Important Word Roots

Stimuli

- To Spur, incentive

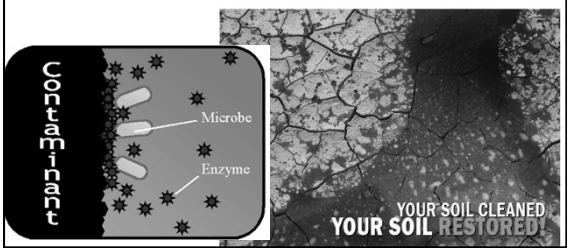
Photo	Thigmo	Gravi	Tropism	Period
• light	• Greek: touch	• Weight/ heavy	**Tropos = turning** ***Tropisms*** *are directed growth responses that cause parts of a plant to grow*	• Latin periodus, Latin < Greek períodos circuit, period of time

Transpiration

- Trans = Across
- Spiration = Breathing
- The passage of water out the top

Biology and Society: Bioremediation

– Bioremediation
- is the use of living organisms to detoxify polluted sites and
- includes phytoremediation, the use of plants to help clean up polluted soil and groundwater.

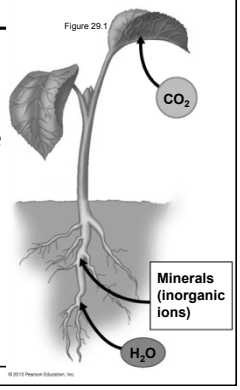


Biology and Society: Planting Hope in the Wake of Disaster

– Sunflowers and other domestic plant species are being used to help clean up after
- the Hurricane Katrina disaster of 2005

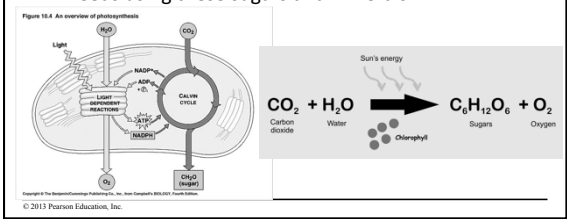
HOW PLANTS ACQUIRE AND TRANSPORT NUTRIENTS

- About 96% of a plant's dry weight is organic material synthesized from inorganic nutrients extracted from the surroundings.
- Plants obtain
  - carbon dioxide (CO_2) from the air at the shoots and
  - water (H_2O) and **minerals** (inorganic ions) from the soil in the roots.



HOW PLANTS ACQUIRE AND TRANSPORT NUTRIENTS

- Plants produce sugars via photosynthesis using
  - CO_2 and
  - H_2O.
- A plant constructs all the other organic materials it needs using these sugars and minerals.



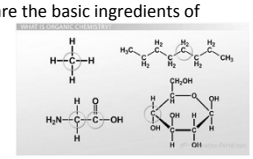
Plant Nutrition

- A plant's **essential elements** are chemical elements,
  - obtained from its environment and
  - needed to complete its life cycle.
- Of the 17 essential elements,
  - 9 are **macronutrients**, required in relatively large amounts,
    - Six of the nine macronutrients, carbon, oxygen, hydrogen, nitrogen, sulfur, and phosphorus, make up almost 98% of a plant's dry weight.
    - The other three macronutrients, calcium, potassium, and magnesium, make up another 1.5% of a plant's dry weight.
  - 8 are **micronutrients**, which plants require in relatively small amounts.

Macronutrients

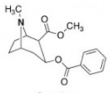
What does a plant do with macronutrients?

- Carbon, oxygen, and hydrogen are the basic ingredients of a plant's organic compounds.

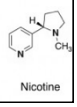


- Nitrogen is a component of
  - all nucleic acids,
  - all proteins,
  - ATP,
  - chlorophyll, and
  - many plant hormones.

Caffeine



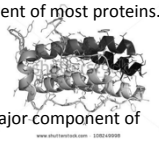
Cocaine

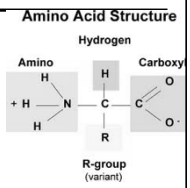


Nicotine

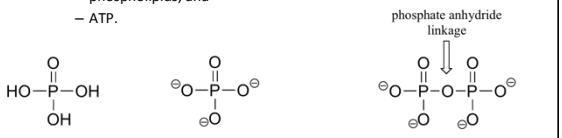
Macronutrients

- Sulfur is a component of most proteins.





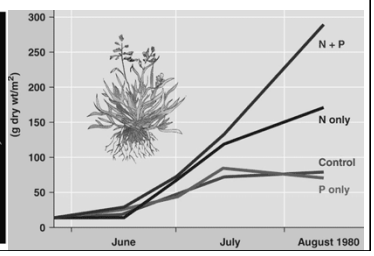
- Phosphorus is a major component of
  - nucleic acids,
  - phospholipids, and
  - ATP.



phosphoric acid inorganic phosphate (P_i) inorganic pyrophosphate (PP_i)

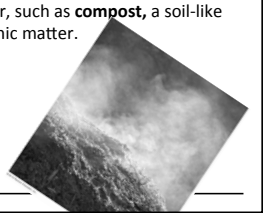
Fertilizers

- The quality of soil affects
  - the health of plants and
  - their nutritional value to organisms that eat them.
- Nitrogen shortage is the most common nutritional problem for plants.



Fertilizers

- **Fertilizers** are compounds given to plants via the soil to promote the plants' growth.
- There are two basic types of fertilizers.
  1. Inorganic fertilizers contain simple, inorganic minerals.
  2. Organic fertilizers are composed of chemically complex organic (carbon based) matter, such as **compost,** a soil-like mixture of decomposed organic matter.



Fertilizers

- **Organic farming**
  - uses compost and other organic fertilizers,
  - uses no (or few) synthetic pesticides,
  - maintains and replenishes soil quality,
  - avoids genetically modified organisms,
  - conserves water, and
  - is one of the fastest-growing segments of agriculture.

From the Soil into the Roots

- A plant uses its roots to absorb water and essential nutrients from the soil.
- Root hairs
  - are extensions of epidermal cells and
  - dramatically increase the surface area available for absorption.

- All substances that enter a plant root are dissolved in water.
- To reach the xylem, the solution must pass through the selectively permeable plasma membranes of root cells.

From the Soil into the Roots

– Many plants form **mycorrhizae**, mutually beneficial associations with fungi that
  - increase the absorptive surface area of the roots and
  - nourish the fungus.

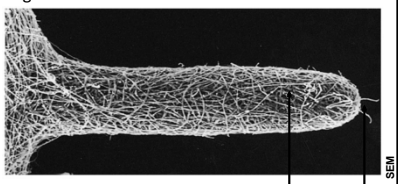
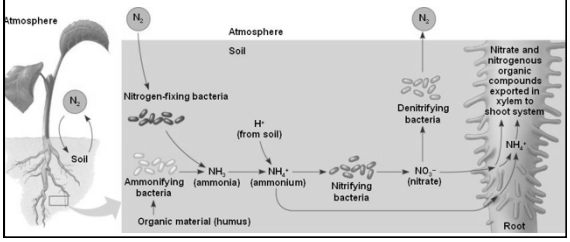


Figure 29.6

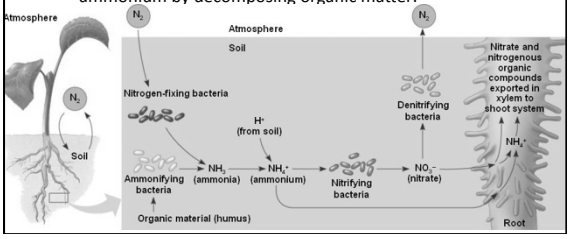
The Role of Bacteria in Nitrogen Nutrition

– Most plants rely on bacteria to supply them with usable nitrogen in the form of
  - ammonium (NH_4^+) or
  - nitrate (NO_3^-).



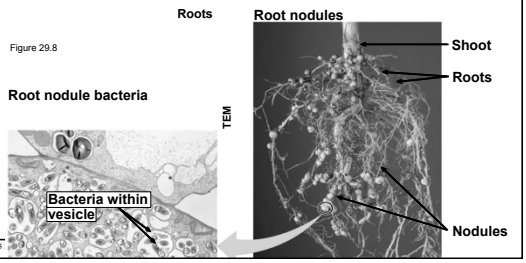
Soil Bacteria and Nitrogen

– Three types of soil bacteria play an essential role in supplying plants with nitrogen.
  1. Nitrogen-fixing bacteria convert atmospheric N_2 to ammonium, a process called **nitrogen fixation**.
  2. Ammonifying bacteria add to the soil's supply of ammonium by decomposing organic matter.



Root Nodule Bacteria and Nitrogen

– Legumes
- include peas, beans, peanuts, and other plants that produce their seeds in pods and
- have their own nitrogen-fixing bacteria in root nodules that produce ammonium.



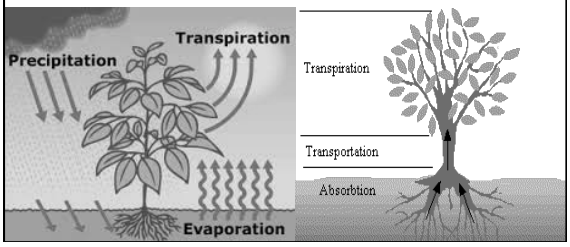
The Transport of Water

– To thrive, a plant must be able to transport
- water and
- dissolved ions from its roots to the rest of the plant.

– **Xylem sap**
- is a solution of water and inorganic nutrients and
- is transported from the roots to the tips of the leaves through vertical xylem tubes.

The Ascent of Xylem Sap

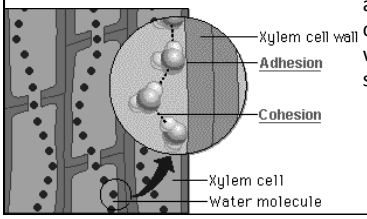
– **Transpiration**, the loss of water vapor from the leaves of a plant by evaporation,
- mostly occurs through the stomata of leaves and
- pulls xylem sap up the plant against gravity.



The Ascent of Xylem Sap

– Transpiration relies on two special properties of water.

1. **Adhesion** is the sticking together of molecules of different kinds.
2. **Cohesion** is the sticking together of molecules of the same kind.



– Together, adhesion and cohesion create a continuous string of water molecules that stick

- to each other and
- to the inside walls of the xylem tubes.

The Ascent of Xylem Sap

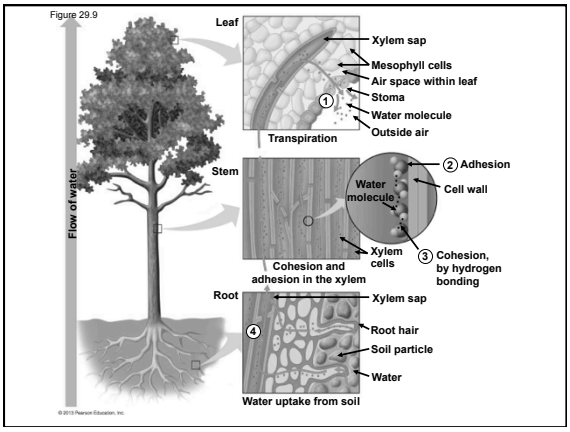
– The ascent of xylem sap is called the **transpiration-cohesion-tension mechanism**.

PLAY Animation: Transpiration

PLAY Animation: Transport in Roots

PLAY BioFlix Animation: Water Transport in Plants

PLAY Animation: Water Transport



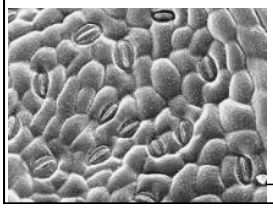
The Regulation of Transpiration by Stomata

– Transpiration
  - helps to distribute water within a plant but
  - can cause plants to lose large amounts of water.

– Plants adjust their transpiration rates to changing environmental conditions.

The Regulation of Transpiration by Stomata

– In many plants, stomata are open during the day, which
  - allows CO_2 to enter the leaf from the atmosphere and
  - keeps photosynthesis going when sunlight is available.
- At night, when there is no light for photosynthesis, and therefore no need for CO_2, many plants close their stomata.
- Stomata are opened and closed by changes in the shape of the two guard cells flanking each stoma.



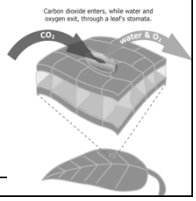
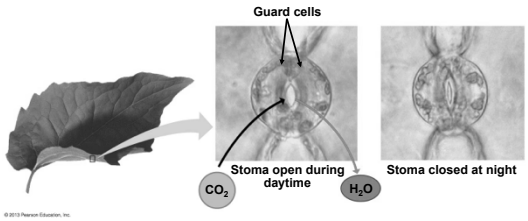
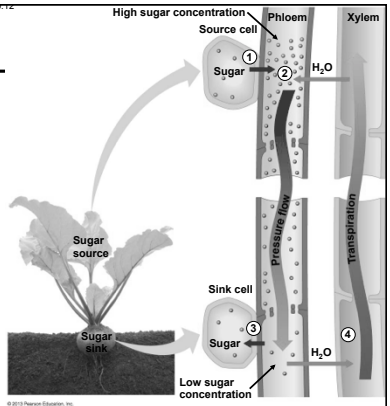


Figure 29.10



The Transport of Sugars

– **Phloem sap** contains
  - inorganic ions,
  - amino acids,
  - hormones, and
  - the disaccharide sugar sucrose a plant makes by photosynthesis.



The Transport of Sugars

– Phloem sap moves in various directions,
  - from a **sugar source,** where sugar is produced,
  - to a **sugar sink**, where sugar is stored or consumed.

– Phloem sap moves from a sugar source to a sugar sink by the **pressure-flow mechanism**.

PLAY Animation: Translocation of Phloem Sap in Spring

PLAY Animation: Translocation of Phloem Sap in Summer

Figure 29.11

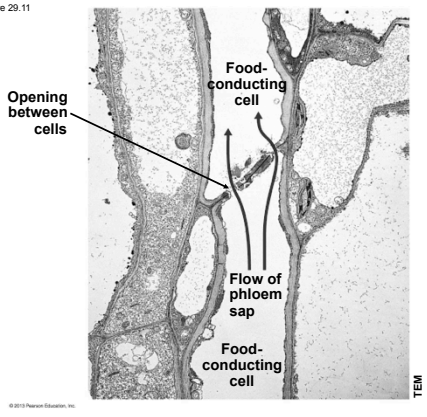


Figure 29.12a

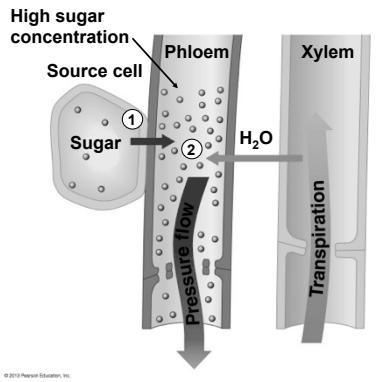
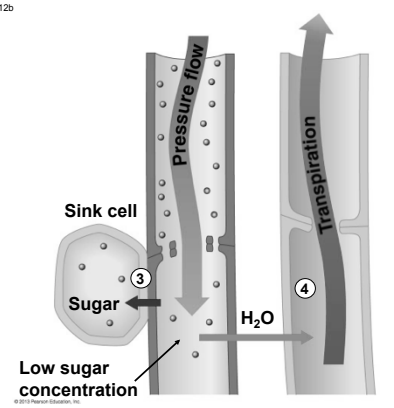


Figure 29.12b



RESPONSE TO STIMULI

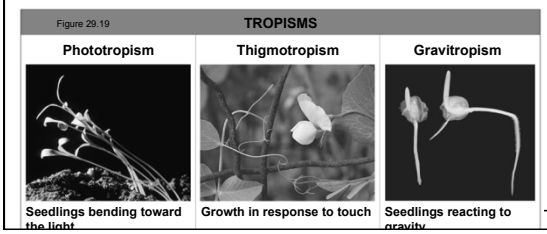
– Plants can respond to physical stimuli from the environment, including
- light,
- touch, and
- gravity.

Tropisms

– **Tropisms** are directed growth responses that cause parts of a plant to grow
  - toward or
  - away from a stimulus.

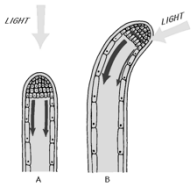
– Phototropism is the directional growth of a plant shoot in response to light.

Figure 29.19 TROPISMS



Tropisms

– **Phototropism**
  - is a response to light
  - Works by lengthening cells on the shaded side



PLAY Video: Mimosa Leaf

PLAY Video: Sun Dew Trapping Prey

Figure 29.19a

Phototropism

Seedlings bending toward the light

Tropisms

– **Thigmotropism**
  - is a response to touch and
  - occurs when a pea plant tendril coils around a string or wire it touches for support.

PLAY Video: Mimosa Leaf

PLAY Video: Sun Dew Trapping Prey

Figure 29.19b

Thigmotropism

Growth in response to touch

Tropisms

– **Gravitropism**
  - is the directional growth of a plant organ in response to gravity and
  - occurs when
    – shoots grow upward and
    – roots grow downward.

Figure 29.19c

Gravitropism

Seedlings reacting to gravity

PLAY Video: Gravitropism

Photoperiod

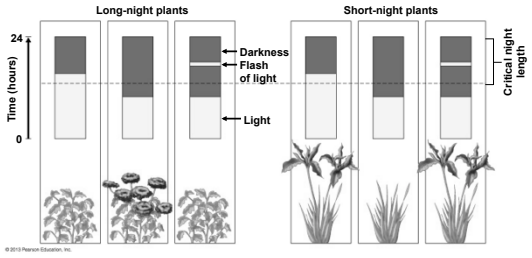
– Light
  - provides energy for photosynthesis,
  - directs growth, and
  - regulates a plant's life cycle, including
    – flowering,
    – seed germination, and
    – the onset and ending of dormancy.

– Florists apply knowledge of the photoperiod of particular plants to bring us flowers out of season.

– A **photoperiod**
  - is the relative lengths of day and night and
  - the environmental stimulus that plants most often use to detect the time of year.

– Plants whose flowering is triggered by photoperiod fall into two groups:
  1. long-night plants and
  2. short-night plants.

Figure 29.20



PLANT HORMONES

- A **hormone** is a chemical signal that
  - is produced in one part of an organism,
  - is transported to other parts, and
  - acts on target cells to change their functions.
- Hormones in plants control growth and development by affecting the
  - division,
  - elongation, and
  - differentiation of cells.
- Plant biologists have identified five major types of plant hormones.

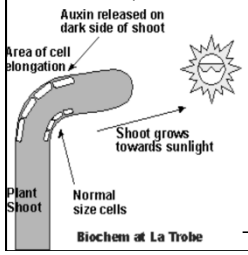
Table 29.1

Table 29.1 Major Types of Plant Hormones

Hormone	Major Functions	Where Produced or Found in Plant
Auxins	Stimulate stem elongation; affect root growth, differentiation, and branching; stimulate development of fruit, apical dominance, phototropism, and gravitropism	Meristems of apical buds, young leaves, embryos within seeds
Ethylene	Promotes fruit ripening; opposes some auxin effects; promotes or inhibits growth and development of roots, leaves, and flowers, depending on species	Ripening fruit, nodes of stems, aging leaves and flowers
Cytokinins	Affect root growth and differentiation; stimulate cell division and growth; stimulate germination; delay aging	Made in roots and transported to other organs
Gibberellins	Promote seed germination, bud development, stem elongation, and leaf growth; stimulate flowering and fruit development; affect root growth and differentiation	Meristems of apical buds and roots, young leaves, embryos
Abscisic acid	Inhibits growth; closes stomata when water is scarce; helps maintain dormancy	Leaves, stems, roots, green fruit

Auxins

- **Auxins**
  - are a group of related hormones and
  - are responsible for a wide range of growth and development effects in plants.



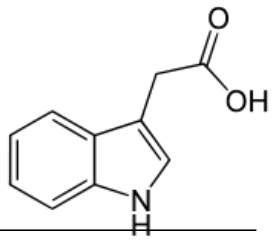
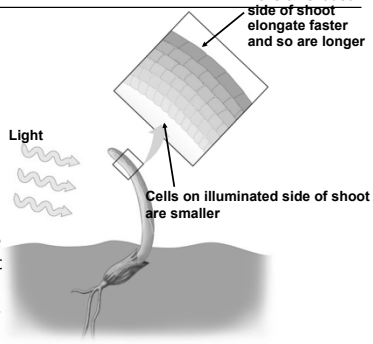


Figure 29.14
Phototropism and Cell Elongation

- **Phototropism**
  - is the directional growth of a plant shoot in response to light and
  - is caused by the elongation of cells on the side of the stem that gets the least amount of light.



PL

Figure 29.13

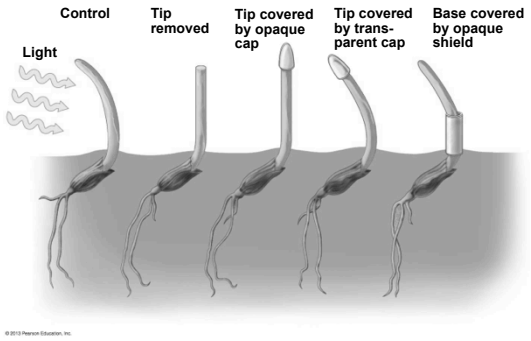
The Process of Science:
Do Chemical Signals Affect Plant Growth?

- Charles Darwin and his son Francis performed some of the earliest experiments on phototropism.
- **Observation**: Grass seedlings bend toward light only if the tips of their shoots are present.
- **Question:** Do the tips of the seedlings produce some kind of growth signal?

The Process of Science: Do Chemical Signals Affect Plant Growth?

- **Hypothesis**: Plant tips sensed light and produced a growth signal in response.
- **Prediction**: Removing a shoot tip or blocking its access to light will prevent phototropism.
- **Experiments**: The Darwins performed several experiments to test their hypotheses.

Figure 29.15



The Process of Science: Do Chemical Signals Affect Plant Growth?

- **Results:**
  - Growth toward light was prevented by
    - removing the tip of a grass shoot or
    - preventing the cap of a shoot from receiving light.
  - Growth toward light occurred when placing
    - a transparent cap on the tip of a grass shoot or
    - an opaque shield around its base.

The Process of Science:
Do Chemical Signals Affect Plant Growth?

– **Conclusions**:
- The tip of the shoot was responsible for sensing light.
- The growth response, the bending of the shoot, occurred below the tip.
- Some unknown growth signal was transmitted downward from the tip to the growing region of the shoot.

The Action of Auxins

– The hormones responsible for the phototropism observed by the Darwins are auxins produced by the apical meristem at the tip of the shoot.
– An uneven distribution of auxin on each side of a shoot causes
- higher auxin concentrations in the cells on the dark side,
- cells on the dark side to elongate, and
- the shoot to bend.

The Action of Auxins

– Auxins demonstrate that
- different concentrations of the same hormone may have different effects in the same target cell and
- the same concentration of a hormone may have different effects on different target cells.

The Action of Auxins

– The use of synthetic plant hormones allows more food to be produced at lower cost.
– One widely used herbicide is a weed killer that
  • is a synthetic auxin that disrupts the normal balance of hormones that regulate plant growth and
  • affects monocots more than dicots.

Figure 29.16 Ethyle

– **Ethylene** is a hormone that is released as a gas that triggers a variety of aging responses in plants, including
  • fruit ripening and
  • dropping of leaves.

Banana alone

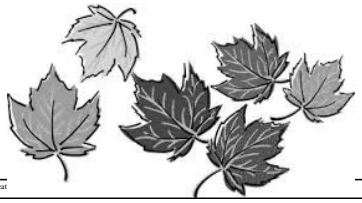
Banana plus ethylene-releasing peach

Fruit Ripening

– Fruit ripening is
  • triggered by a burst of ethylene production in the fruit and
  • spread from fruit to fruit by ethylene gas.
– Some fruits ripen faster if stored with ripe fruit in a bag that accumulates ethylene gas.
– Stored apples are often flushed with CO_2, which inhibits the action of ethylene.

Leaf Drop

– The loss of leaves in autumn is affected by ethylene.
– Leaf drop is triggered by environmental stimuli that
  • cause a change in the balance of ethylene and auxin and
  • weaken cell walls in a layer of cells at the base of the leaf stalk.

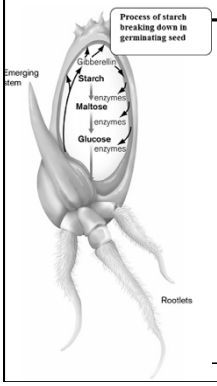


Cytokinins

– **Cytokinins**
  • are a group of closely related hormones that act as growth regulators that promote cell division,
  • are produced in actively growing tissues, and
  • counter the inhibitory effects of auxin, resulting in complex growth patterns in most plants.

Key Concept
Cytokinins = More Mitosis
More Mitosis = More Cells
More Cells = Plant Growth

Gibberellins



– **Gibberellins**
  • are growth-regulating plant hormones and
  • stimulate cell elongation and division in stems and leaves.

Gibberellins

– A combination of gibberellins and auxins can
  - influence fruit development,
  - make apples, currants, and eggplants develop without pollination and seed production, and
  - make seedless grapes grow larger and farther apart in a cluster.

Figure 29.17

Abscisic Acid

– **Abscisic acid**
  - slows growth and
  - can inhibit seed germination, allowing seeds to go dormant.

– Some desert plants remain dormant until a downpour of rain
  - washes out abscisic acid and
  - allows the seeds to germinate when water is available.

Evolution Connection:
Plants, Mantises, and People

- Plants rely on organisms from two other kingdoms to help acquire nutrients:
  1. soil bacteria and
  2. the fungi of mycorrhizae.
- Nearly all land animals depend on plants or animals that ate plants for food.
- Consider the African mega mantis on the cover of the textbook.
  - The mantis depends on protists, plants, and animals for food.
  - In turn, the mantis is eaten by other animals.