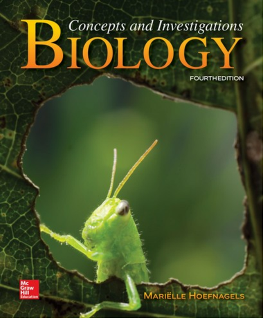

Chapter 23

Plant Nutrition and Transport

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Plants require 16 essential elements

All plants require several nutrients to stay healthy.

These plants have nutrient deficiencies.


a.


b.

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Figure 23.2

16 essential elements

Essential elements are required for metabolism, growth, and reproduction.

a. b.

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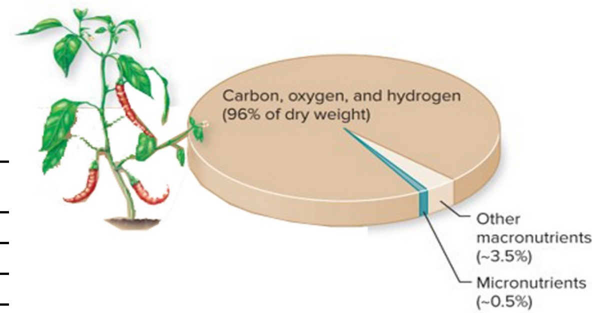


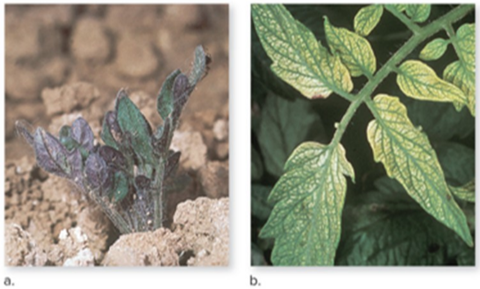
Macronutrients	Form Taken Up by Plants	Percent Dry Weight	Selected Functions
Carbon (C)		45	Part of organic compounds
Oxygen (O)	, ,	45	Part of organic compounds
Hydrogen (H)		6	Part of organic compounds
Nitrogen (N)		1.5	Part of nucleic acids, amino acids, coenzymes, chlorophyll, ATP
Potassium (K)		1.0	Controls opening and closing of stomata, activates enzymes
Calcium (Ca)		0.5	Cell wall component, activates enzymes, second messenger in signal transduction, maintains membranes
Magnesium (Mg)		0.2	Part of chlorophyll, activates enzymes, participates in protein synthesis
Phosphorus (P)	,	0.2	Part of nucleic acids, sugar phosphates, ATP, coenzymes, phospholipids
Sulfur (S)		0.1	Part of cysteine and methionine (amino acids), coenzyme A

Micronutrients	Form Taken Up by Plants	Percent Dry Weight	Selected Functions
Chlorine (Cl)		0.01	Water balance
Iron (Fe)	,	0.01	Chlorophyll synthesis, cofactor for enzymes, part of electron carriers
Boron (B)		0.002	Growth of pollen tubes, sugar transport, regulates certain enzymes
Zinc (Zn)		0.002	Hormone synthesis, activates enzymes, stabilizes ribosomes
Manganese (Mn)		0.005	Activates enzymes, electron transfer, photosynthesis
Copper (Cu)		0.0006	Part of plastid pigments, lignin synthesis, activates enzymes
Molybdenum (Mo)		0.00001	Nitrate reduction

Figures 23.1, 23.2

Essential elements: macronutrients

Macronutrients are required in large amounts. Carbon, oxygen, and hydrogen are the most abundant macronutrients.



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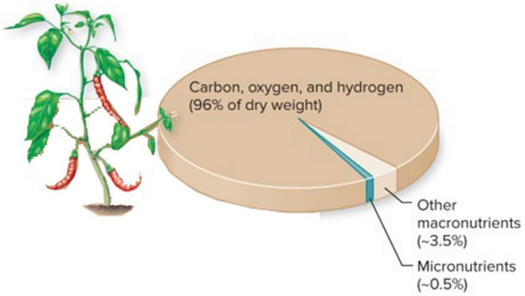

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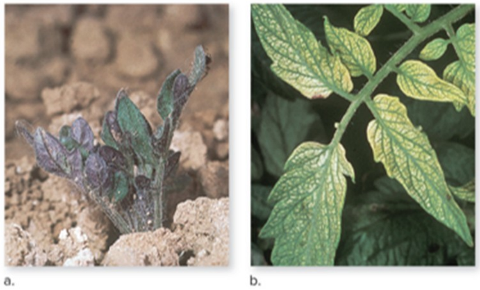
Manganese (Mn)		0.005	Activates enzymes, electron transfer, photosynthesis
Copper (Cu)		0.0006	Part of plastid pigments, lignin synthesis, activates enzymes
Molybdenum (Mo)		0.00001	Nitrate reduction

Figures 23.1, 23.2

Essential elements: micronutrients

Micronutrients are required in much smaller amounts.



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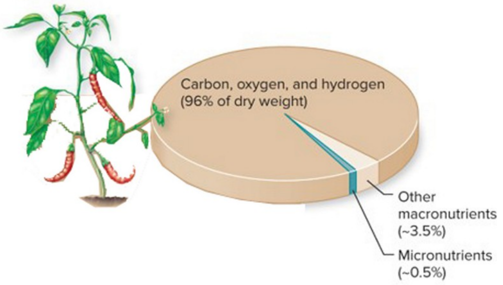

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Copper (Cu)		0.0006	Part of plastid pigments, lignin synthesis, activates enzymes
Molybdenum (Mo)		0.00001	Nitrate reduction

Section 23.1

Figures 23.1, 23.2

Soil

Plant roots absorb nutrients from the soil.

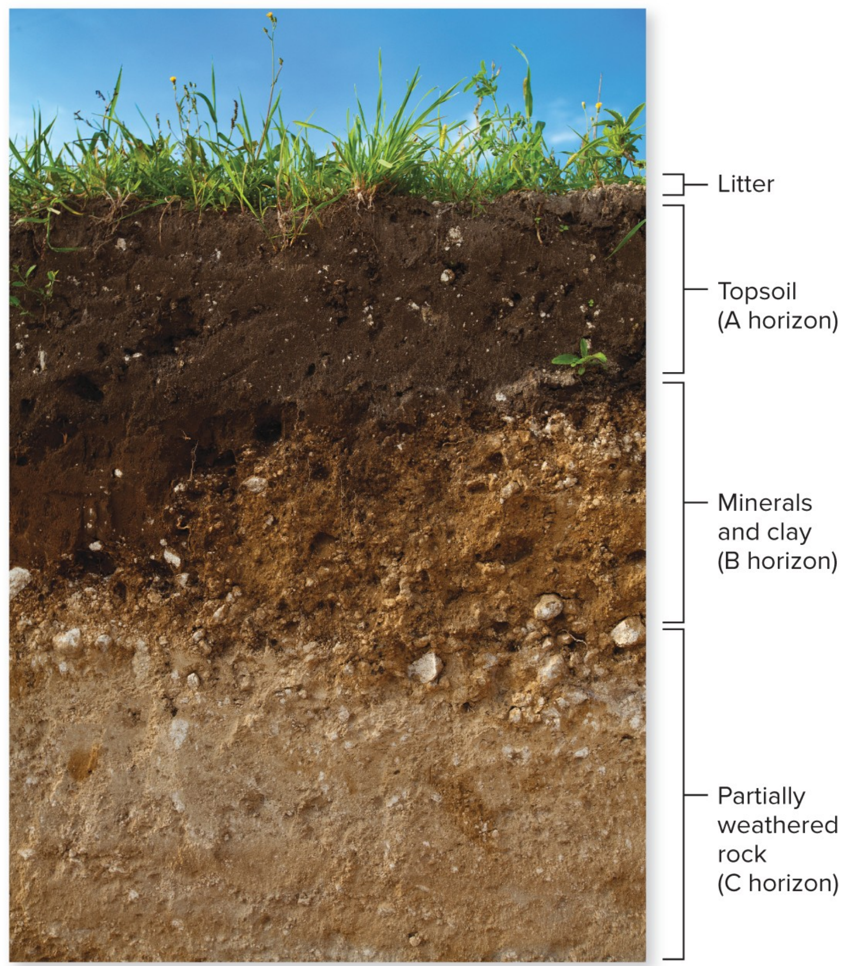

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Figure 23.3

What is soil?

Soil is a complex mixture of rock particles, organic matter, air, and water.

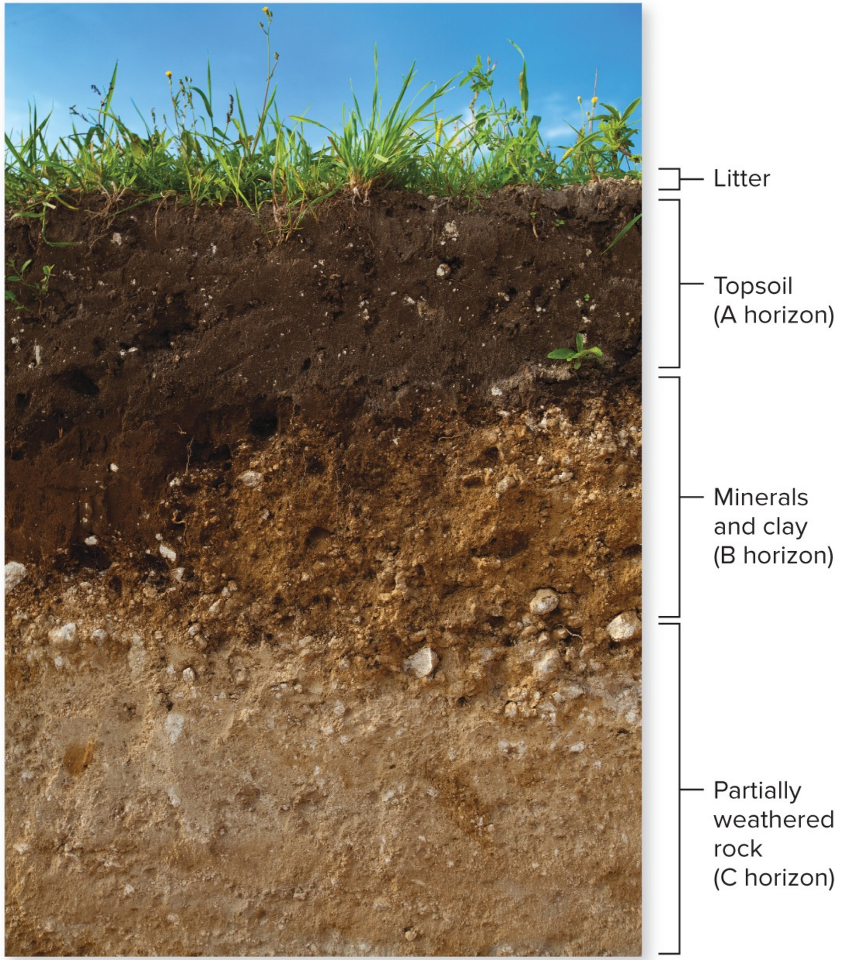

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Figure 23.3

Soil is home to many organisms

Many organisms live in the soil, decomposing organic matter and releasing inorganic nutrients.

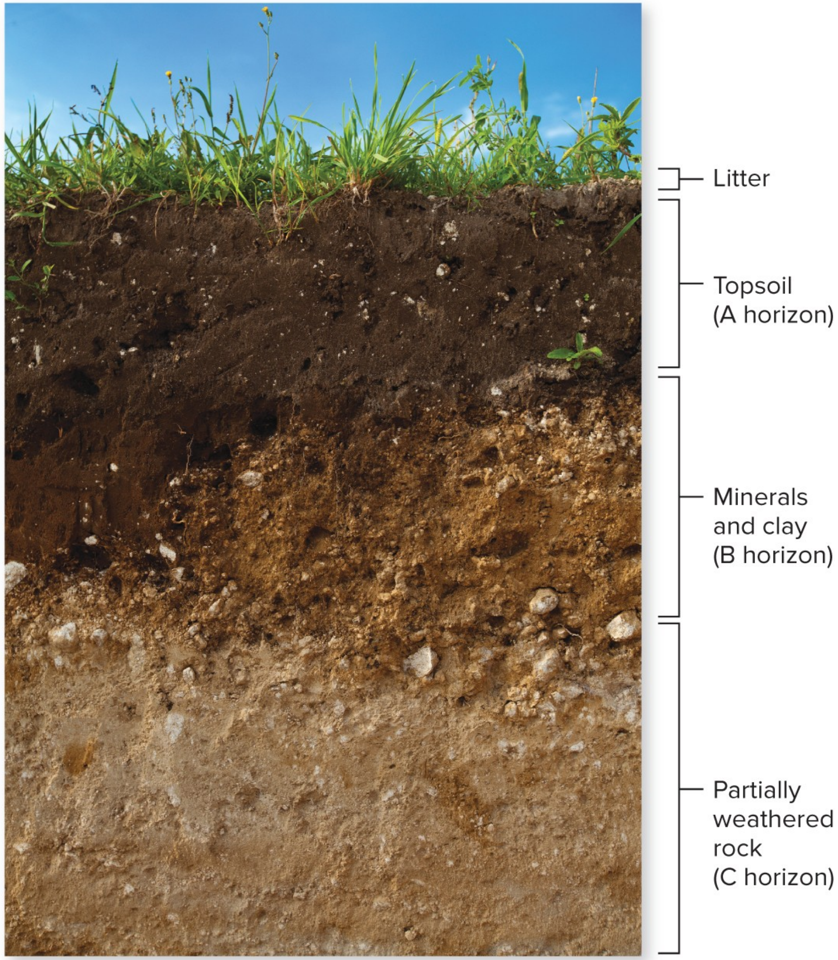

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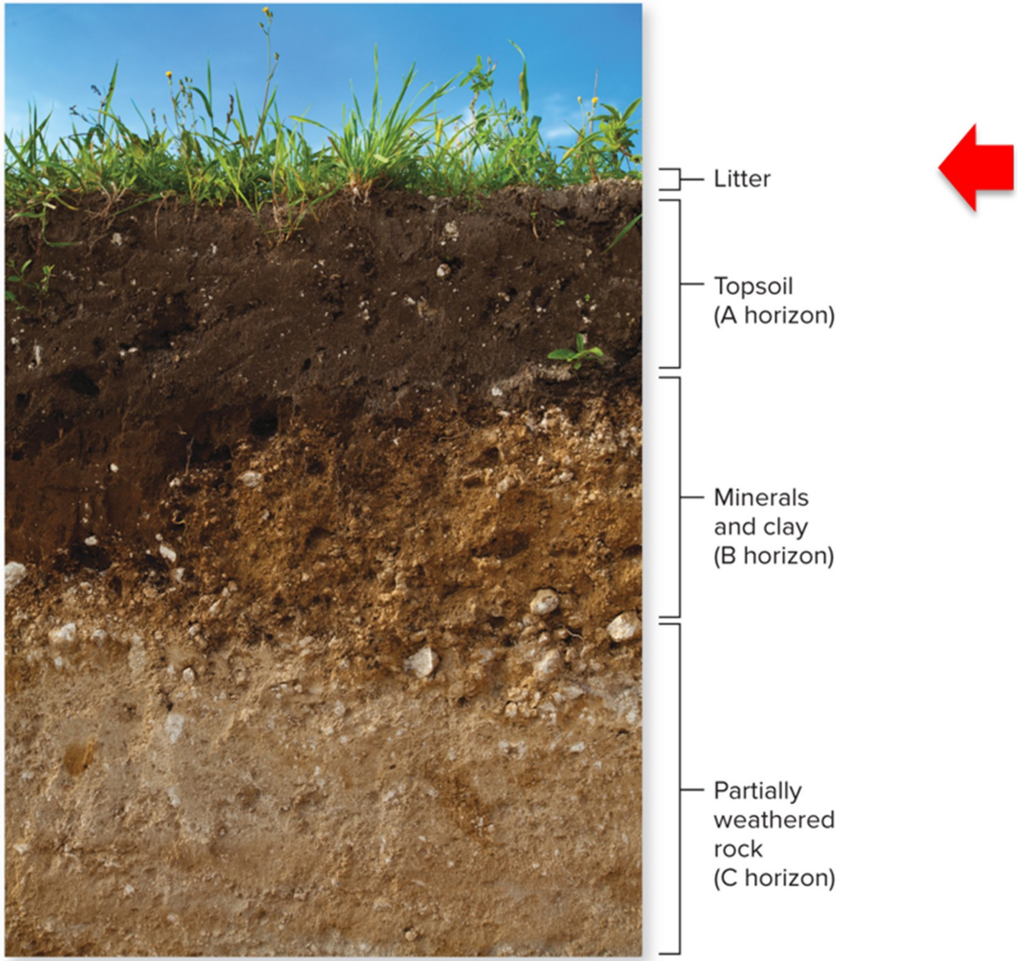
Figure 23.3

Soil layers: litter

Lying on the soil's surface is litter, which consists of decomposing leaves and stems.



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Soil layers: humus

As microbes decompose the litter, carbon dioxide is released into the atmosphere. The carbon that remains in the soil forms a layer of soil called **humus**.

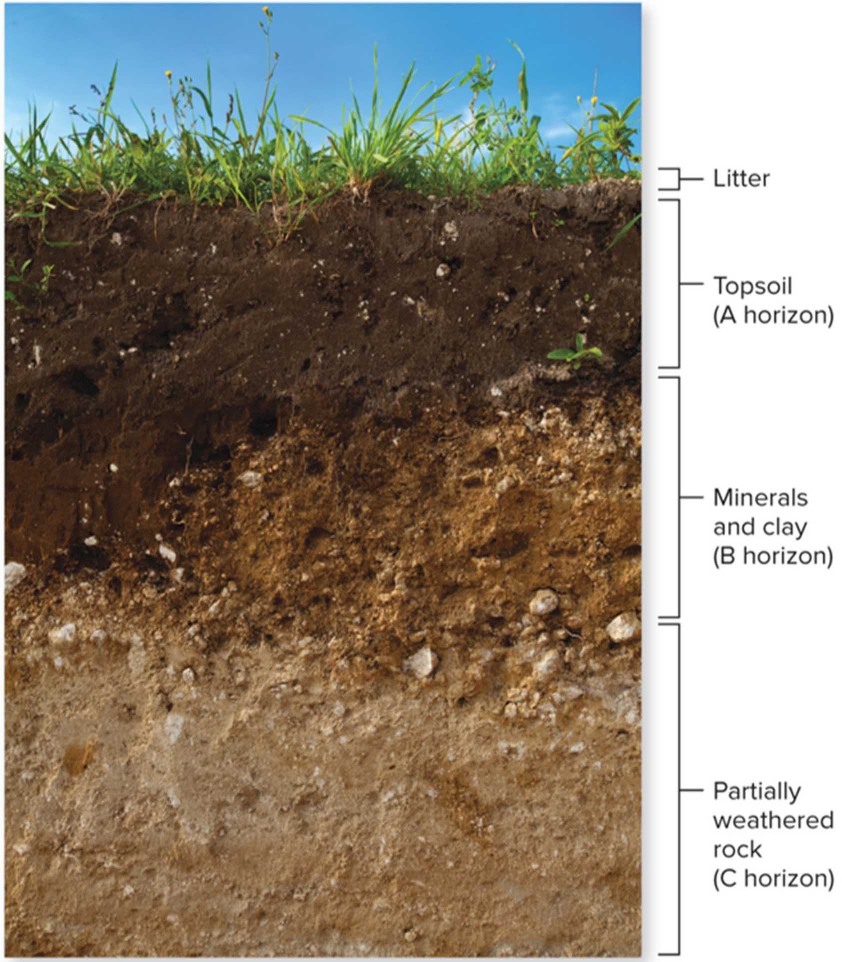

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Figure 23.3

Soil layers: A horizon

Most humus is in the **topsoil** (the A horizon). This layer of soil also supplies most of a plant's water and nutrients. Plant roots stabilize the topsoil, helping to prevent **erosion**.

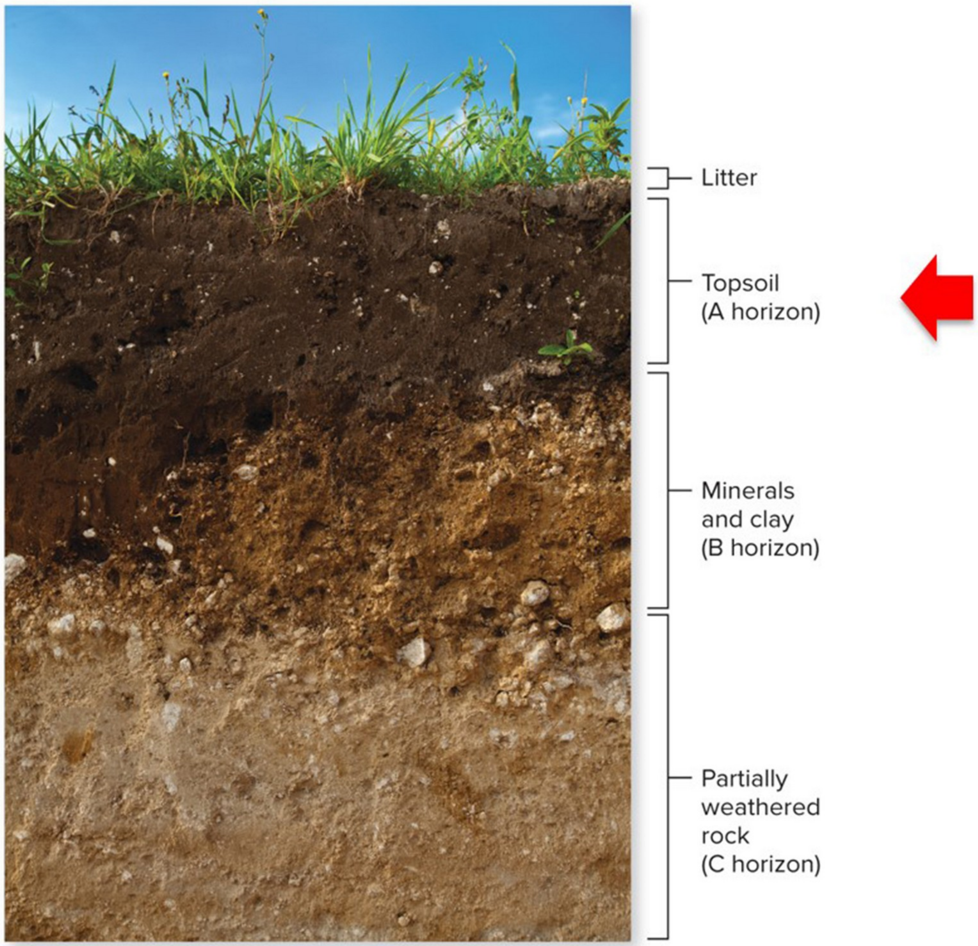

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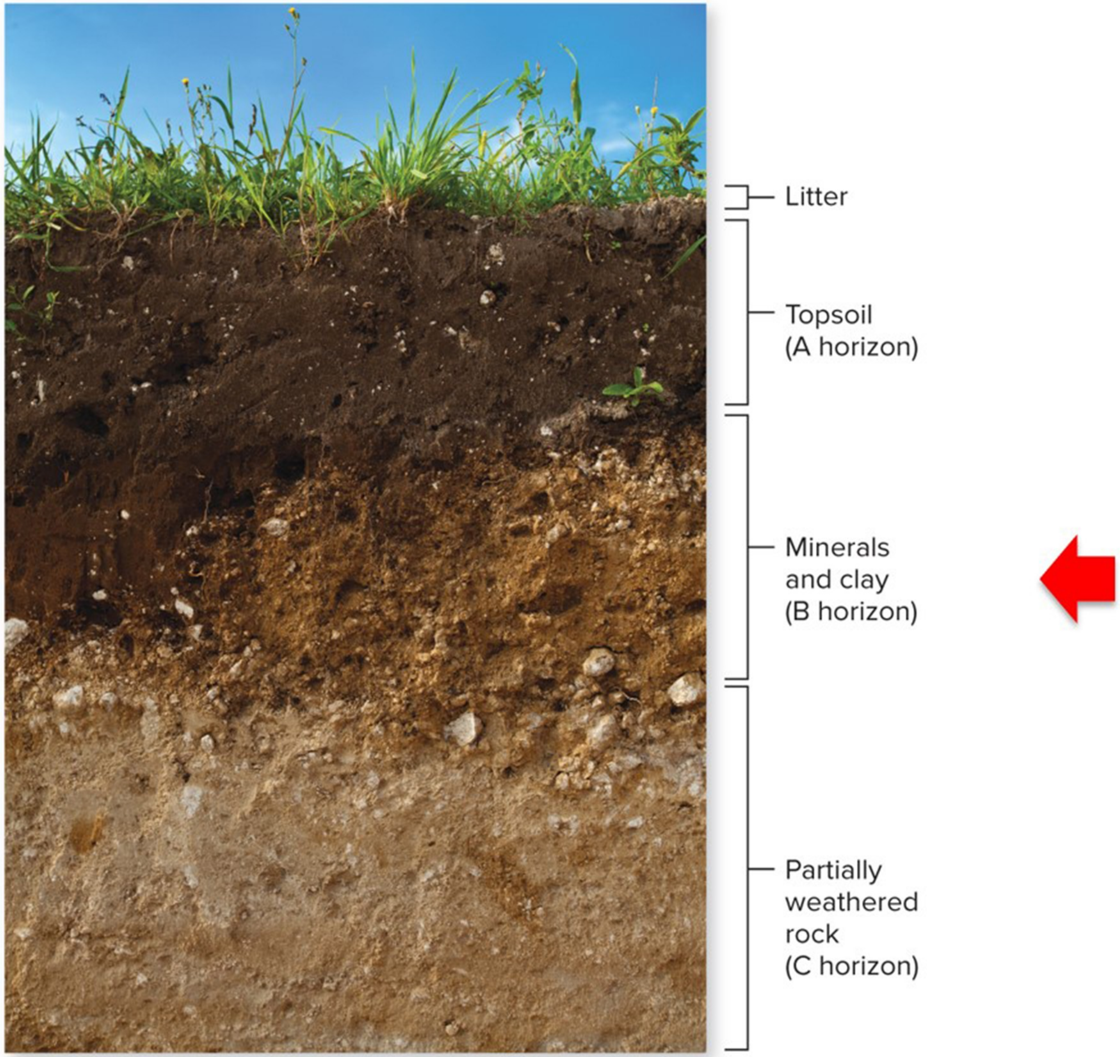
Figure 23.3

Soil layers: B horizon

Below the topsoil is the B horizon, which has less organic matter. Roots extend into the B horizon.



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Section 23.1

Figure 23.3

Soil layers: C horizon

The C horizon mostly has weathered rocks.

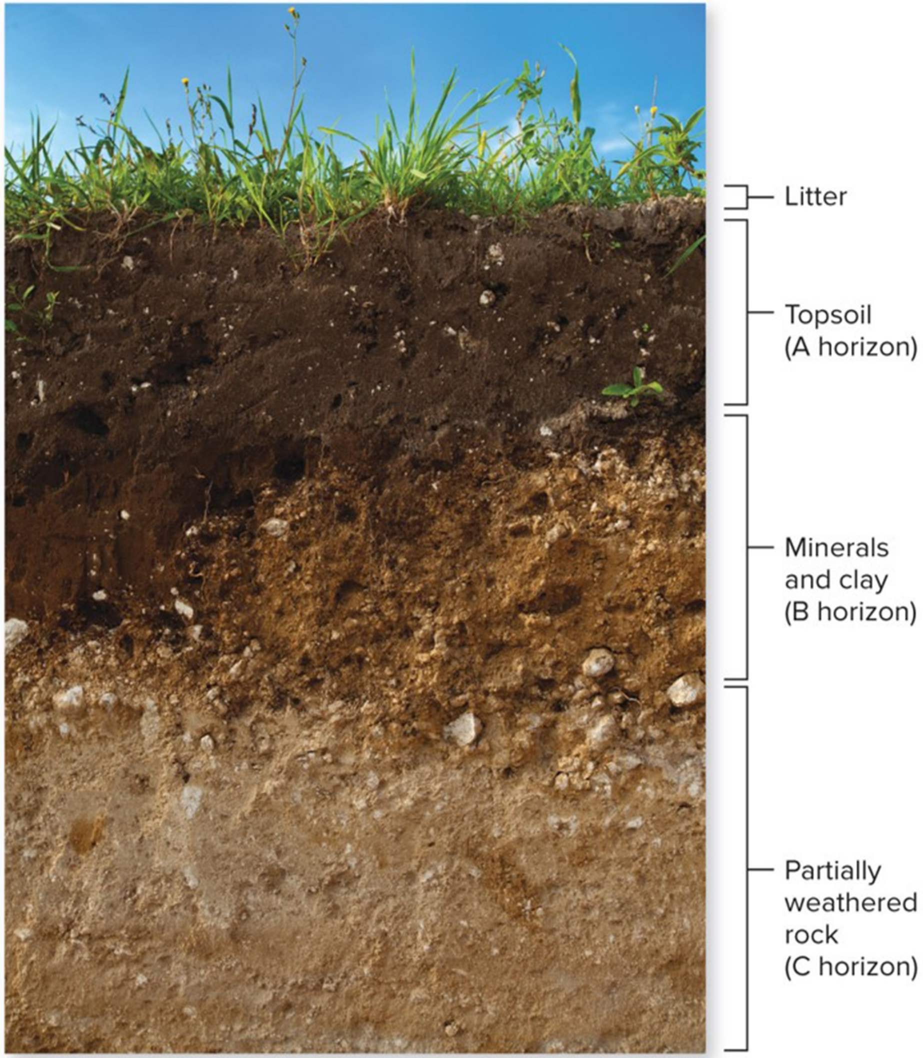

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Figure 23.3

Soil layers: bedrock

Below the C horizon is bedrock.

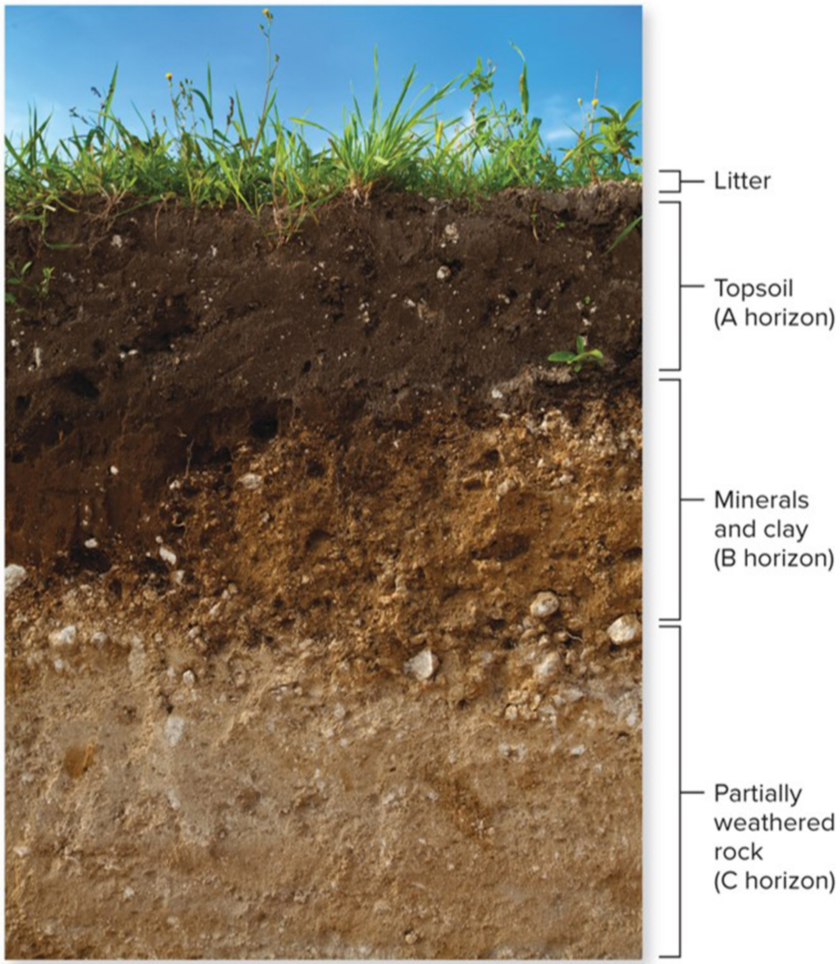

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Figure 23.3

Plants obtain nutrients from soil and air

Symbiotic relationships with **nitrogen-fixing** bacteria help plants obtain useful forms of nitrogen.

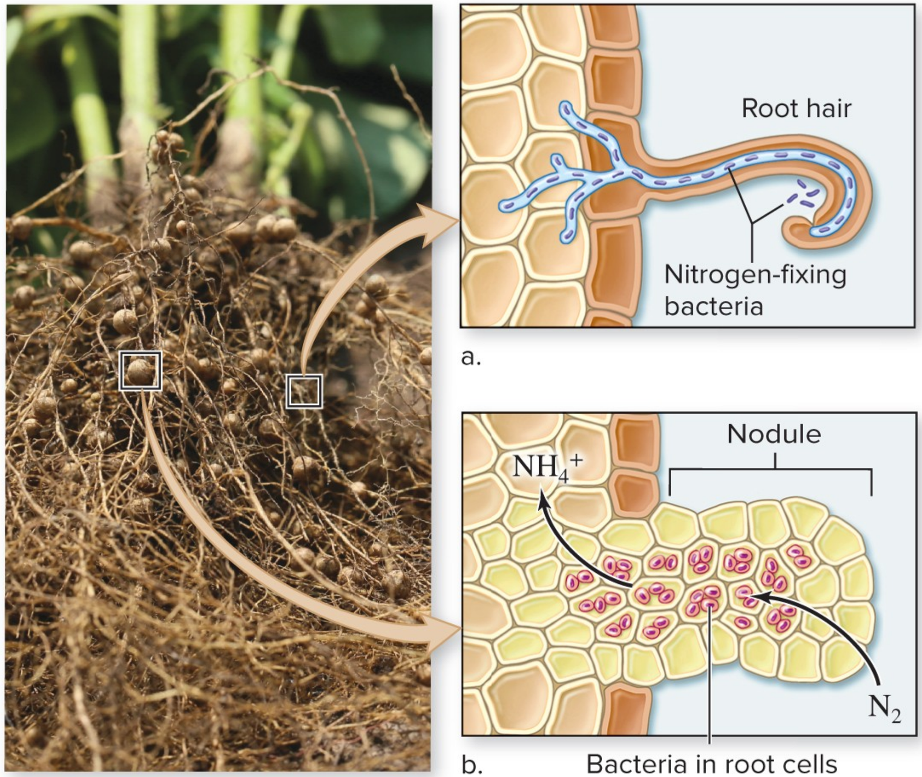

Figure 23.4

How plants obtain nutrients: nodules

Some nitrogen-fixing bacteria live in growths called **nodules** on the roots of plants.

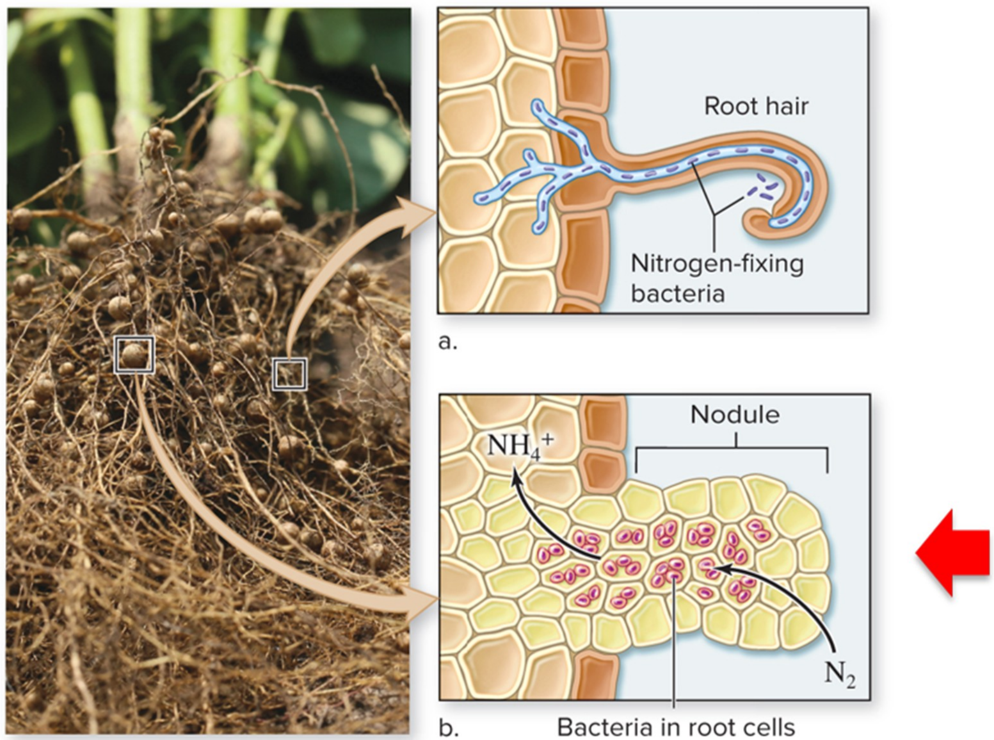

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Figure 23.4

How plants obtain nutrients: roots

Plants take up other nutrients through their roots as well. These nutrients dissolve in the soil's water and move into the plant as it absorbs water.

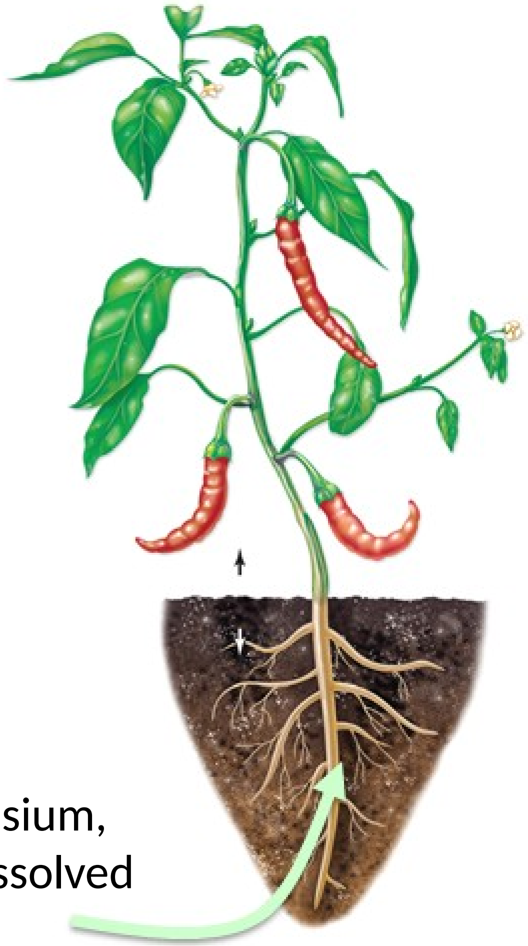


Figure 23.5

How plants obtain nutrients: gas exchange

Plants obtain carbon and oxygen from the atmosphere, in the form of .

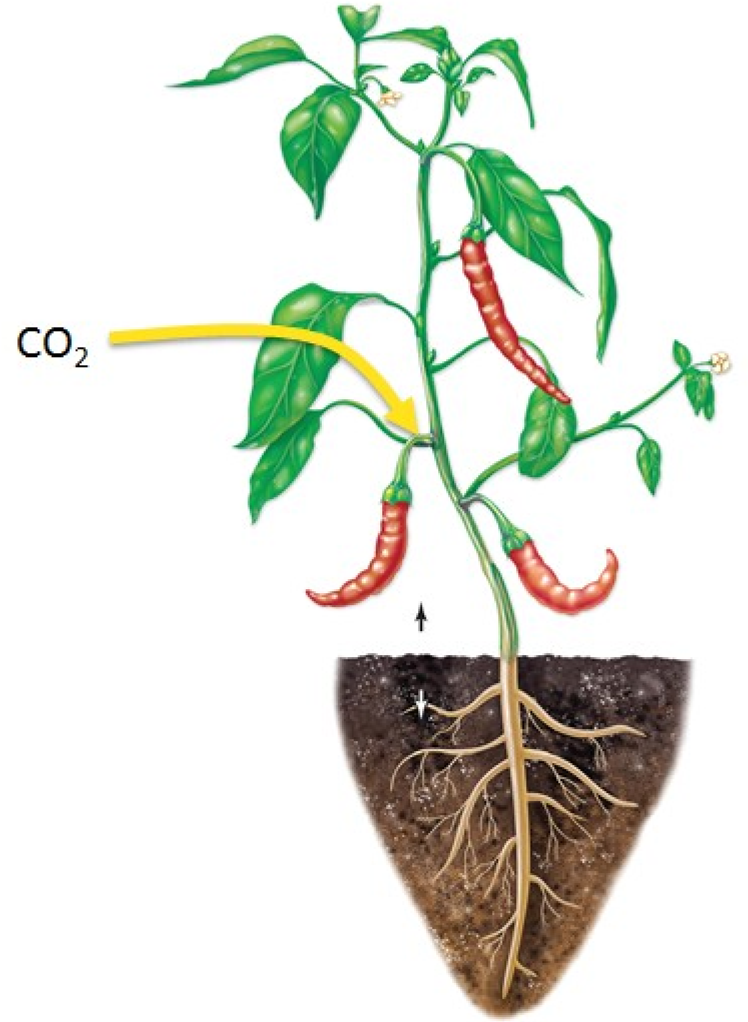
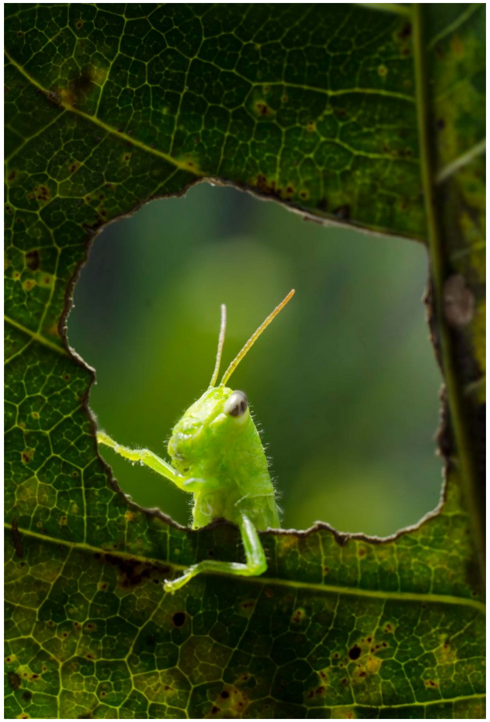


Figure 23.5

Clicker question #1



Plants require abundant carbon and nitrogen. These elements occur in some of the same organic molecules, including:

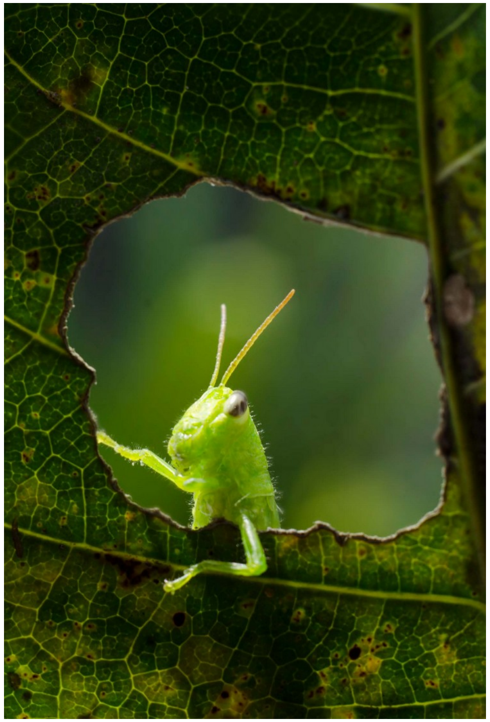
A. proteins.
B. ATP.
C. DNA.
D. sugar.
E. Proteins, ATP, and DNA are all correct.

Clicker question #1, solution

Plants require abundant carbon and nitrogen. These elements occur in some of the same organic molecules, including:

E. Proteins, ATP, and DNA are all correct.

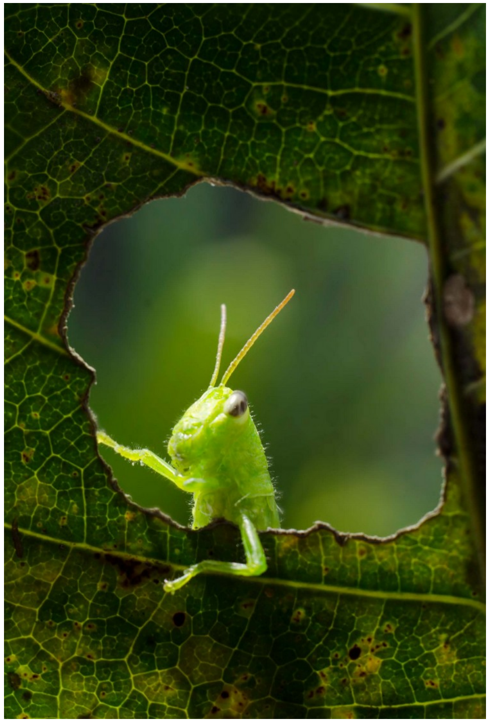
Clicker question #2



Plants extract the most nutrients from this layer of soil.

A. A horizon
B. B horizon
C. C horizon
D. bedrock

Clicker question #2, solution



Plants extract the most nutrients from this layer of soil.

A. A horizon

21.1 Mastering concepts

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Which macro- and micronutrients do all plants require?

Vascular tissue transports substances

Vascular tissue forms the transportation system that connects plant parts.

Xylem and phloem function different ways.

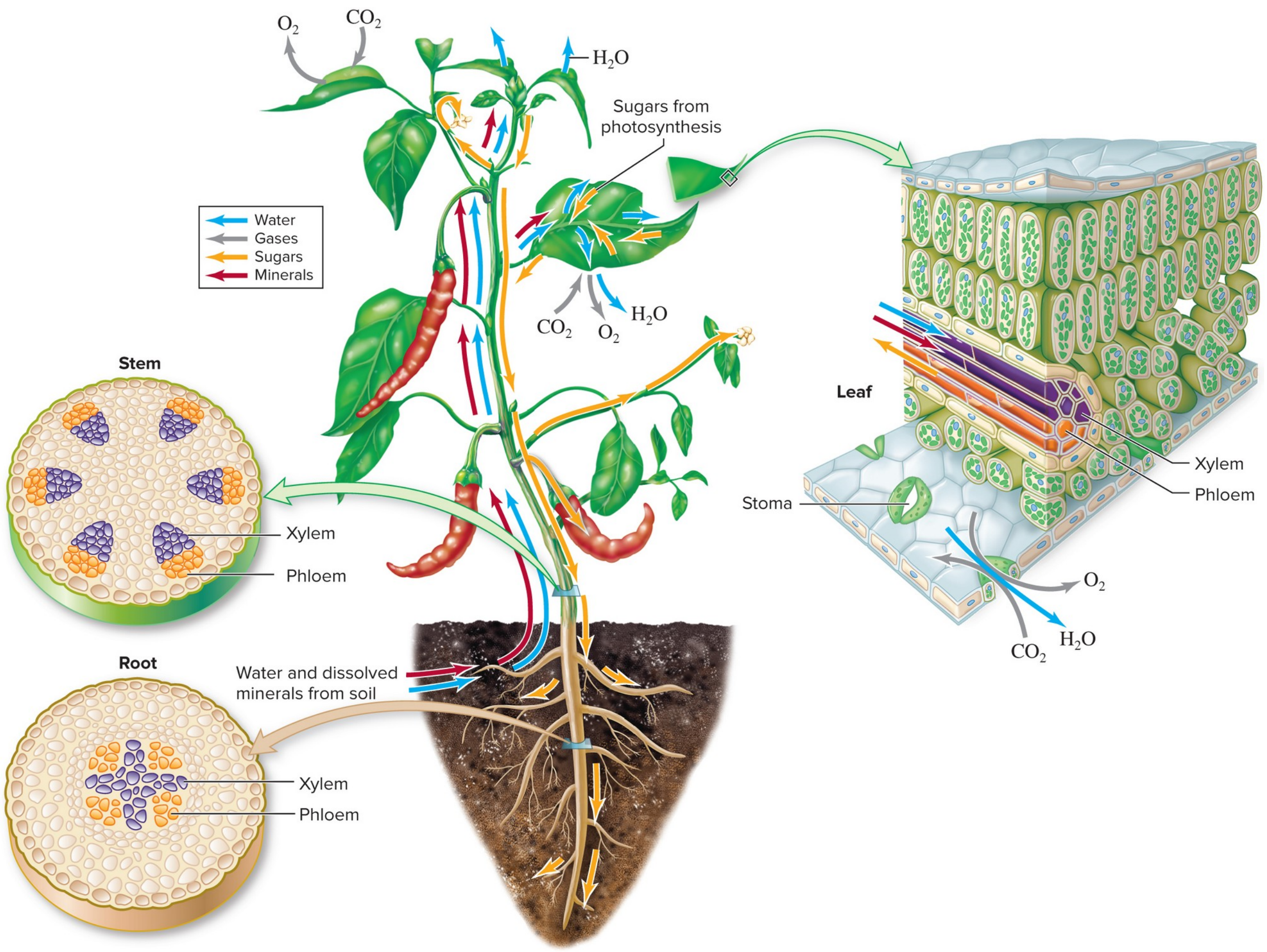


Figure 23.5

Vascular tissue transport: xylem

First, let's look at how water and minerals are pulled up to leaves in **xylem**.

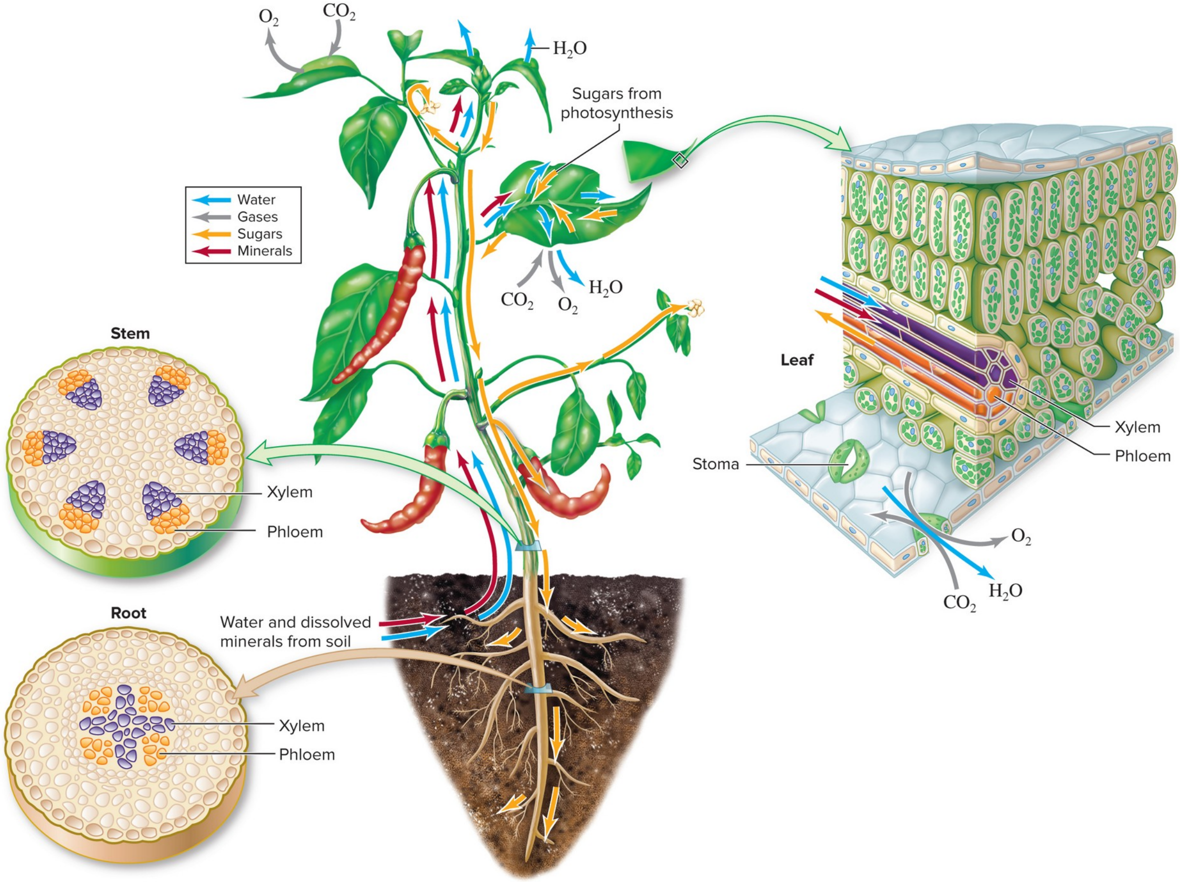
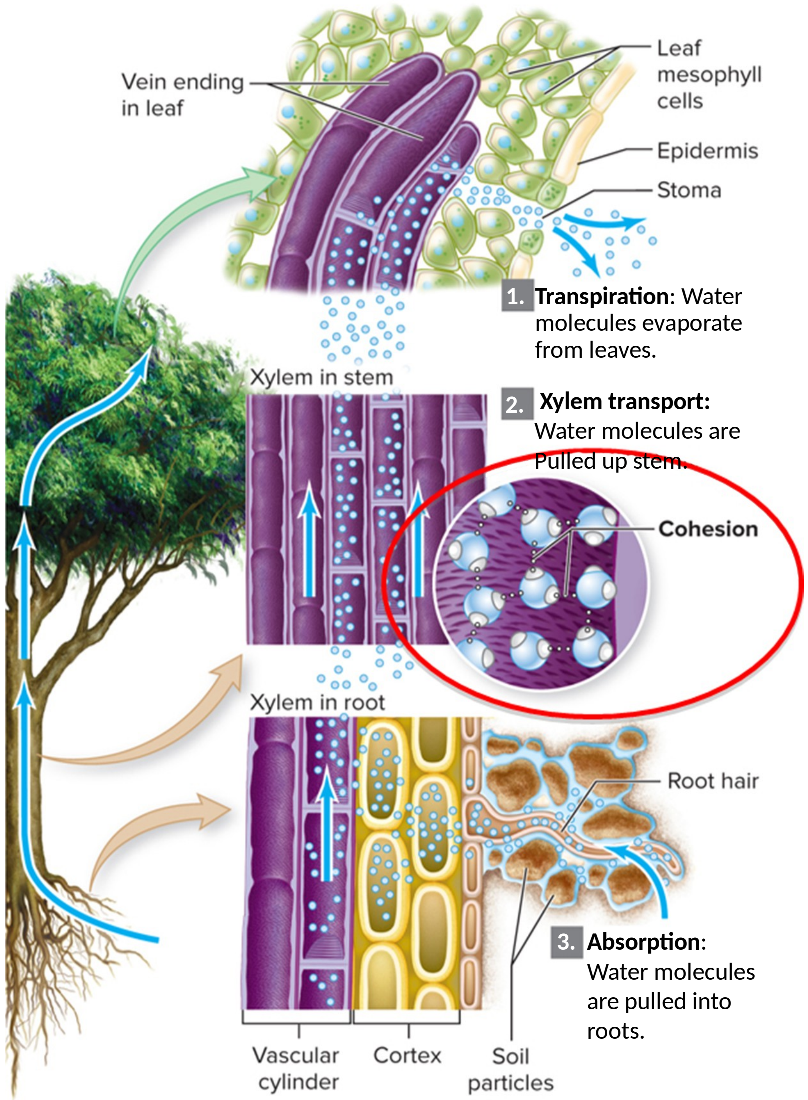


Figure 23.5

Xylem transports water and minerals

Xylem transport is explained by **cohesion-tension theory**. Cohesion is the tendency for water molecules to form hydrogen bonds with one another.



Section 23.2

Figure 23.7

Xylem and water transport: transpiration

Because of cohesion, when water evaporates from the leaves, in a process called **transpiration**, it pulls adjacent molecules closer to the stomata.

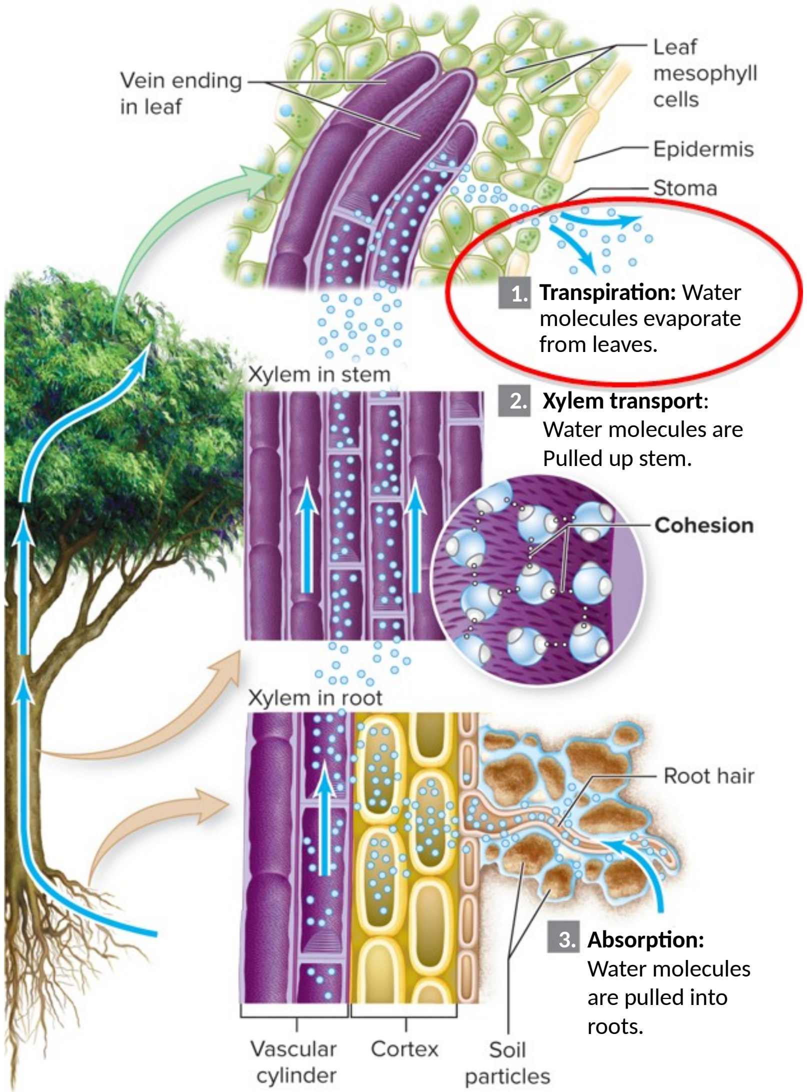


Figure 23.7

Xylem and water transport: diffusion

As the concentration of water within the mesophyll decreases, water molecules diffuse out of nearby veins. Those molecules, in turn, pull neighboring water molecules up the xylem.

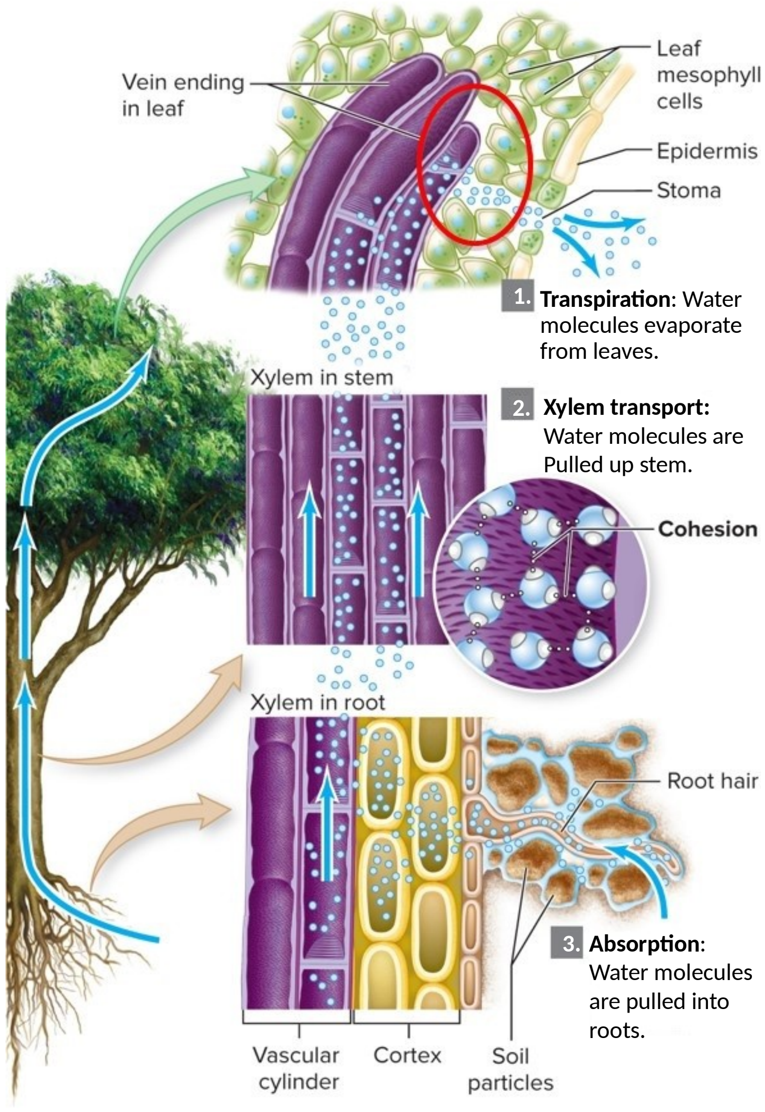
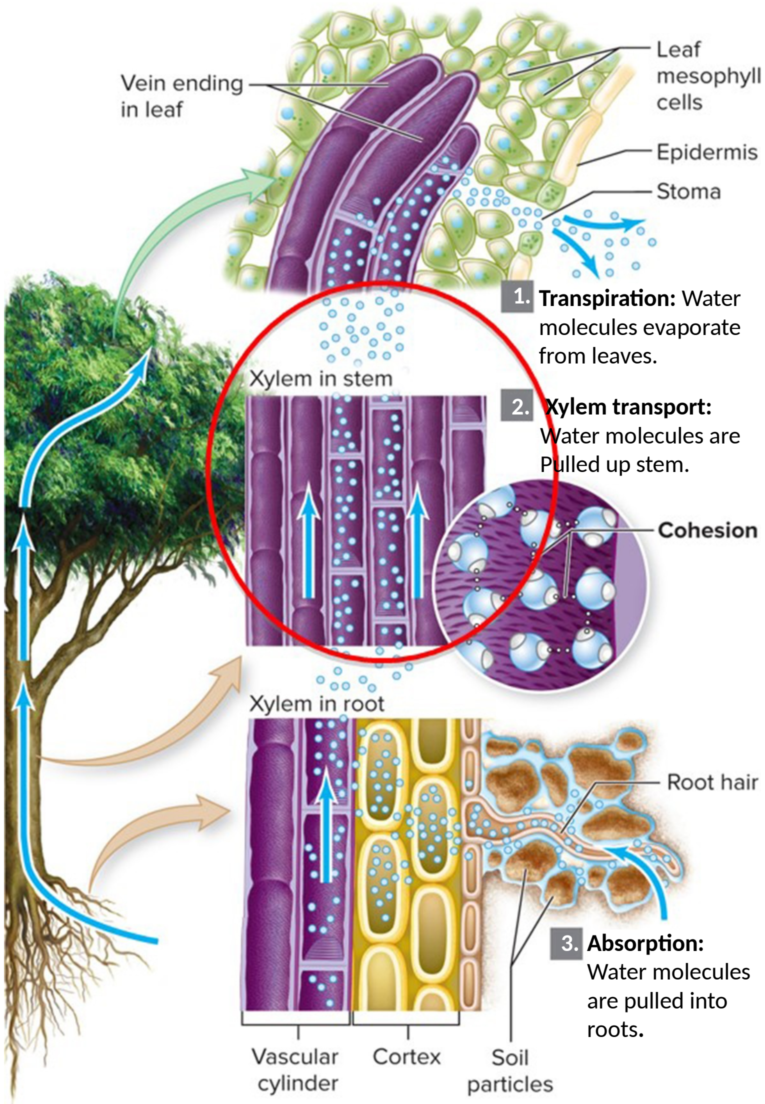


Figure 23.7

Xylem transports water into tissues

This movement of water molecules is repeated all the way down the xylem. Along the way, water molecules diffuse into “thirsty” tissues.



Xylem and water transport: Casparian strip

Water molecules are pulled in to roots. The **Casparian strip** is a waxy barrier that ensures all incoming material passes through cells.

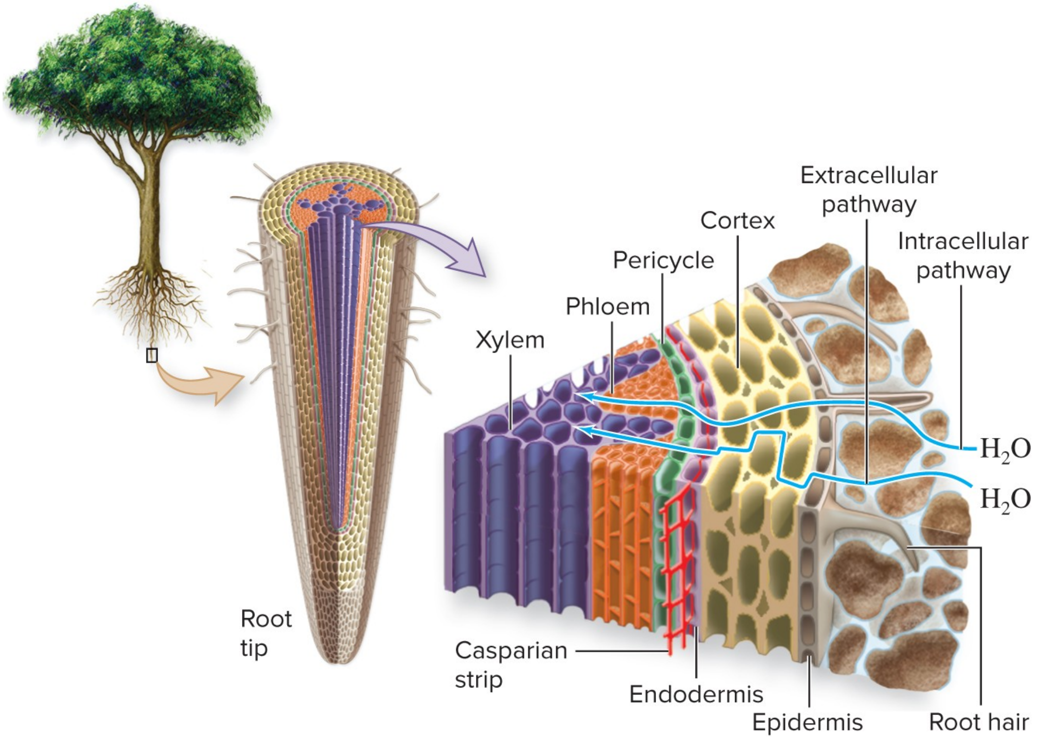


Figure 23.6

Xylem and water transport: stomata

A waxy layer on leaves called the **cuticle** helps prevent water loss. Also, pores in leaves called **stomata** close when the plant needs to conserve water.

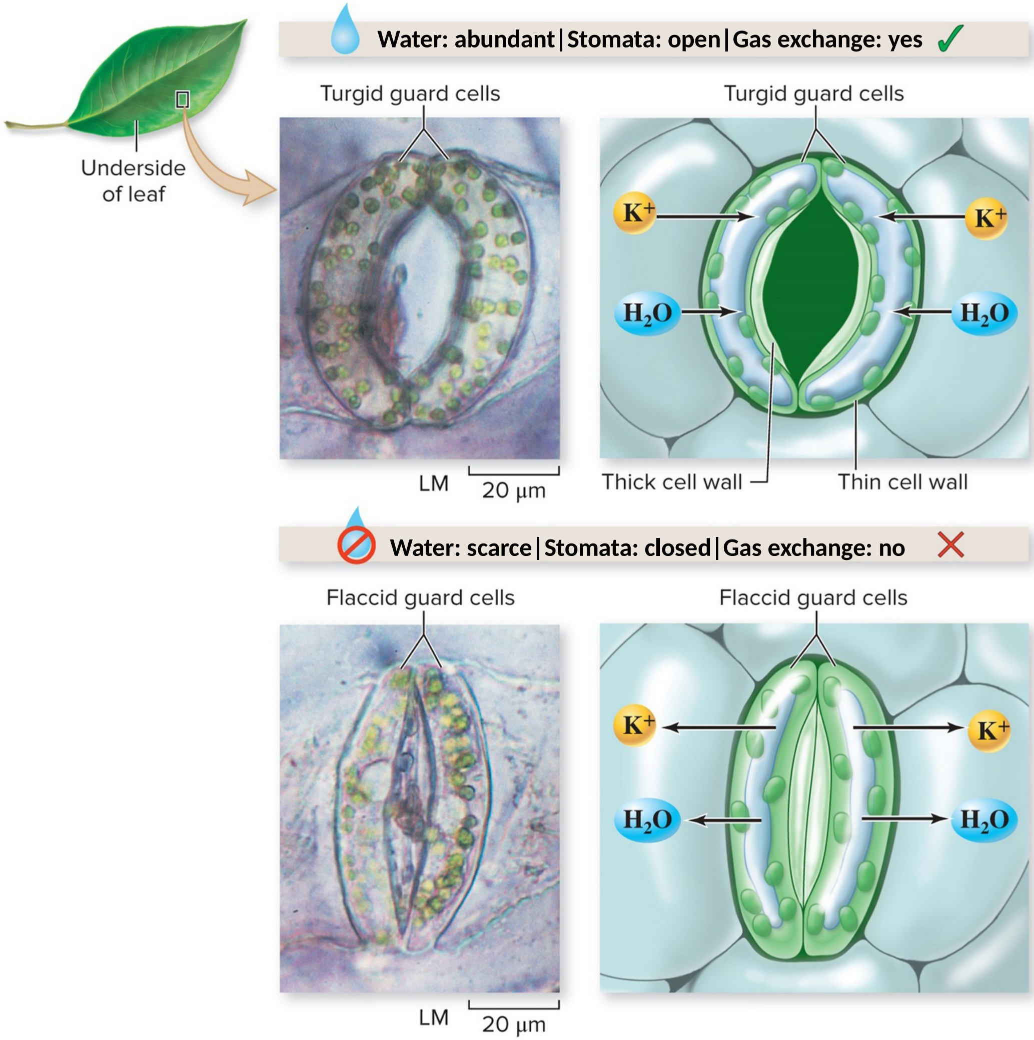


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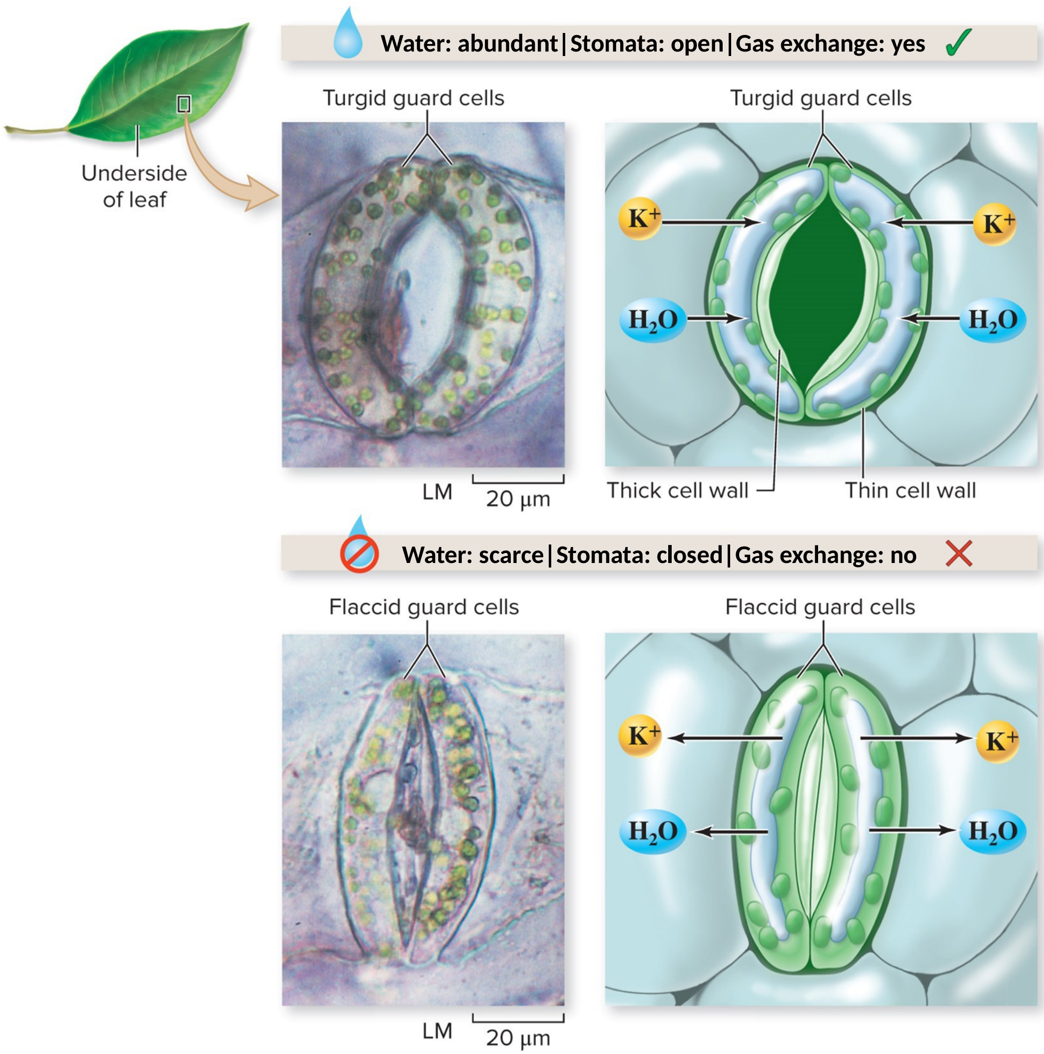
Figure 23.8

Xylem and water transport: guard cells

Guard cells determine whether a stoma is open or closed.



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Section 23.2

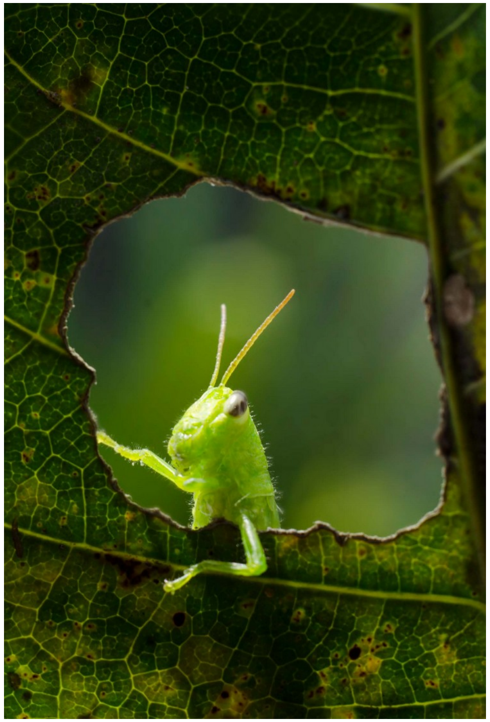
Figure 23.8

Clicker question #3

If all stomata in a plant are closed, then

A. no water evaporates from the leaves.
B. no water moves through the xylem.
C. no water enters the roots.
D. All of the above are true.

Clicker question #3, solution



If all stomata in a plant are closed, then

D. All of the above are true.

23.2 Mastering concepts

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Summarize cohesion-tension theory.

Phloem pushes sugars

Now, let's see how sugars are *pushed* to nonphotosynthetic cells in **phloem**.

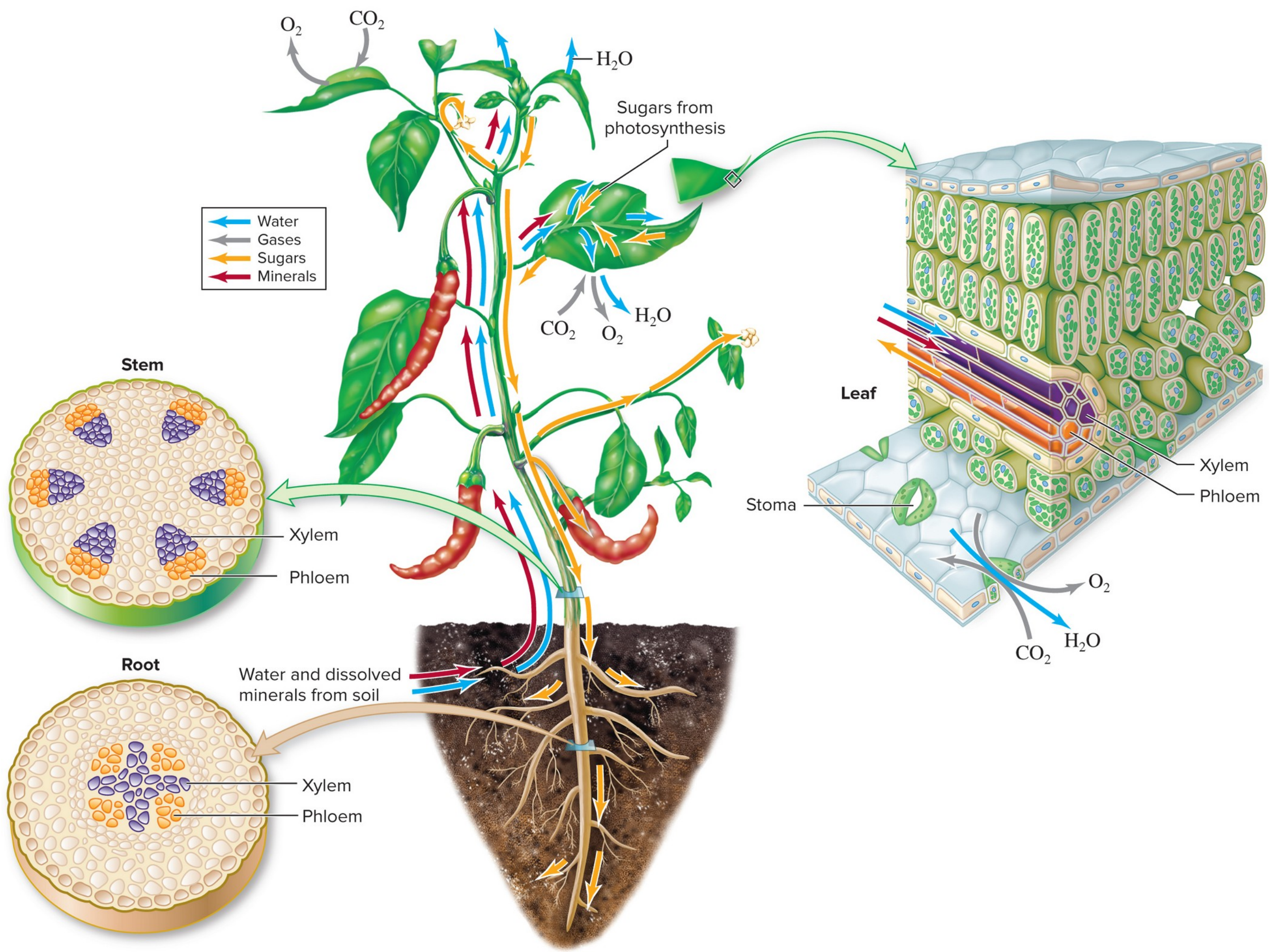

Figure 23.5

Phloem and sugar transport: sources

The green leaves of this strawberry plant are sugar "**sources**" because they carry out photosynthesis.

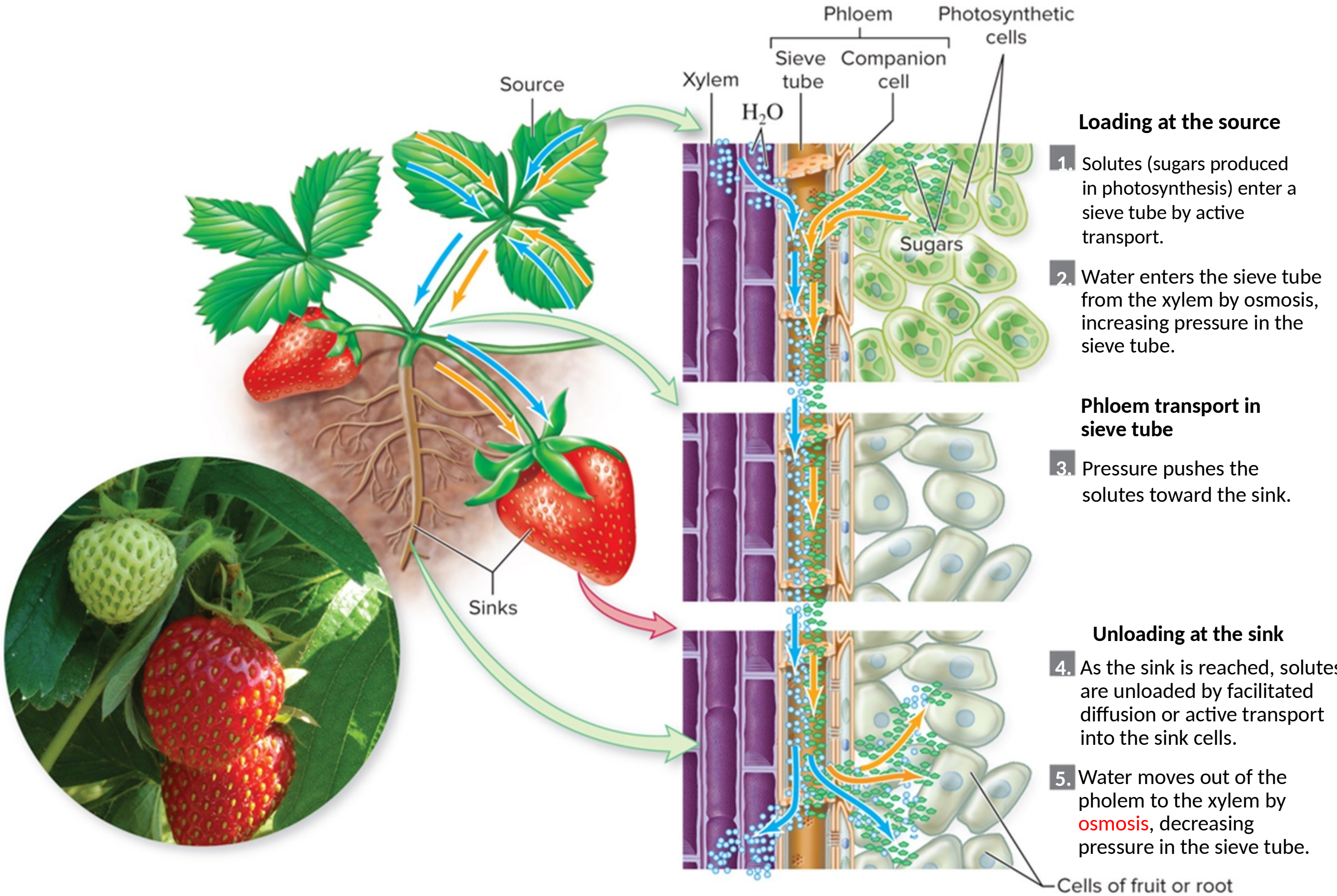

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Figure 23.10

Phloem and sugar transport: sinks

Roots and fruits, which require sugar but do not carry out photosynthesis, are "**sinks**."

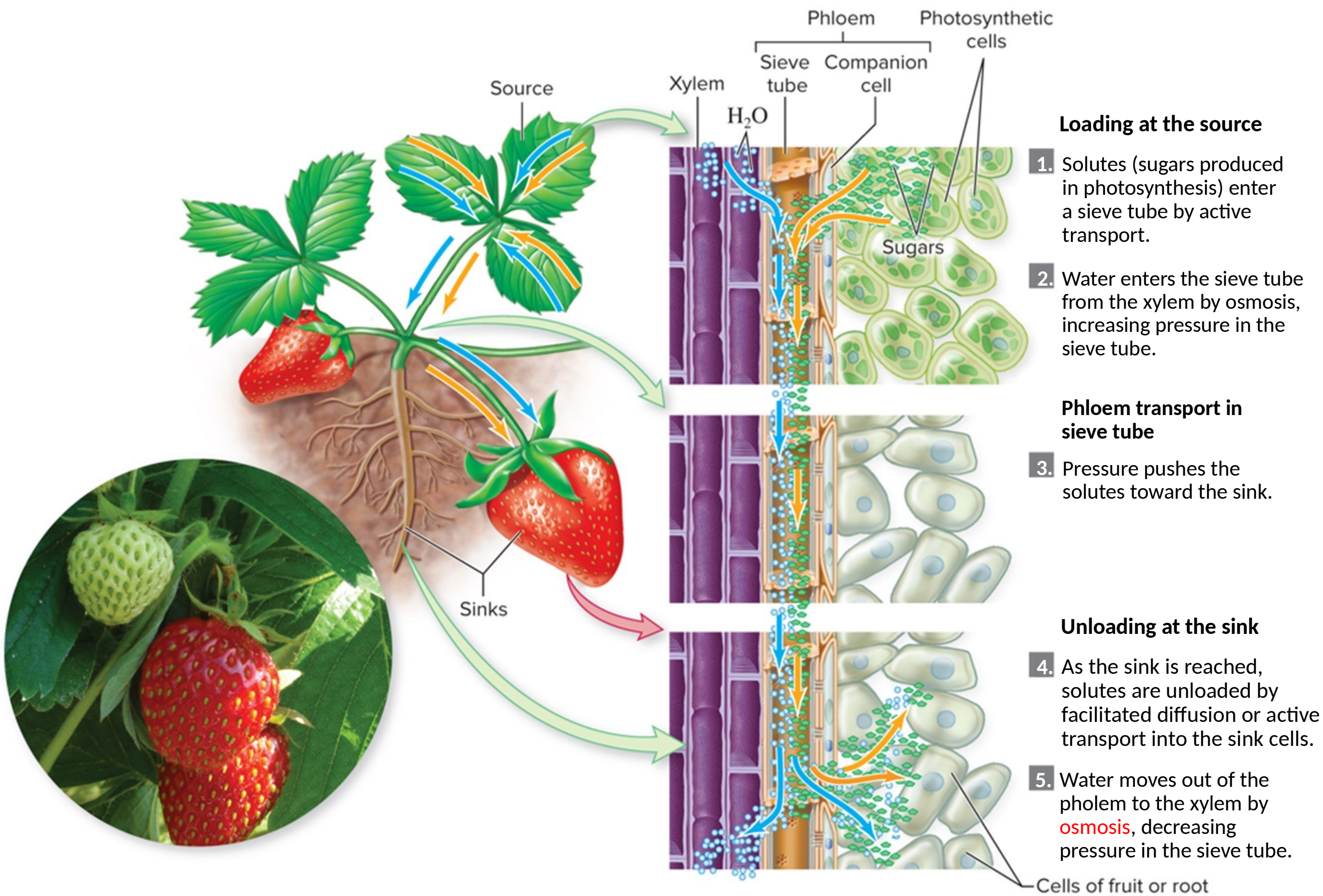

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Figure 23.10

Phloem and sugar transport: pressure flow

According to **pressure flow theory**, phloem sap moves from high pressure at sources to low pressure at sinks. Water movement causes the pressure changes in the phloem tissue.

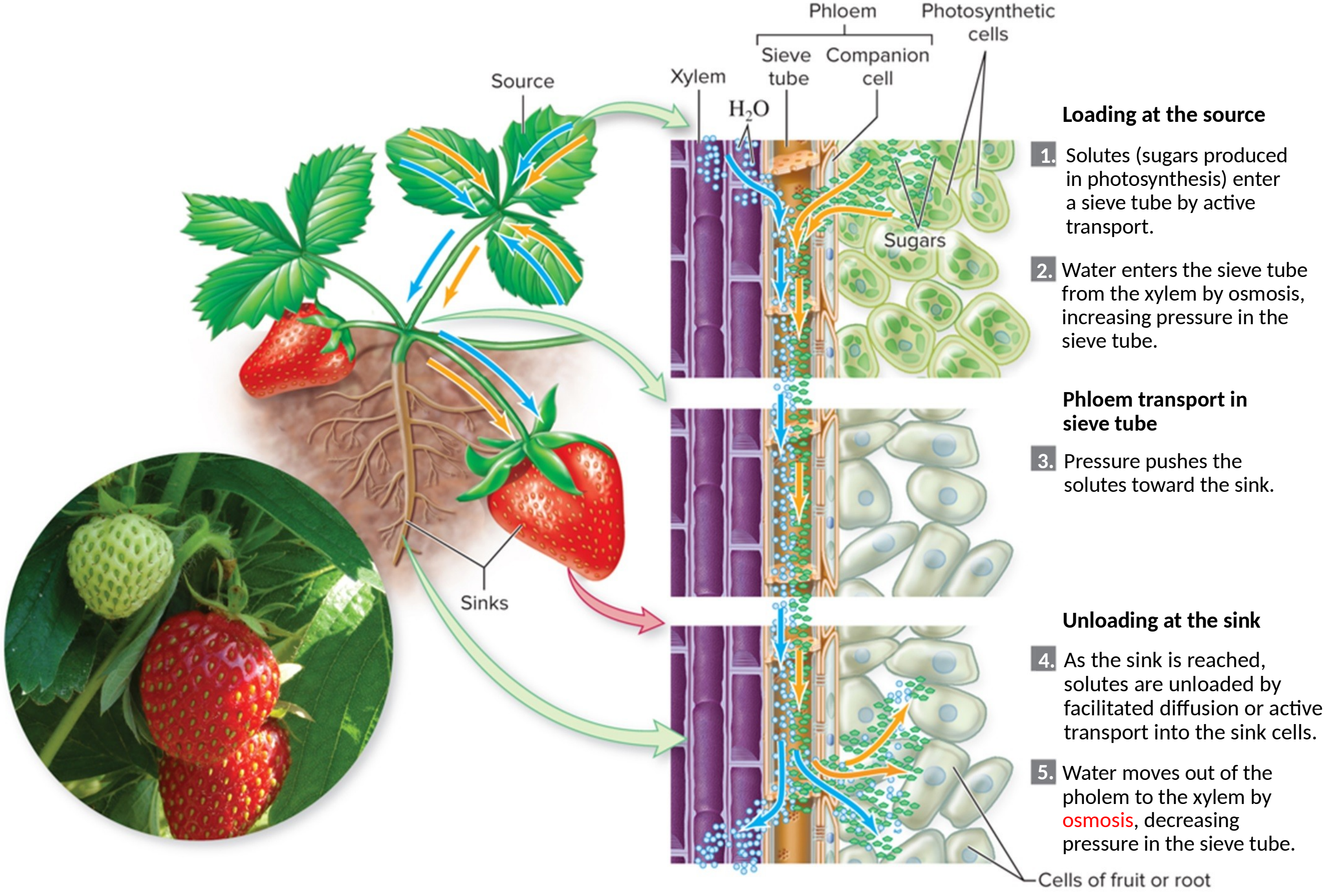

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Figure 23.10

Phloem and sugar transport: pathway of sugar flow

First, sugars are actively transported from photosynthetic cells to companion cells and then into the sieve tube.

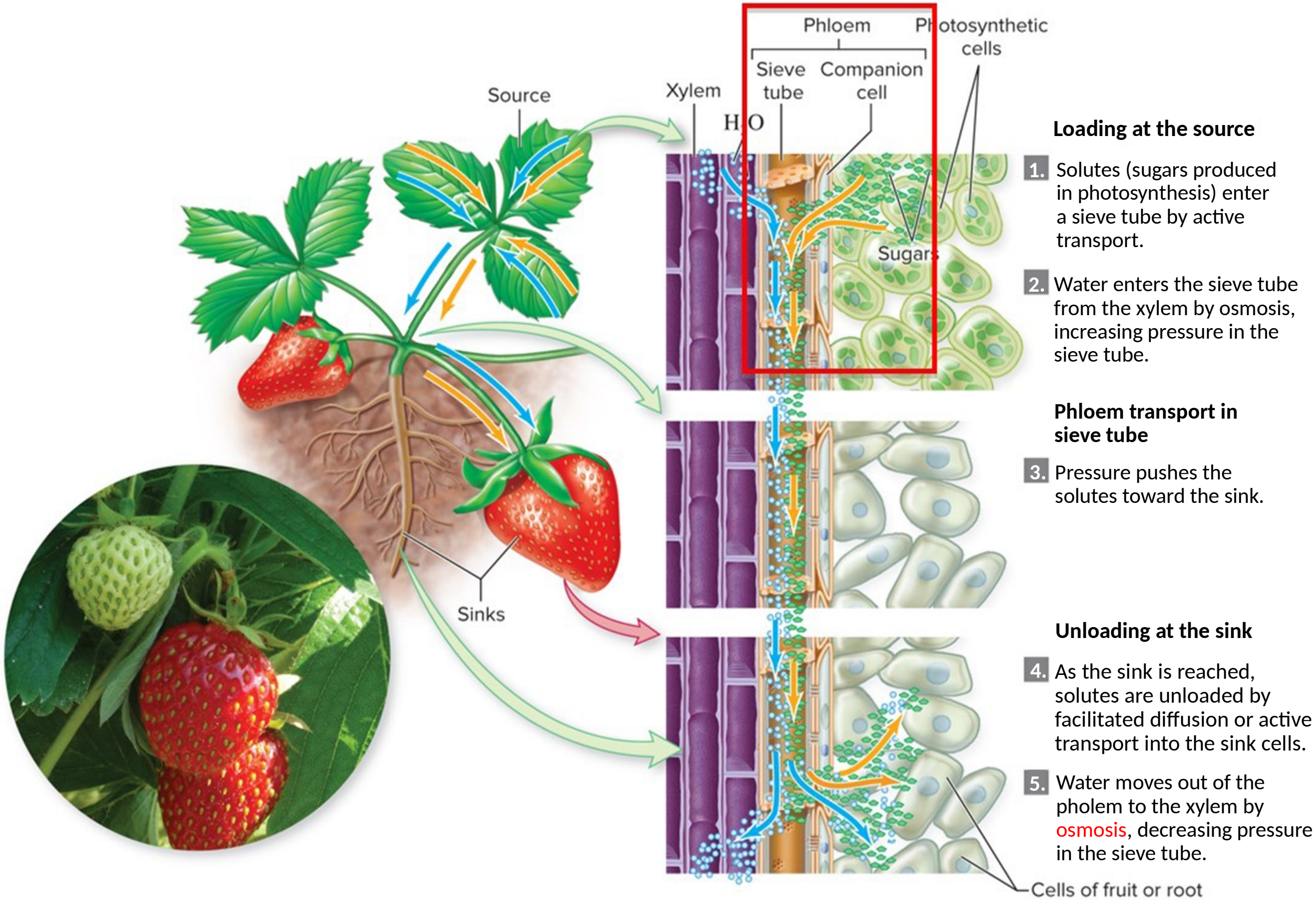

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Figure 23.10

Phloem receives water from the xylem

Then, water moves by osmosis from xylem into the sieve tube, increasing sieve tube pressure.

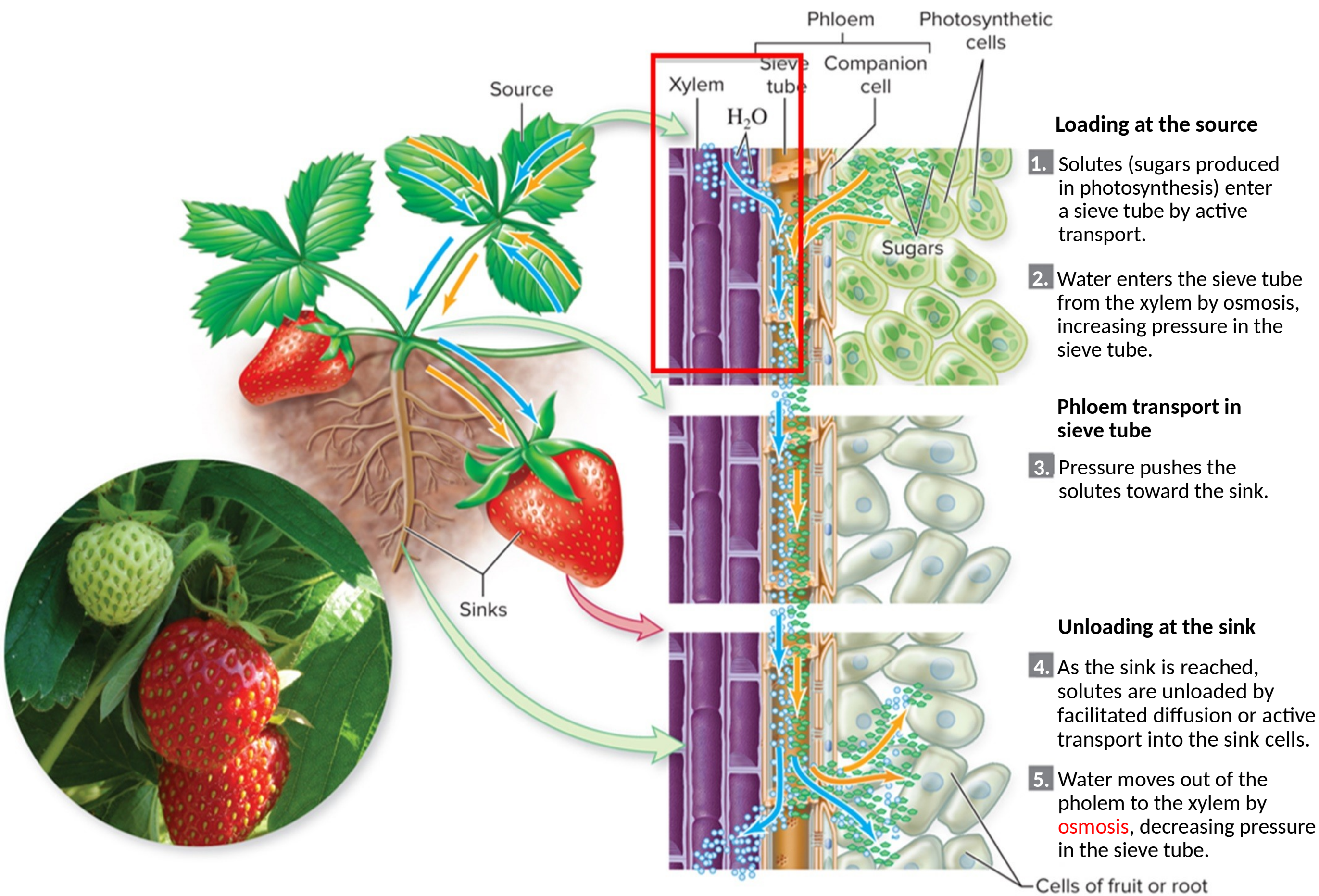

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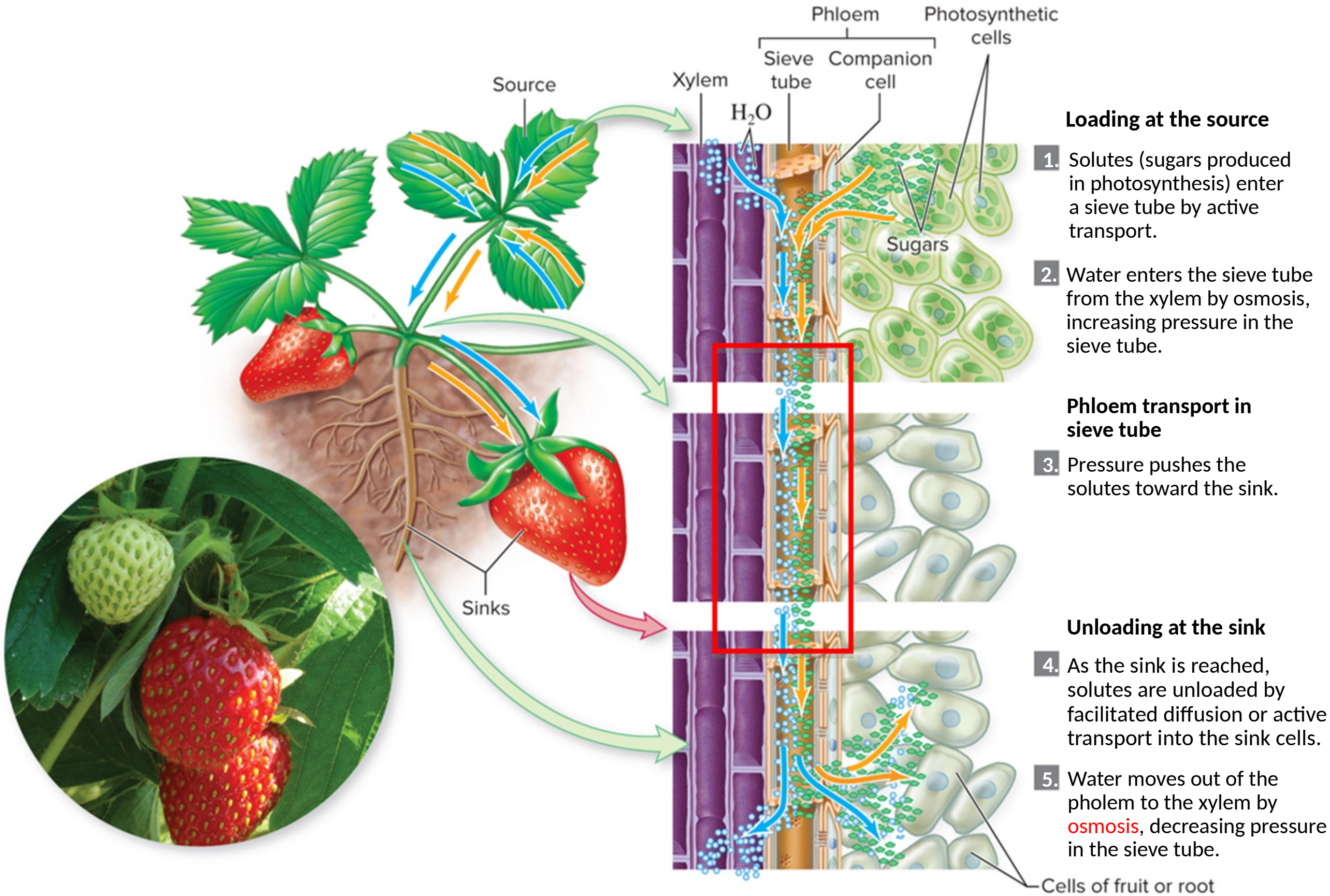
Figure 23.10

Pressure pushes sugars towards the sink

This pressure pushes the sugars toward the sink.



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Section 23.3

Figure 23.10

Sugars are deposited in the sink

At the sink, transport proteins move sugars out of the sieve tube. Since the solute concentration in the phloem decreased, water leaves the sieve tube by osmosis.

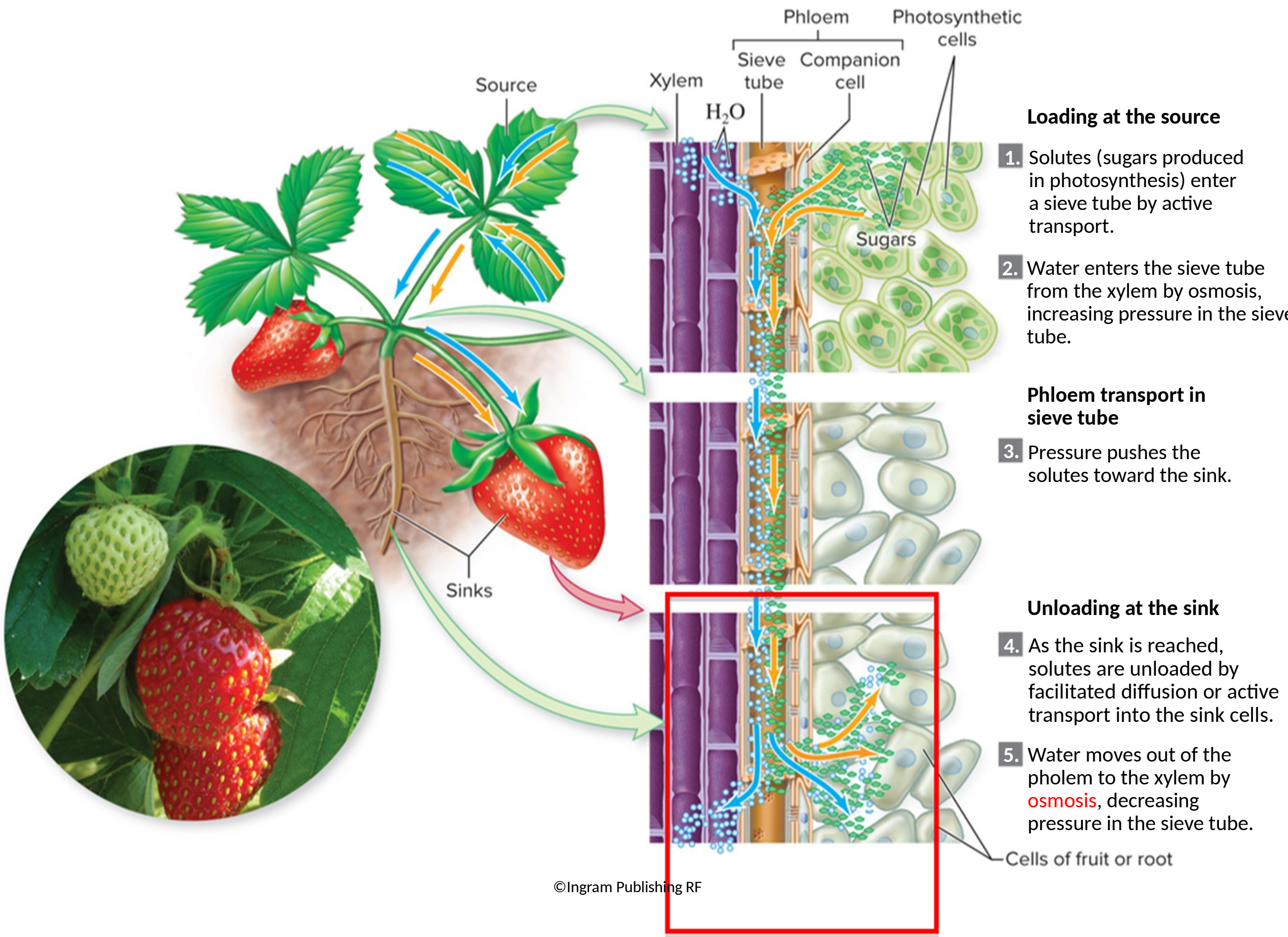
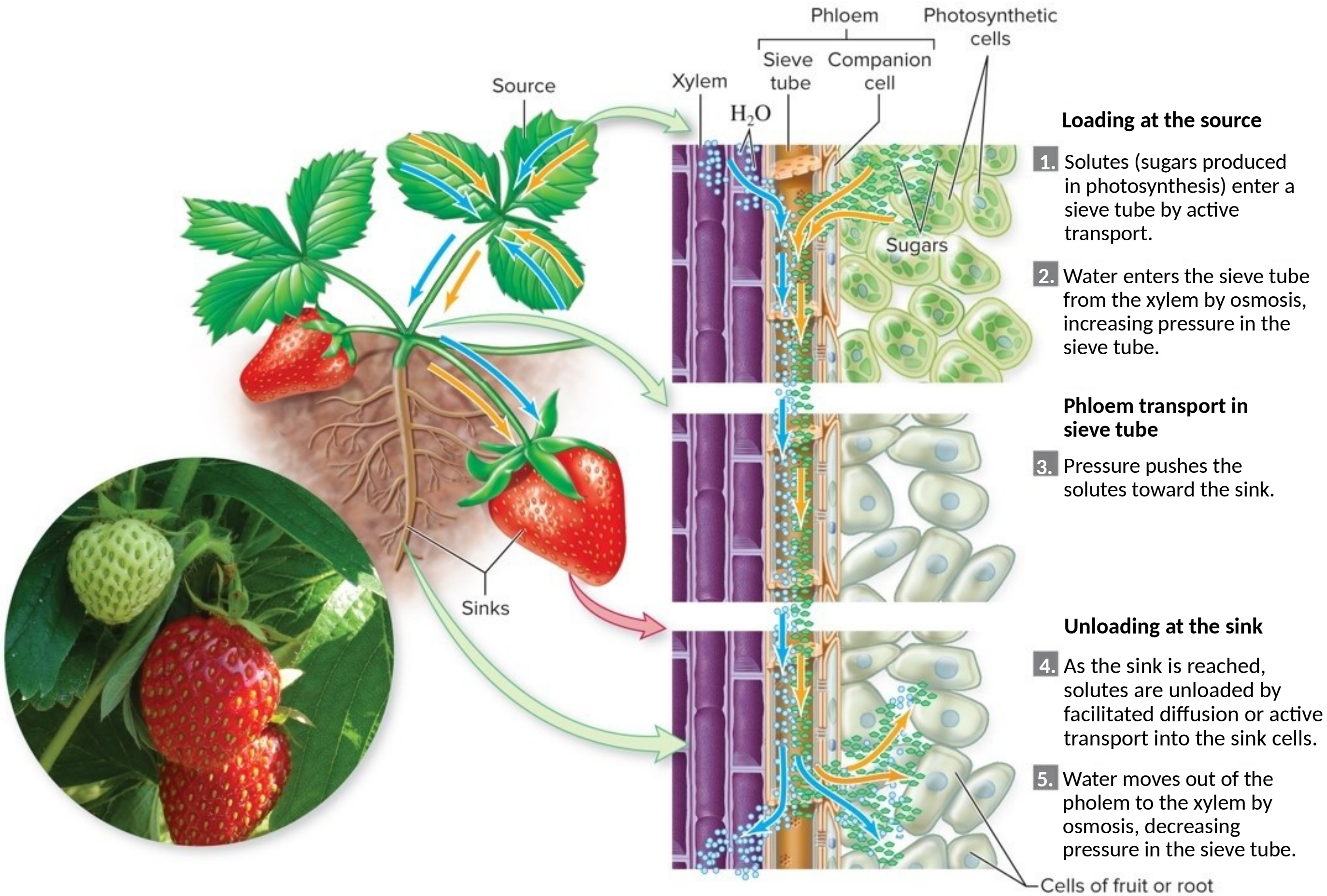


Figure 23.10

Why fruits are sweet

Transport of sugars from sources to sinks explains how non-photosynthetic cells obtain sugars (and why fruits are often sweet).



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Section 23.3

Figure 23.10

Xylem and phloem

This figure summarizes xylem and phloem transport.

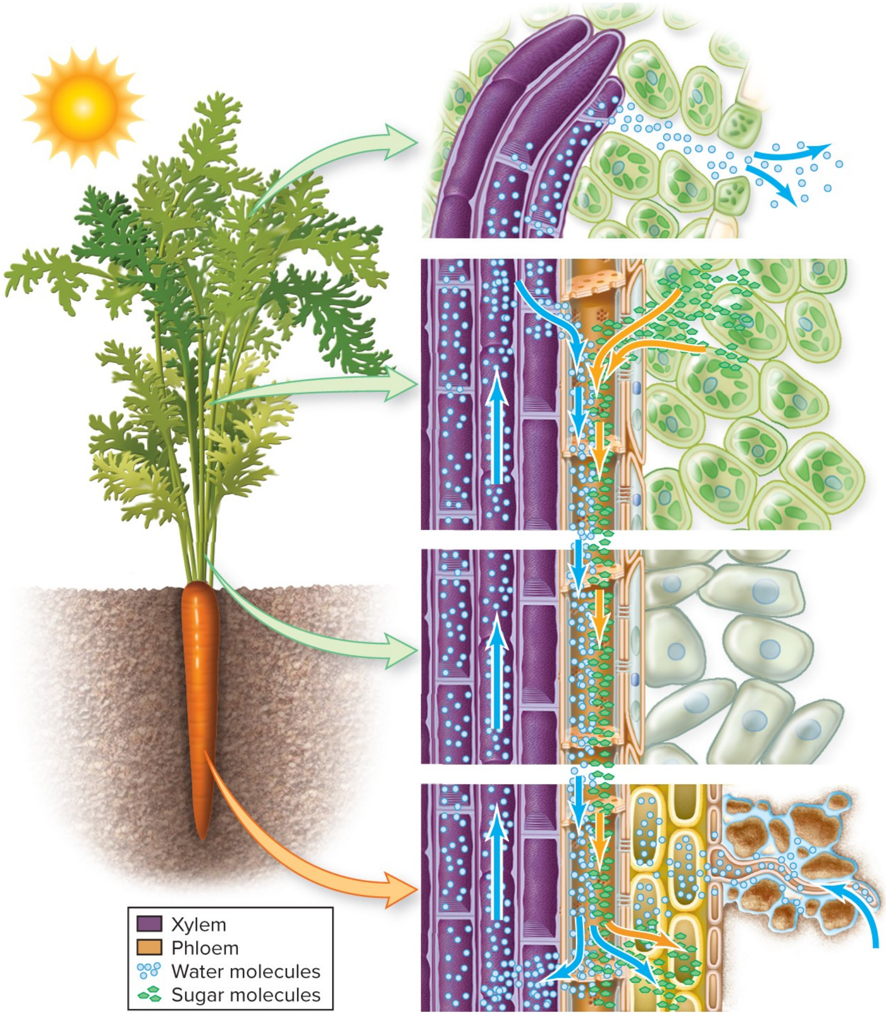

Figure 23.14

Phloem parasites

Parasitic plants tap into the vascular tissue of other plants. Mistletoe roots push through the epidermis of this tree, connecting to its xylem and phloem.

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Clicker question #4

Throughout a growing season, a plant uses up to 1,000 liters (or kg) of water to produce just one kilogram of tissue. What happens to most of the remaining 999 kg of water?

A. It fills the cytoplasm of the plant's cells.
B. It is consumed in photosynthesis.
C. It evaporates.
D. It passes back through roots into the soil.
E. It enters the phloem.

Clicker question #4, solution

Throughout a growing season, a plant uses up to 1,000 liters (or kg) of water to produce just one kilogram of tissue. What happens to most of the remaining 999 kg of water?

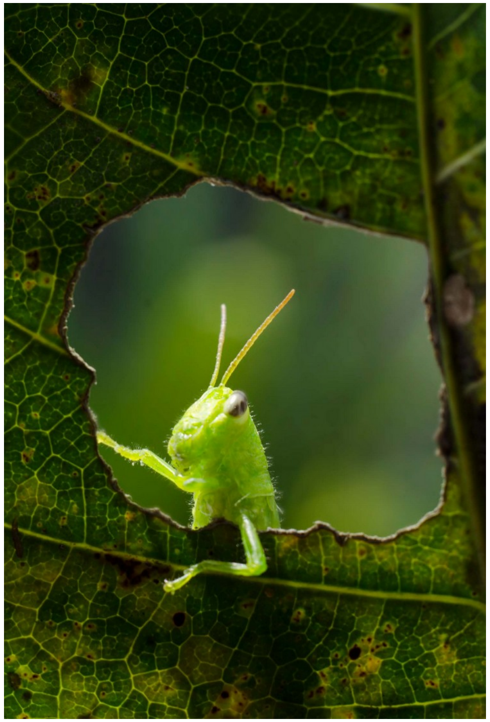
C. It evaporates.

Clicker question #5

A potato tuber stores starches for a potato plant. When the rate of photosynthesis is low (that is, during the winter), the plant uses the sugars stored in potato tubers to survive. In the winter, the tuber is mainly

A. a source of phloem sap.
B. a sink for phloem sap.
C. a photosynthetic tissue.

Clicker question #5, solution



A potato tuber stores starches for a potato plant. When the rate of photosynthesis is low (that is, during the winter), the plant uses the sugars stored in potato tubers to survive. In the winter, the tuber is mainly

A. a source of phloem sap.

23.3 to 23.4 Mastering concepts

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Explain the pressure flow theory of phloem transport.

Investigating life:
The hidden cost of traps

Carnivorous plants have modified leaves that trap invertebrate prey, which provide nutrients that the soil lacks.

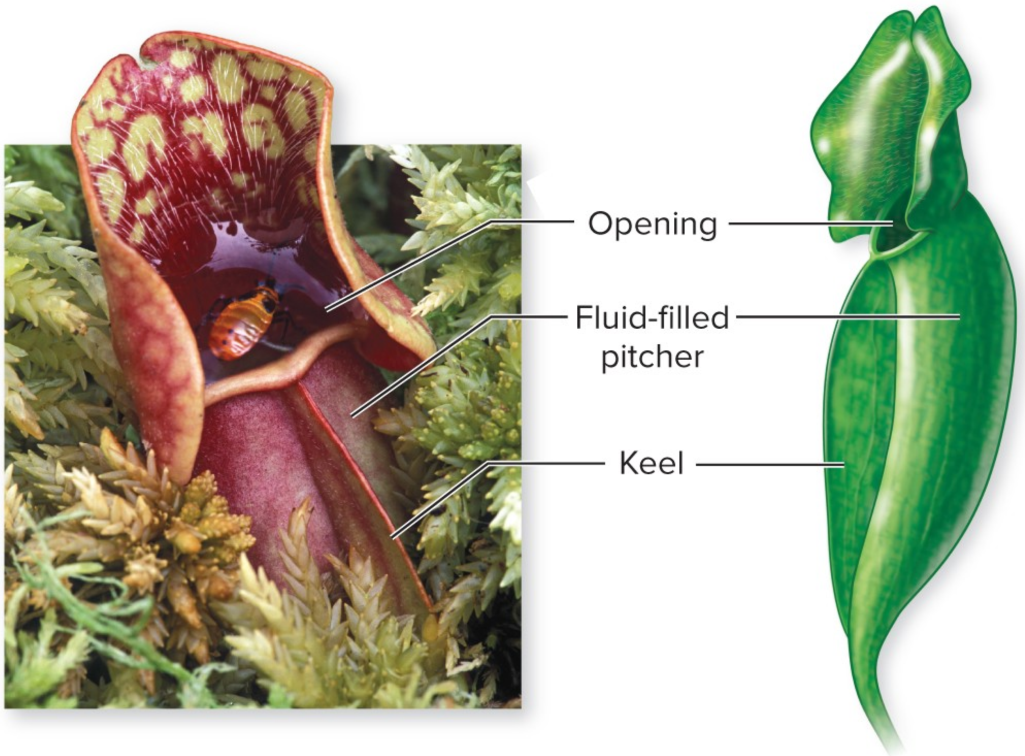

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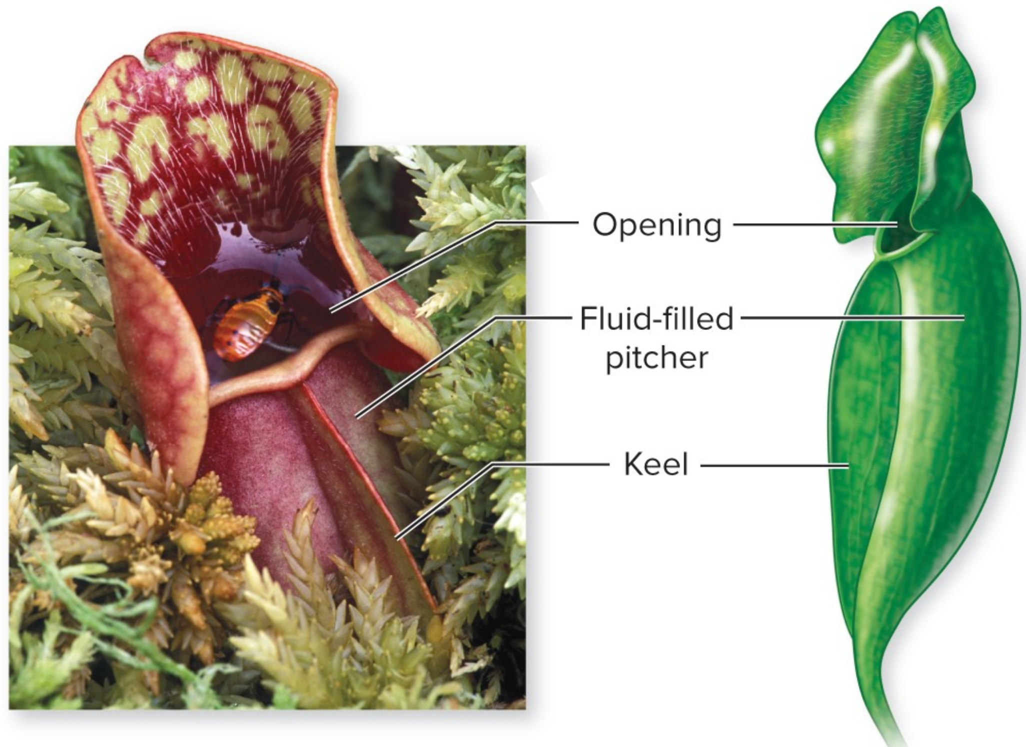
Figure 23.12

Investigating life:
When are traps advantageous?

But larger traps mean less surface area for photosynthesis. So traps are only advantageous in sunny habitats with nutrient-poor soils.



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Investigating life:
Analyzing the data

In nutrient-rich soils, pitcher plants invest more energy in producing photosynthetic tissue (called keels) and less energy producing traps.

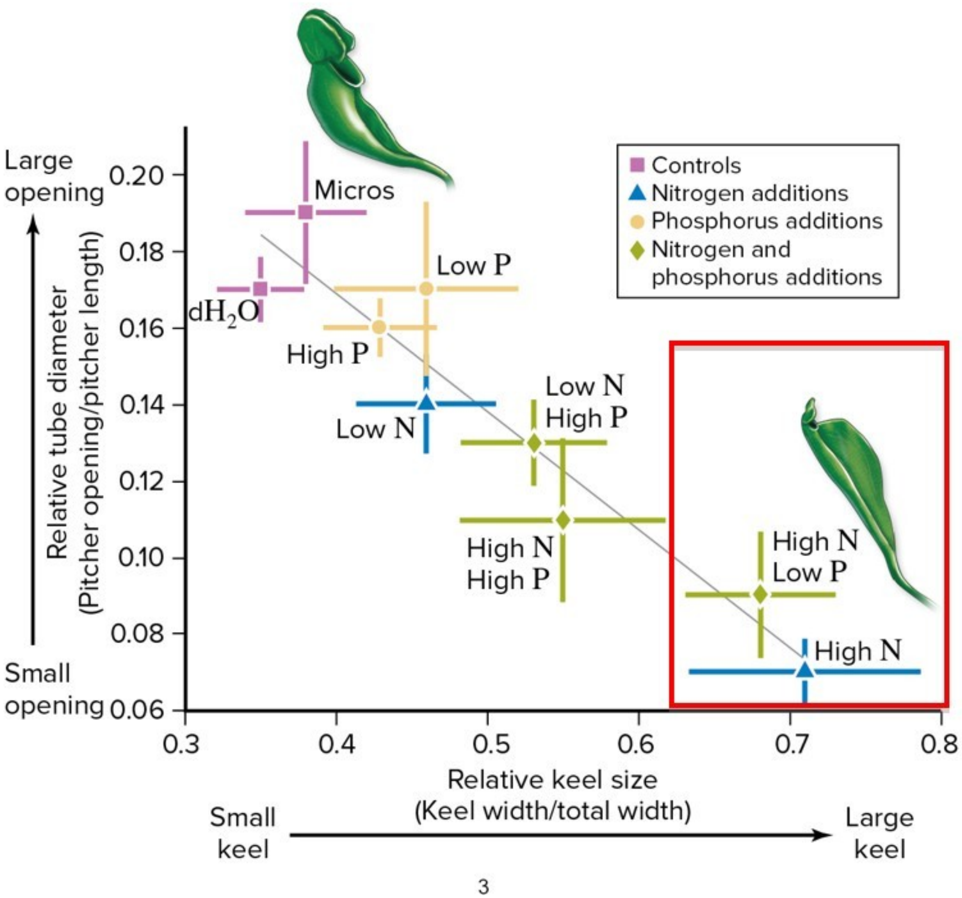

Figure 23.13