the need to use pesticides,
  - are resistant to weed-killing herbicides, reducing the need to till the soil, which promotes erosion, and
  - have improved nutritional quality, allowing less land to feed more people.

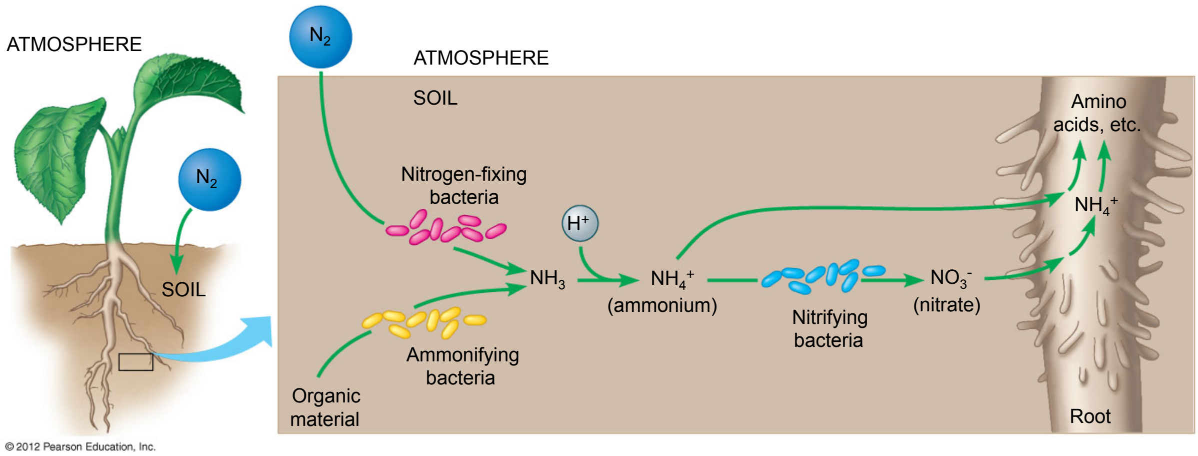
PLANT NUTRITION AND SYMBIOSIS

Most plants depend on bacteria to supply nitrogen

- The Earth's atmosphere consists of about 80% nitrogen.
- However, nitrogen deficiency is the most common nutritional problem in plants. Why is that?
  - Plants cannot absorb nitrogen directly from the air.
  - Instead, to be used by plants, nitrogen must be converted to ammonium (NH_4^+) or nitrate (NO_3^-).

Most plants depend on bacteria to supply nitrogen

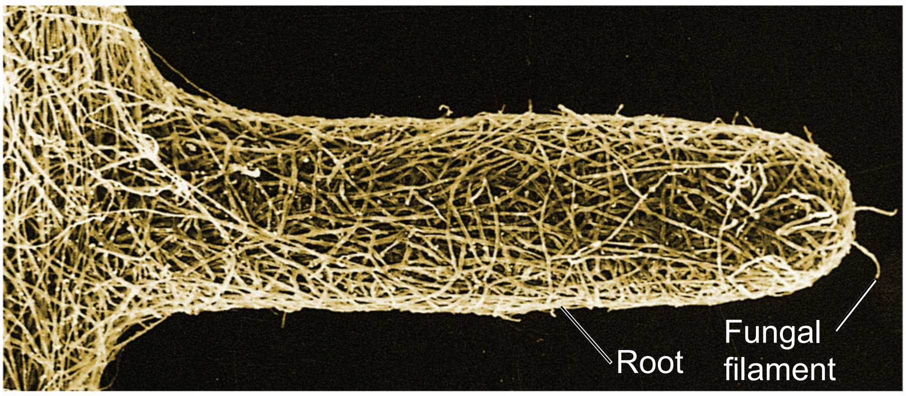
- Soil bacteria can convert N_2 gas from the air into forms usable by plants via several processes.
  - Nitrogen-fixing bacteria convert atmospheric N_2 to ammonia (NH_3) in a process called **nitrogen fixation**.
  - Ammonifying bacteria add to the supply of ammonium by decomposing organic matter.
  - Nitrifying bacteria convert ammonium to nitrates, the form most often taken up by plants.



EVOLUTION CONNECTION: Plants have evolved symbiotic relationships that are mutually beneficial

- Most plants form mutually beneficial symbioses with fungi called **mycorrhizae**, which
  - act like extensions of plant roots, increasing the area for absorption of water and minerals from soil,
  - selectively absorb phosphate and other minerals from the soil,
  - release growth factors and antibiotics into the soil, and
  - have evolved with plants and were important to plants successfully invading land.

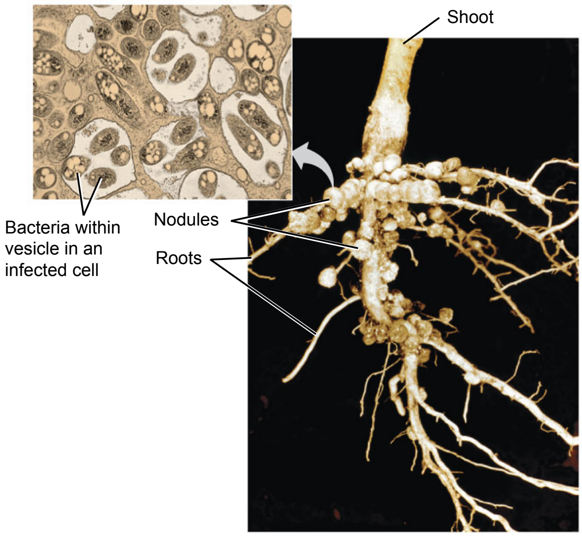
Figure 32.13A



EVOLUTION CONNECTION: Plants have evolved symbiotic relationships that are mutually beneficial

- Some plants form symbioses with nitrogen-fixing bacteria.
  - Legumes (peas, beans, alfalfa, and others) form root nodules to house nitrogen-fixing symbionts in the genus *Rhizobium.*
  - Other plants, such as alders, form symbioses with other kinds of nitrogen-fixing bacteria.
  - Plants that form these associations are rich in nitrogen.
- Mycorrhizae and nitrogen-fixing bacteria benefit by receiving sugars from the plants they colonize.

Figure 32.13B



The plant kingdom includes epiphytes, parasites, and carnivores

- Some plants have nutritional adaptations that take advantage of other organisms.
- Epiphytes, including many orchids,
  - grow anchored on other plants and
  - absorb water and minerals from rain.
- Parasitic plants, such as dodder and mistletoe,
  - may not use photosynthesis,
  - use their roots to tap into the host plant's vascular system, and
  - absorb sugars and minerals from the host plant.

Figure 32.14A

The plant kingdom includes epiphytes, parasites, and carnivores

- Carnivores, such as a sundew plant or Venus flytrap,
  - capture and digest small animals such as insects,
  - absorb inorganic elements from prey, and
  - are found in nutrient-poor environments.