Chapter 8

NUTRITION and DIGESTION

Topics Discussed in this chapter

- **The Nutrition & Digestion Lecture materials include:**
  - What is nutrition?
  - What is digestion?
  - Kinds of diets
  - Ways of ingesting food
  - Stages of food processing
  - Human digestive system & digestion
  - Nutrition
  - Practice test questions
  - Glossary

What is nutrition?

It is the science of the nutrients and "other substances" in food:

- **Their action, interaction, and balance in relation to health and disease**
- **The processes by which the organism ingests, digests, absorbs, transports, utilizes and excretes food substances**

Nutrients

- Substances that we must have in our diets in order for our cells to function properly

- Include:
  - Proteins
  - Carbohydrates
  - Lipids
  - Vitamins
  - Minerals
  - Water

Digestion

How do we get nutrients from food?

OBTAINING AND PROCESSING FOOD

Kinds of diets

- **Most animals have one of three kinds of diets**

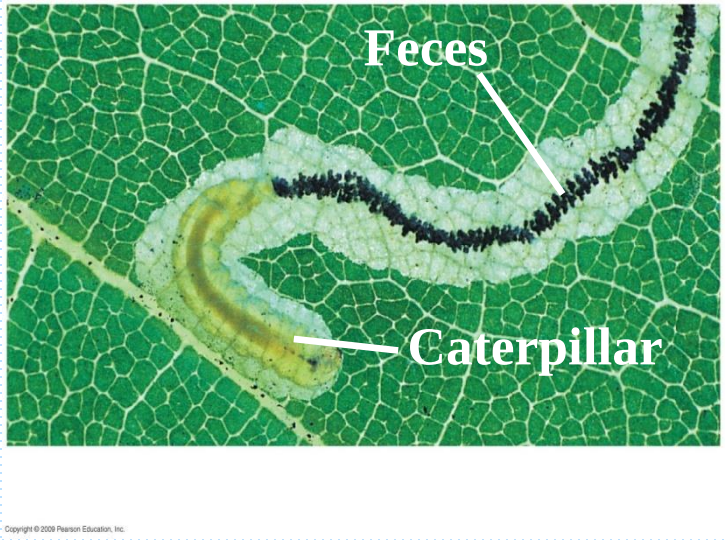
1) **Herbivores,** plant-eaters — cattle, snails and sea urchins

2) **Carnivores,** meat-eaters — lions, hawks and spiders

3) **Omnivores,** eating both plants and other animals — humans, roaches, raccoons and crows

Animals ingest their food in a variety of ways

- **Animals obtain and ingest their food in different ways**
  1) **Suspension feeding**
  2) **Substrate feeding**
  3) **Fluid feeding**
  4) **Bulk feeding**



A substrate feeder:

a caterpillar eating its way through the soft green tissues inside an oak leaf.

A suspension feeder:

a tube worm filtering food from the surrounding water through its tentacles.

A fluid feeder:

a mosquito sucking blood.

A bulk feeder:

a grey heron preparing to swallow a fish head first and the rest next.

Stages of food processing

- **Food is processed in four stages**

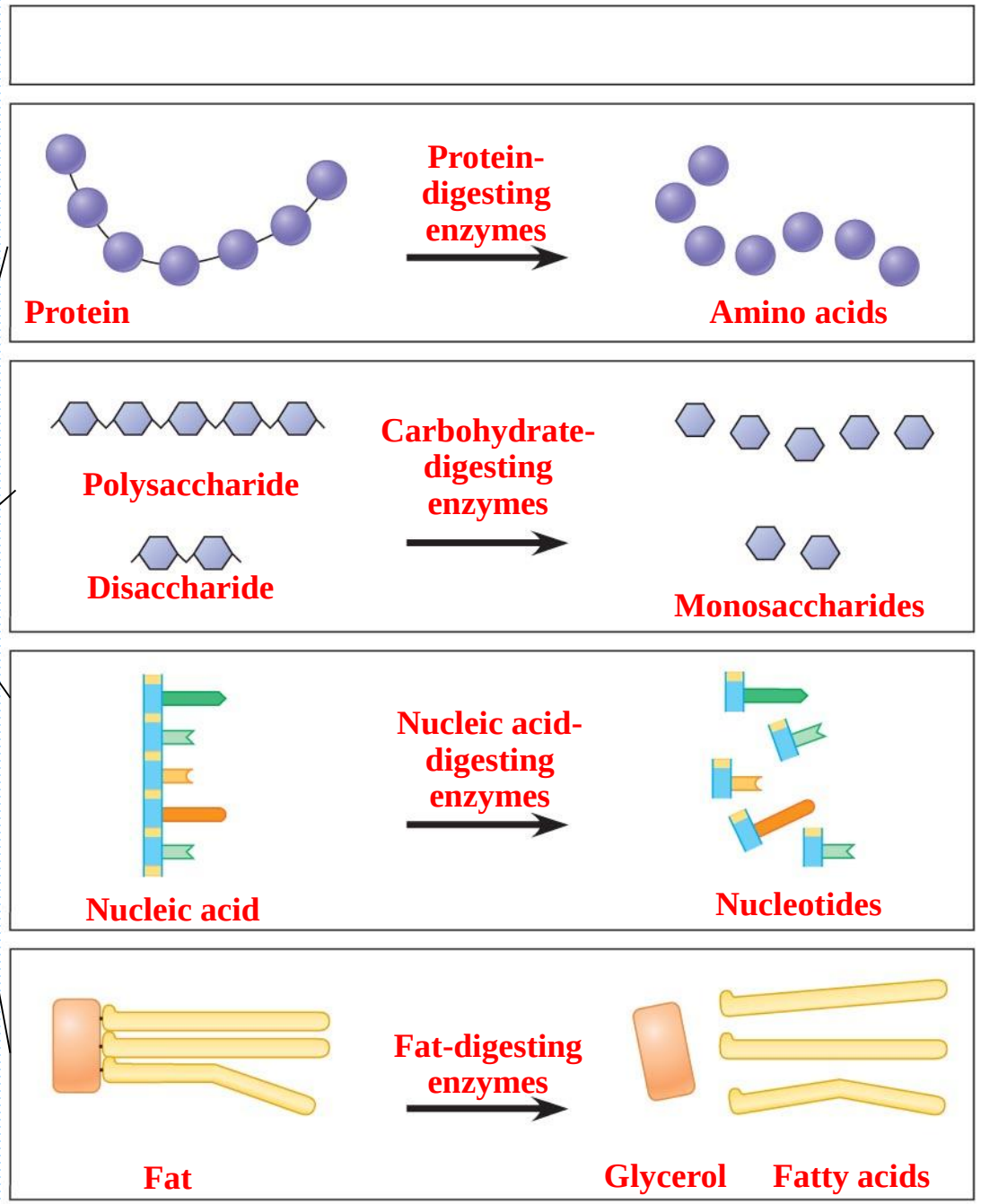
  1) **Ingestion**
  2) **Digestion**
  3) **Absorption**
  4) **Elimination**

Digestion

There are two types of digestion

1. **Mechanical digestion: breaks food down into smaller pieces**
2. **Chemical digestion: enzymatic break down of large organic molecules into their components**

Chemical digestion



HUMAN DIGESTIVE SYSTEM

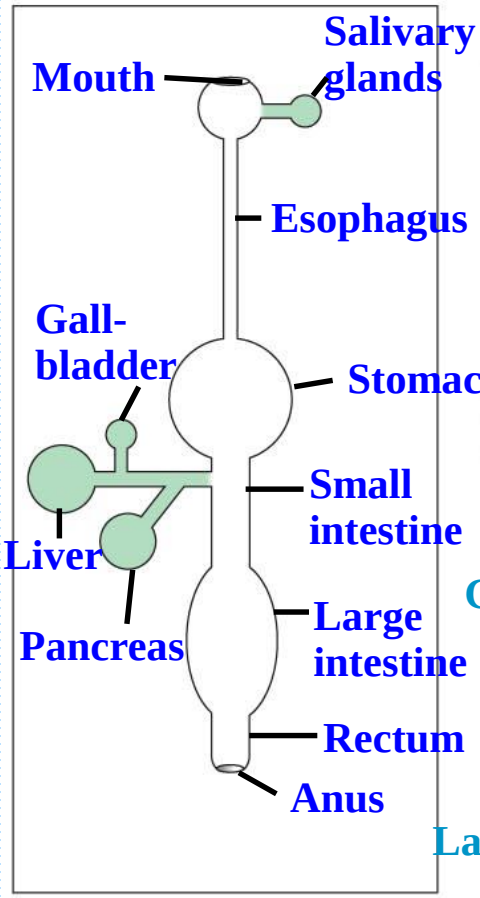
- **Human digestive system consists of:**

1) An alimentary canal

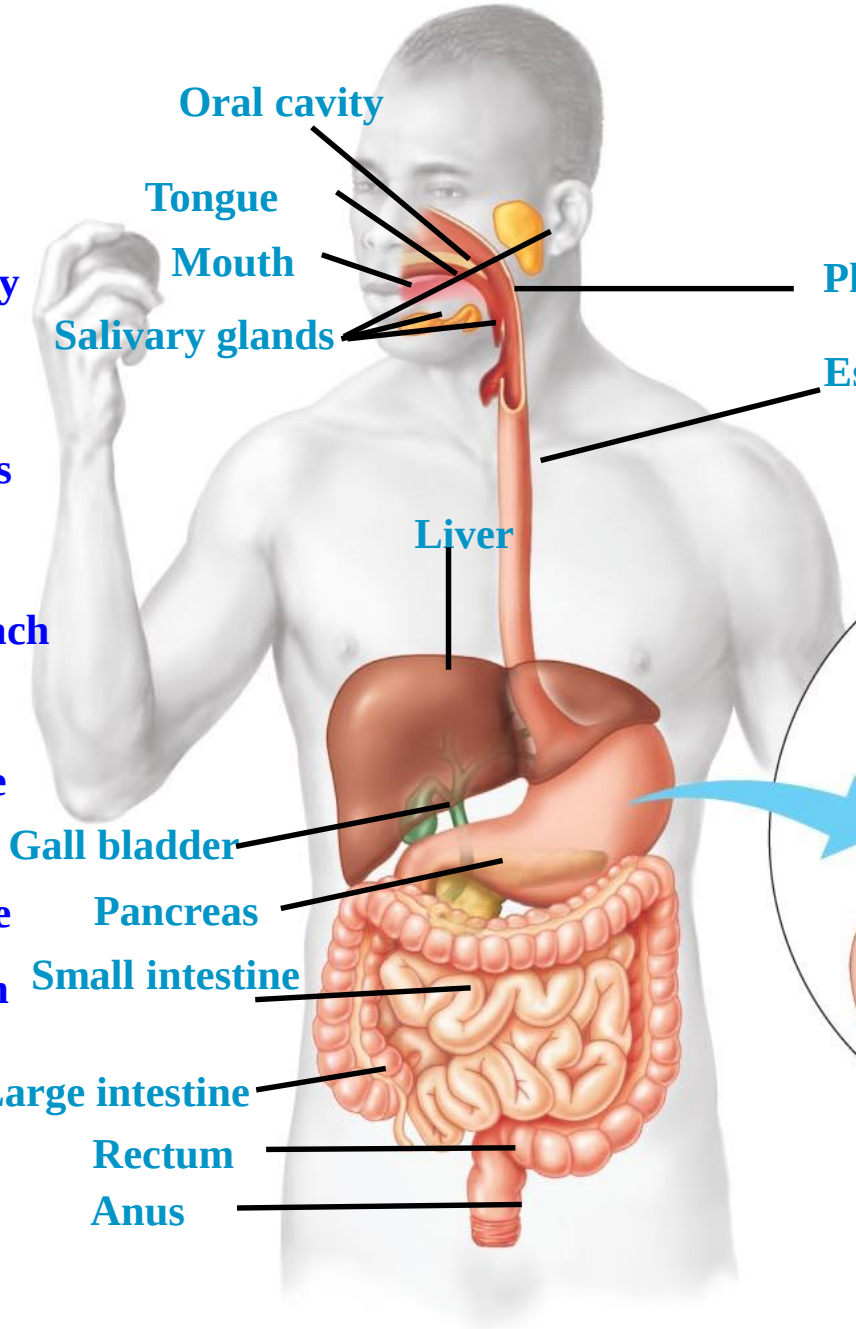
Mouth, pharynx, esophagus, stomach, small intestine, large intestine also known as the colon, rectum and anus.

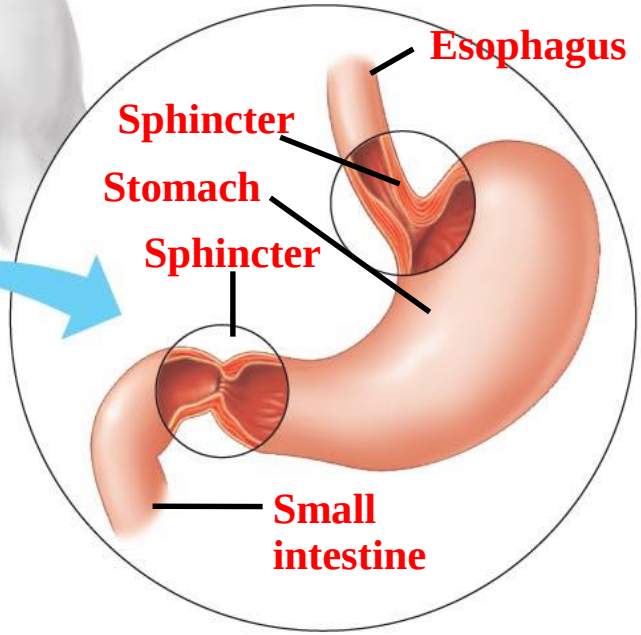
2) Accessory glands

- **Salivary glands → salivary amylase**
- **Pancreas → Pancreatic amylase, chymotrypsin, trypsin, lipases and nucleases**
- **Liver → bile and bile salts**
- **Gallbladder → bile storage**



A schematic diagram of the human digestive system





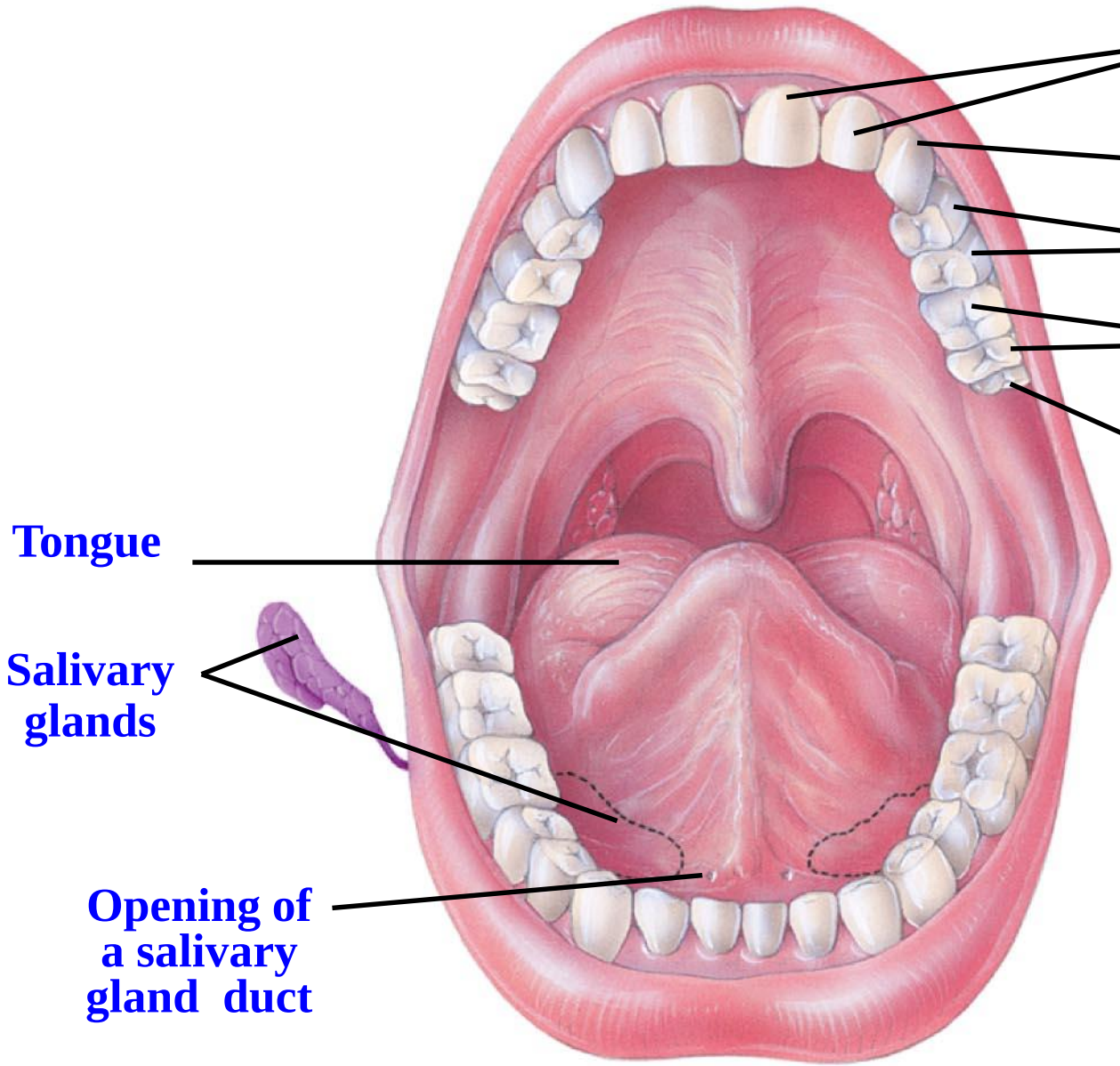
The human digestive system

Process of Digestion

- **Mechanical – Chewing and mixing of food occurs in the mouth and stomach**
- **Teeth break up food, saliva moistens it**
  - **Salivary amylase begins the hydrolysis of starch**
  - **Antibacterial agent kills some bacteria ingested with food**
- **The tongue tastes, shapes the bolus of food, and moves it towards the pharynx.**

The human oral cavity

Teeth

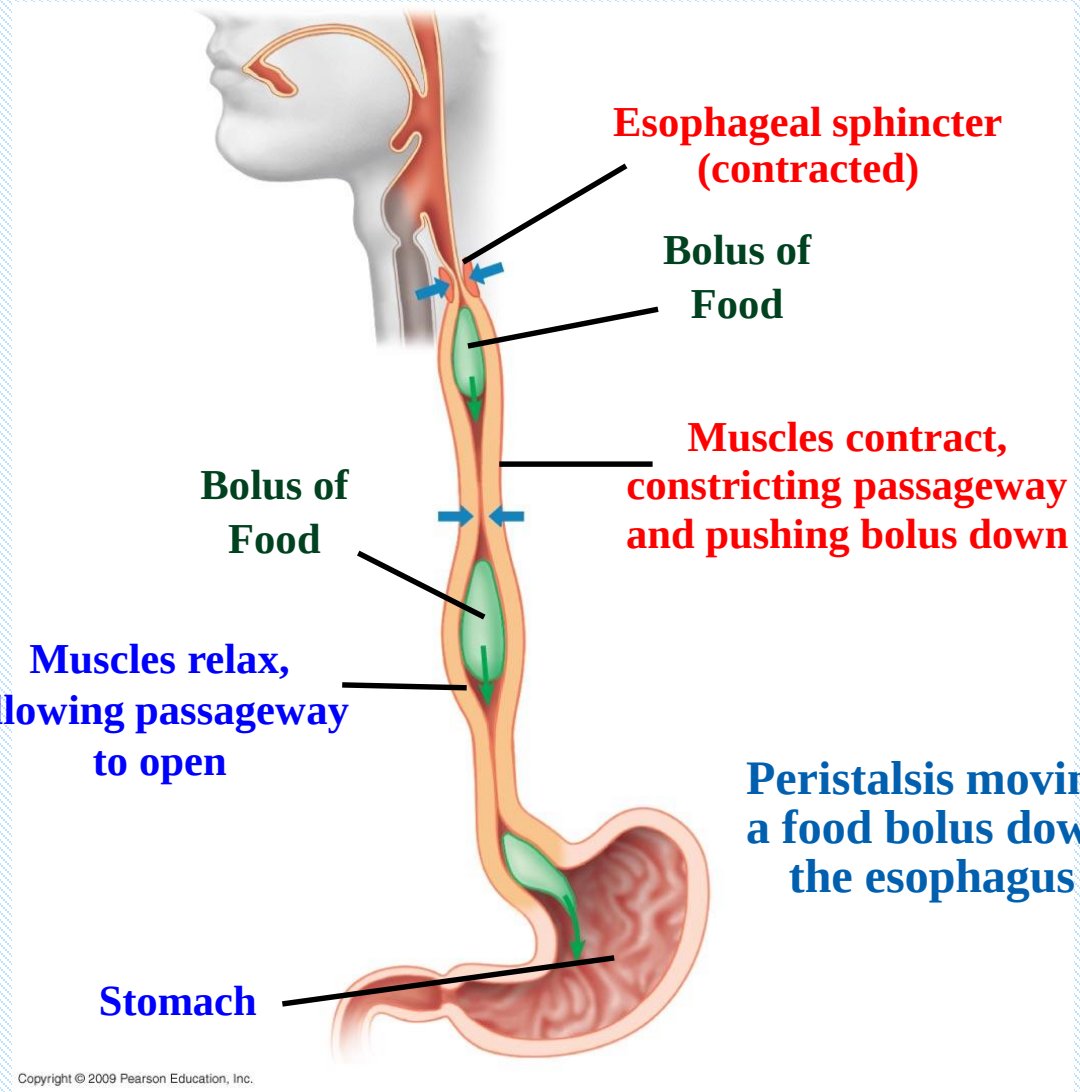


Food movement in the alimentary canal

- Esophagus serves to transport food from mouth to stomach
- Alternating waves of contraction and relaxation by smooth muscle in the walls of the canal move food along in a process called peristalsis
- Sphincters - a circular muscle arrangement that acts as a valve to regulate passage or flow of food into and out of digestive chambers.
- The pyloric sphincter
  - Regulates the passage of food from the stomach to the small intestine
  - Limits the upward movement of acids into the esophagus

Peristalsis moves food through the esophagus to the stomach

- After swallowing, peristalsis moves food through the esophagus to the stomach
- The trachea conducts air to the lungs
- The esophagus conducts food from the pharynx to the stomach



The stomach stores food and breaks it down with acid and enzymes

- **In the stomach**
  - **Parietal cells produce Acid HCl - pH = 2**

    Acid kills bacteria and breaks apart cells in food
  - **Chief cells produce Pepsinogen (inactive).**

    Pepsinogen + HCl ------ pepsin (active).

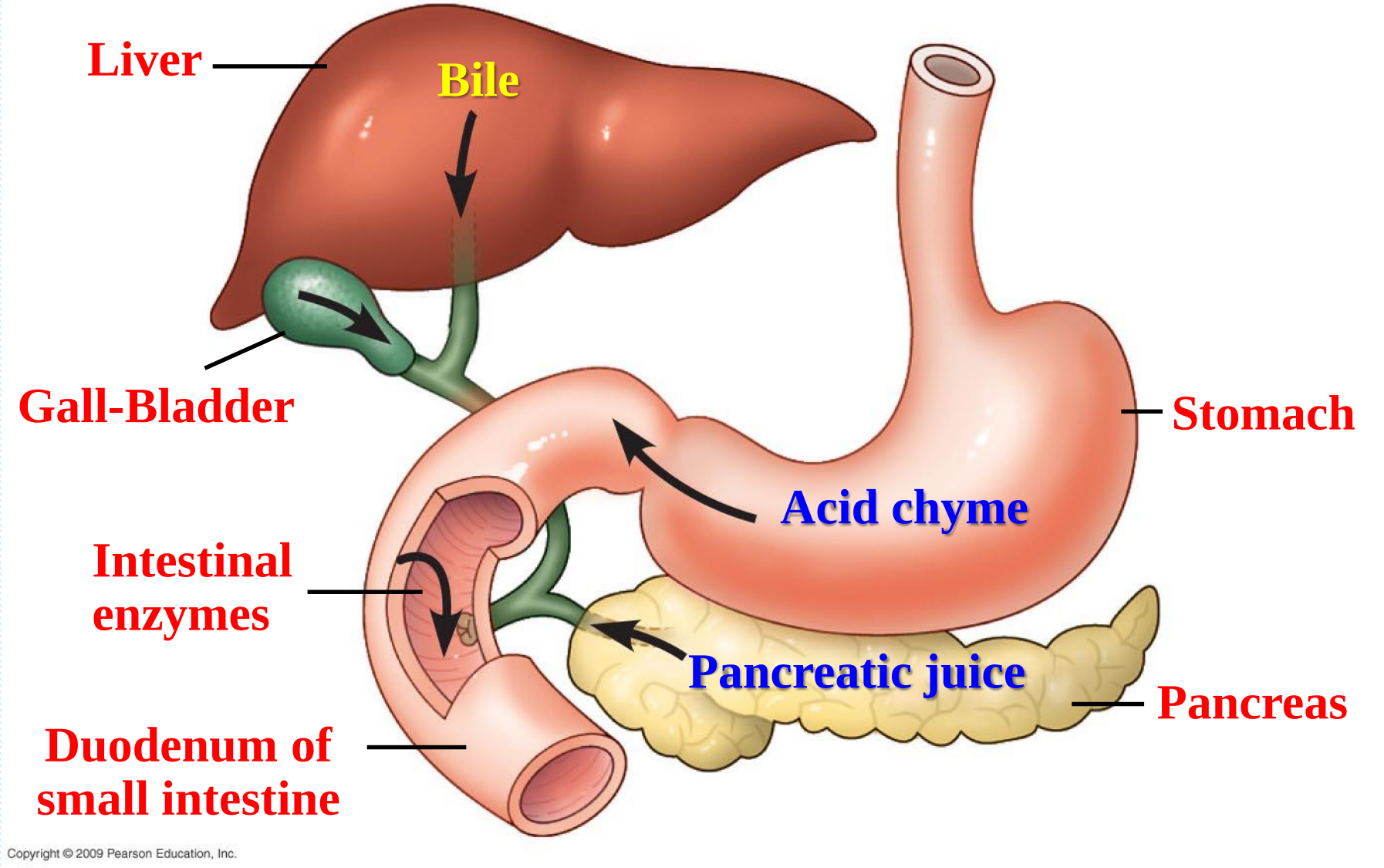
    Pepsin begins the chemical digestion of proteins
  - **Mucous production: helps protect cell wall against HCl and pepsin, cells lining the stomach are renewed about every 3 days**
  - **Acidic gastric juices mix with food to produce acid chyme**

In the small intestine

- Small intestine is the major organ of chemical digestion and nutrient absorption
- Small intestine is named for its smaller diameter — it is about 6 meters long
- Alkaline pancreatic juice neutralizes acid chyme and its enzymes

(pancreatic amylase, lipase, proteases and nucleases) digest food

- Bile, made in the liver and stored in the gall bladder, emulsifies fat for attack by pancreatic lipase



The small intestine and related digestive organs

TABLE 21.10 ENZYMATIC DIGESTION IN THE SMALL INTESTINE

Carbohydrates

Starch —(Pancreatic amylase)→ Maltose (and other disaccharides) —(Maltase, sucrase, lactase, etc.)→ Monosaccharides

Proteins

Polypeptides —(Trypsin, chymotrypsin)→ Smaller polypeptides —(Aminopeptidase, carboxypeptidase, dipeptidase)→ Amino acids

Nucleic acids

DNA and RNA —(Nucleases)→ Nucleotides —(Other enzymes)→ Nitrogenous bases, sugars, and phosphates

Fats

Fat globules —(Bile salts)→ Fat droplets (emulsified) —(Lipase)→ Fatty acids and glycerol

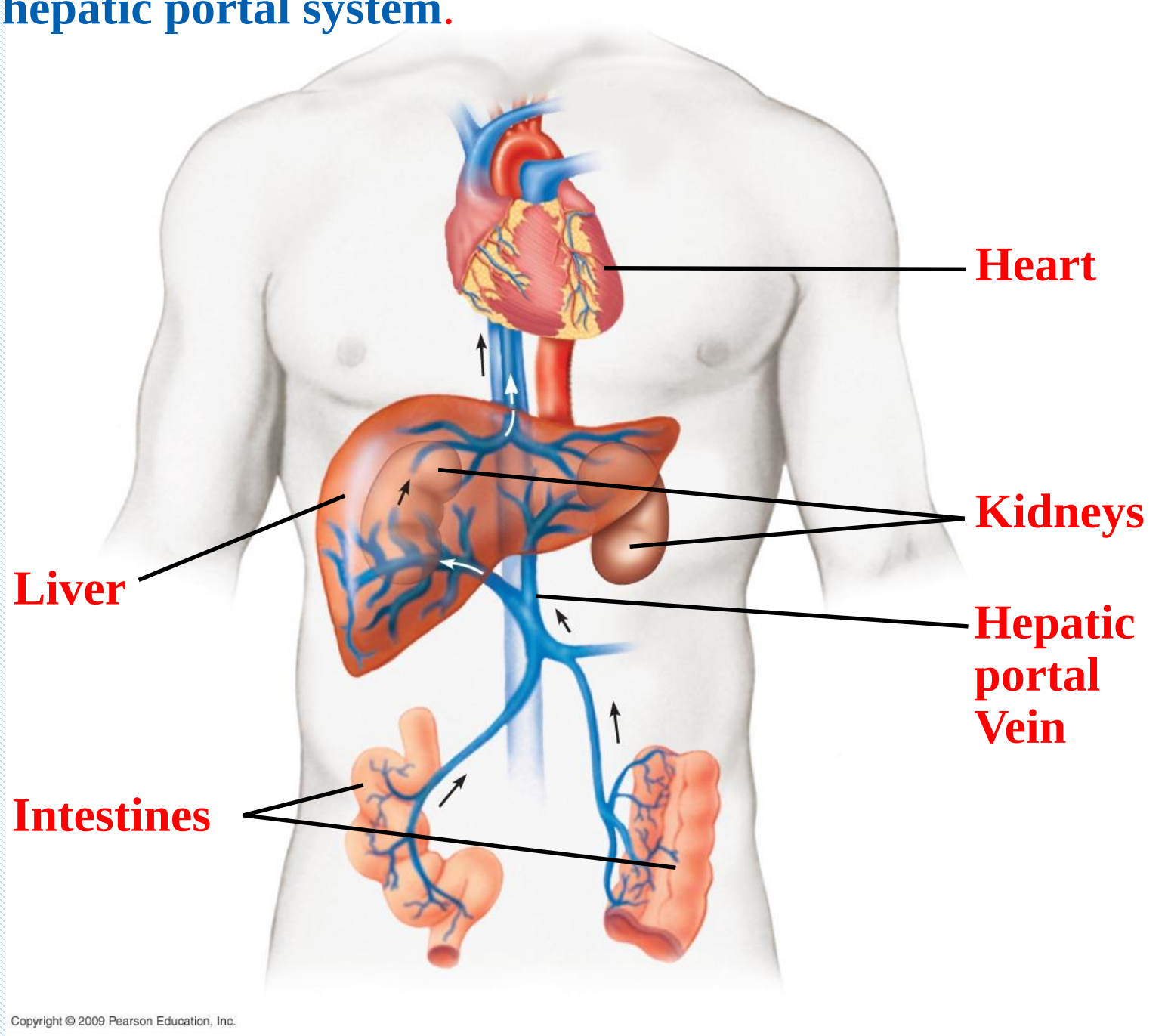
The small intestine is the major organ of chemical digestion and nutrient absorption

- Surface area for absorption is increased by
  - Folds of the intestinal lining
  - Finger-like villi
- Nutrients pass across the epithelium and into blood
- Blood flows to the liver where nutrients are processed and stored

Liver's functions

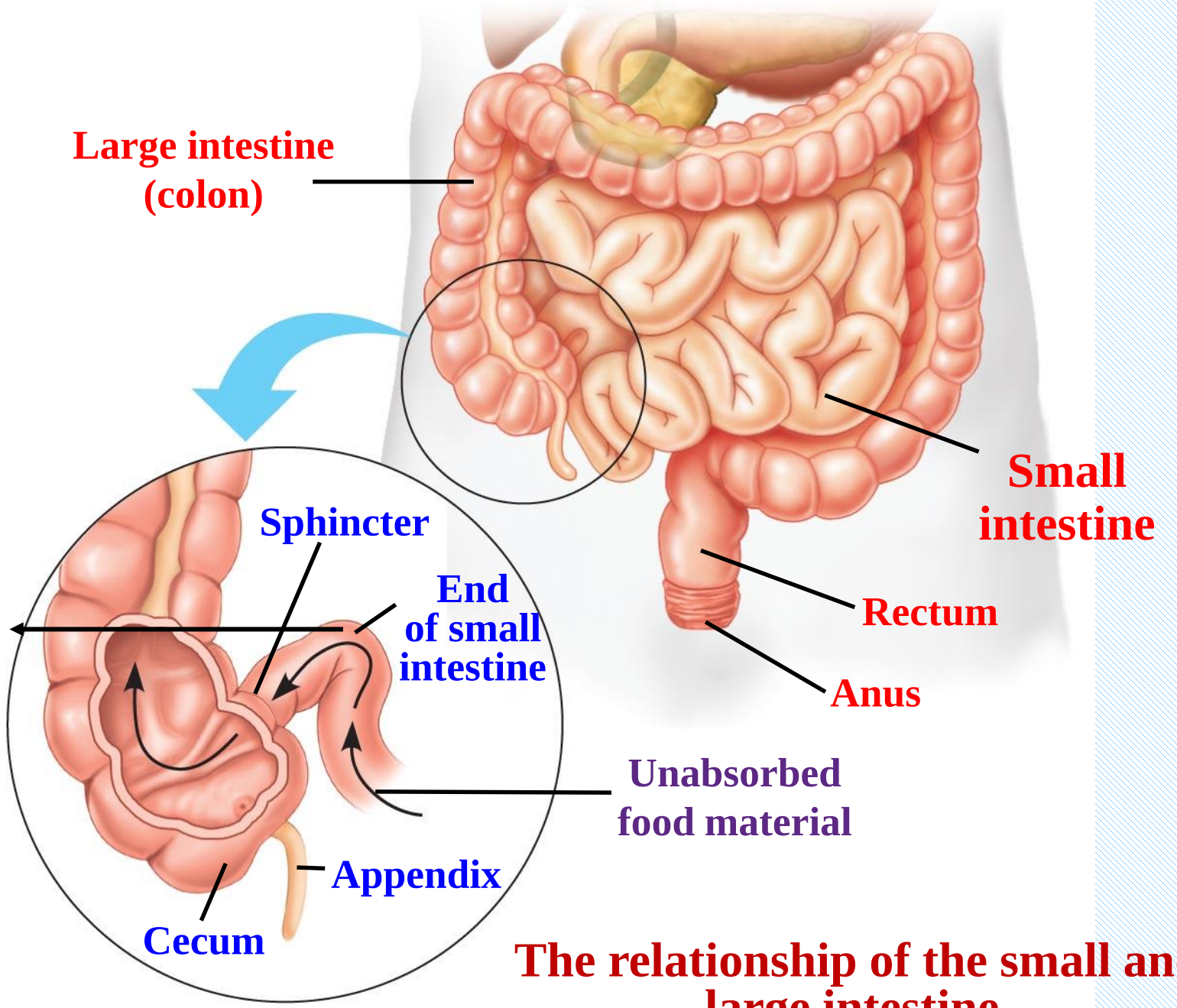
- Blood from the digestive tract drains to the liver
- The liver functions:
  1) Glucose in blood is converted to glycogen and stored in the liver
  2) Liver synthesizes many proteins including blood clotting proteins and lipoproteins that transport fats and cholesterol
  3) Liver changes toxins to less toxic forms
  4) Liver produces bile
- Storage
- Nutrients not used can be stored as
  Glycogen
  Fat

The hepatic portal system.



The large intestine reclaims water and compacts the feces

- **Diarrhea occurs when too little water is reclaimed**
- **Constipation occurs when too much water is reclaimed**
- **Feces are stored in the rectum**
- **Colon bacteria produce vitamins — biotin, vitamin K & B vitamins**
- **Appendix**
  - **Located near the junction of the small intestine and colon**
  - **Makes a minor contribution to immunity**



The relationship of the small and large intestine.

NUTRITION

A healthy diet satisfies three needs

1) Fuel to power the body

2) Organic molecules to build molecules

3) Essential nutrients — raw materials that animals cannot make for themselves like vitamins, minerals and the essential amino acids (animals cannot produce eight of the 20 amino acids named essential amino acids. These eight amino acids must come from the diet)

Chemical energy powers the body

- Nutrients are oxidized inside cells to make ATP
- Proteins, carbohydrates, and fats are the main sources of calories
- Basal metabolic rate (BMR): energy a resting animal requires each day
- Metabolic rate: BMR plus the energy needed for physical activity
- Excess energy is stored as glycogen or fat
- Our metabolic rates typically decrease throughout adulthood

Unhealthy diet

Unhealthy diets are linked to:

- **Undernourishment — not enough calories**
- **Malnourishment — missing essential nutrients**

A healthy diet includes 13 vitamins and many essential minerals

Essential vitamins and minerals

- **Required in minute amounts**
- **Extreme excesses can be dangerous**
- **Excess water-soluble vitamins can be eliminated in urine**
- **Excess fat-soluble vitamins accumulate to dangerous levels in body fat**

Essential vitamins

- **Main function is to allow chemical reactions to occur in body**
  - **Required in minute amounts**
    - **Help release energy trapped in carbohydrates, lipids and proteins**
- **13 vitamins divided into 2 groups:**
    - **Fat soluble- A, D, E, K**
    - **Water soluble- C and B vitamins**

Minerals

- **Minerals are simple inorganic nutrients include:**
- **Na^+, K^+ and Mg^{++} which usually required in small amounts**
- **Ca^{++} and $PO4^{3-}$ which are required in larger amounts**
- **They are critical for nervous system function, maintaining electrolyte levels, water balance, and skeletal system**

A Vitamin Requirements of Humans

TABLE 21.18A VITAMIN REQUIREMENTS OF HUMANS

Vitamin	Major Dietary Sources	Functions in the Body	Symptoms of Deficiency Symptoms of Extreme Excess
Water-Soluble Vitamins			
Vitamin B_1 (thiamine)	Pork, legumes, peanuts, whole grains	Coenzyme used in removing CO_2 from organic compounds	Beriberi (nerve disorders, emaciation, anemia)
Vitamin B_2 (riboflavin)	Dairy products, meats, enriched grains, vegetables	Component of coenzyme FAD	Skin lesions such as cracks at corners of mouth
Niacin (B_3)	Nuts, meats, grains	Component of coenzymes NAD^+ and $NADP^+$	Skin and gastrointestinal lesions, nervous disorders Liver damage
Vitamin B_6 (pyridoxine)	Meats, vegetables, whole grains	Coenzyme used in amino acid metabolism	Irritability, convulsions, muscular twitching, anemia Unstable gait, numb feet, poor coordination
Pantothenic acid (B_5)	Most foods: meats, dairy products, whole grains, etc.	Component of coenzyme A	Fatigue, numbness, tingling of hands and feet
Folic acid (folacin) (B_9)	Green vegetables, oranges, nuts, legumes, whole grains	Coenzyme in nucleic acid and amino acid metabolism; neural tube development in embryo	Anemia, gastrointestinal problems May mask deficiency of vitamin B_{12}
Vitamin B_{12}	Meats, eggs, dairy products	Coenzyme in nucleic acid metabolism; maturation of red blood cells	Anemia, nervous system disorders
Biotin	Legumes, other vegetables, meats	Coenzyme in synthesis of fat, glycogen, and amino acids	Scaly skin inflammation, neuromuscular disorders
Vitamin C (ascorbic acid)	Fruits and vegetables, especially citrus fruits, broccoli, cabbage, tomatoes, green peppers	Used in collagen synthesis (e.g., for bone, cartilage, gums); antioxidant; aids in detoxification; improves iron absorption	Scurvy (degeneration of skin, teeth, blood vessels), weakness, delayed wound healing, impaired immunity Gastrointestinal upset
Fat-Soluble Vitamins			
Vitamin A (retinol)	Dark green and orange vegetables and fruits, dairy products	Component of visual pigments; maintenance of epithelial tissues; antioxidant; helps prevent damage to cell membranes	Vision problems; dry, scaly skin Headache, irritability, vomiting, hair loss, blurred vision, liver and bone damage
Vitamin D	Dairy products, egg yolk (also made in human skin in presence of sunlight)	Aids in absorption and use of calcium and phosphorus; promotes bone growth	Rickets (bone deformities) in children; bone softening in adults Brain, cardiovascular, and kidney damage
Vitamin E (tocopherol)	Vegetable oils, nuts, seeds	Antioxidant; helps prevent damage to cell membranes	None well documented; possibly anemia
Vitamin K	Green vegetables, tea (also made by colon bacteria)	Important in blood clotting	Defective blood clotting Liver damage and anemia

CONNECTION: Diet can influence cardiovascular disease and cancer

- A healthy diet may reduce the risk of cardiovascular disease and cancer
- Two main types of cholesterol
  - LDL : contributes to blocked blood vessels and higher blood pressure
  - HDL : tends to reduce blocked blood vessels
- Exercise increases HDL levels
- Smoking decreases HDL levels

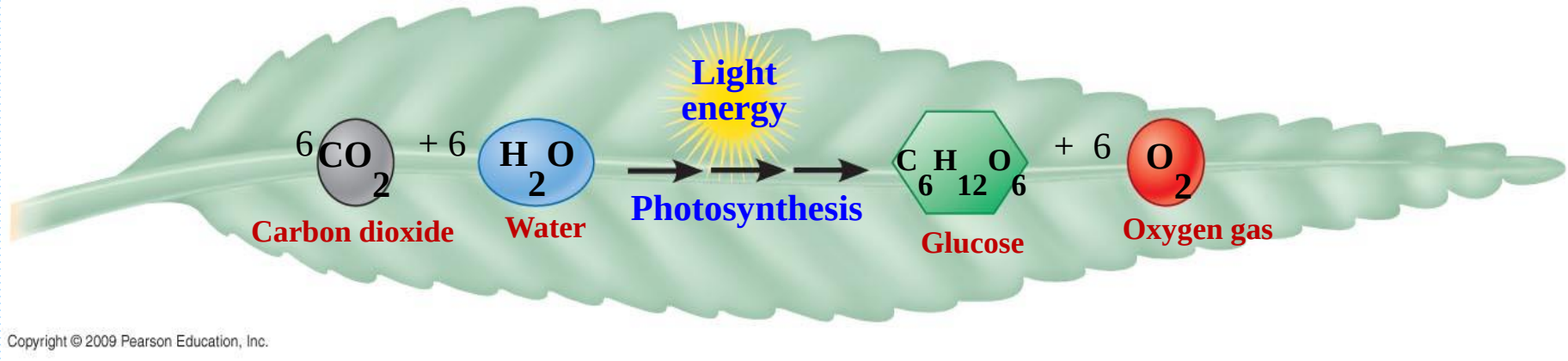
Plant Nutrition and Transport

Plant Nutrition and Transport

The uptake and transport of plant nutrients

Plants acquire their nutrients from soil and air

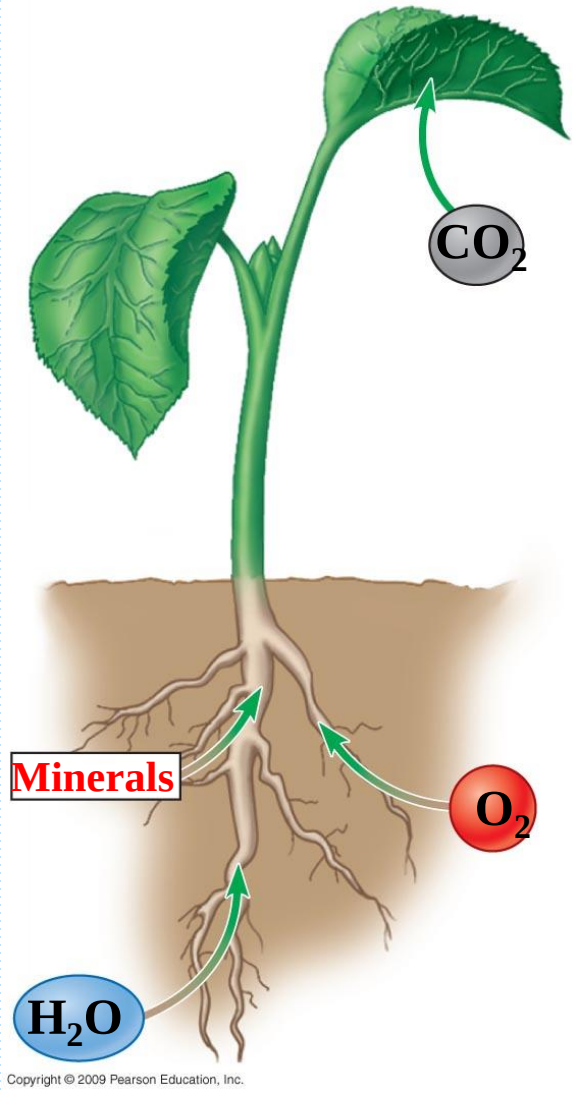
- Plants take up carbon dioxide from the air to produce sugars via photosynthesis; oxygen is produced as a product of photosynthesis



- Plants obtain water, minerals, and some oxygen from the soil. Using simple sugars as an energy source and as building blocks, plants convert the inorganic molecules they take up into the organic molecules of living plant tissue

Plants acquire their nutrients from soil and air

- **Inorganic molecules taken up by plants**
  - Carbon dioxide
  - Nitrogen
  - Magnesium
  - Phosphorus
- **Organic molecules produced by plants**
  - Carbohydrates
  - Lipids
  - Proteins
  - Nucleic acids



Uptake of nutrients by a plant

The plasma membranes of root cells control solute uptake

- Minerals taken up by plant roots are in a watery solution
- Water and minerals are absorbed through the epidermis of the root and must be taken up by root cells before they enter the xylem
- Selective permeability of the plasma membrane of root cells controls what minerals enter the xylem

Pathways by which water and minerals enter the xylem

- There are two pathways by which water and minerals enter the xylem

  1) **Intracellular route:** water and solutes are selectively taken up by a root epidermal cell, usually a root hair, and transported from cell to cell through plasmodesmata

  2) **Extracellular route:** water and solutes pass into the root in the porous cell walls of root cells; they do not enter any cell plasma membrane until they reach the root endodermis

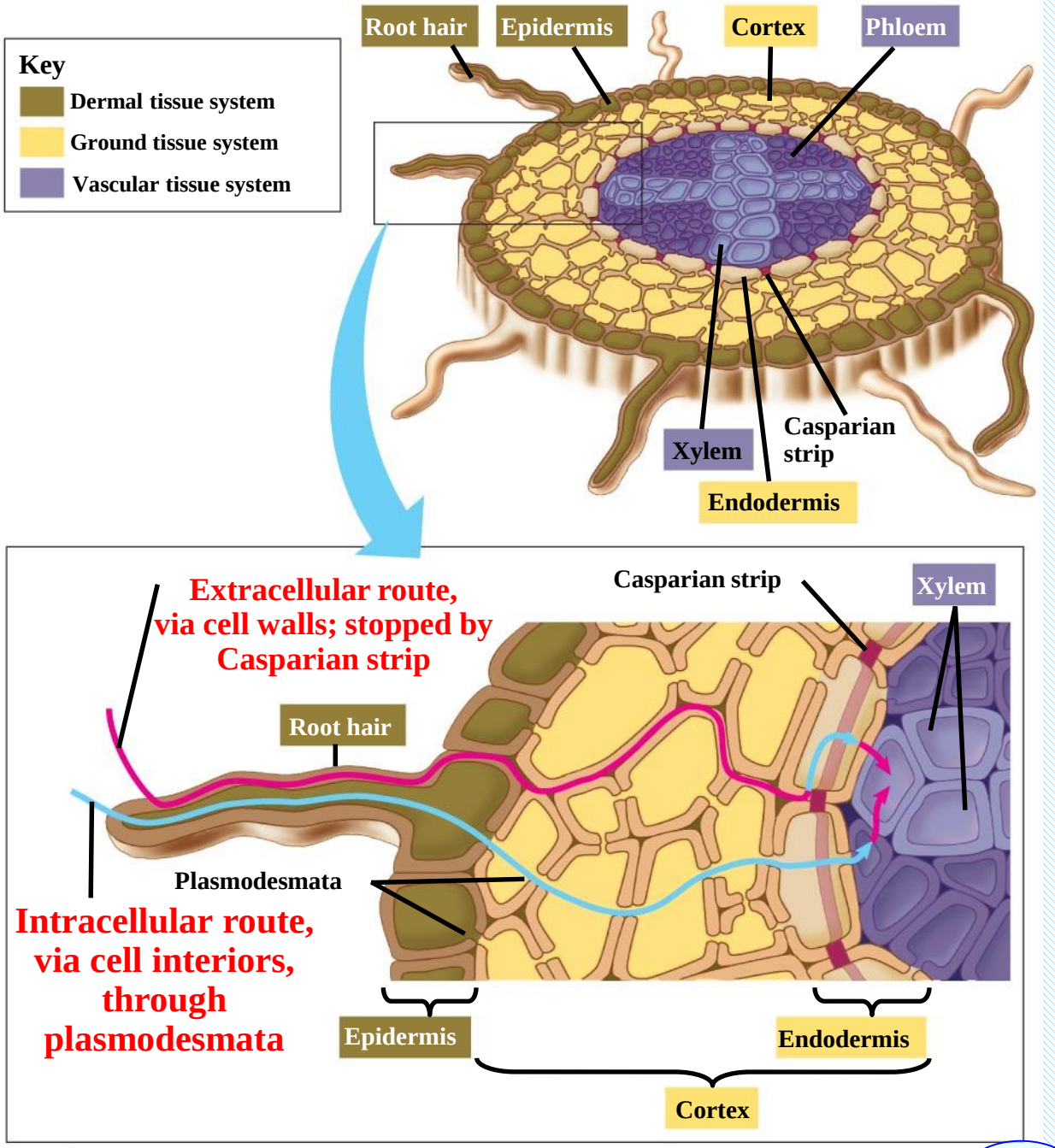
- The cells of the endodermis contain a waxy barrier called the Casparian strip

  – Specialized cells of the endodermis take up water and minerals selectively

  – The Casparian strip regulates uptake of minerals that enter the root via the extracellular route

Root hairs of radish seedling

Routes of water and solutes from soil to root xylem

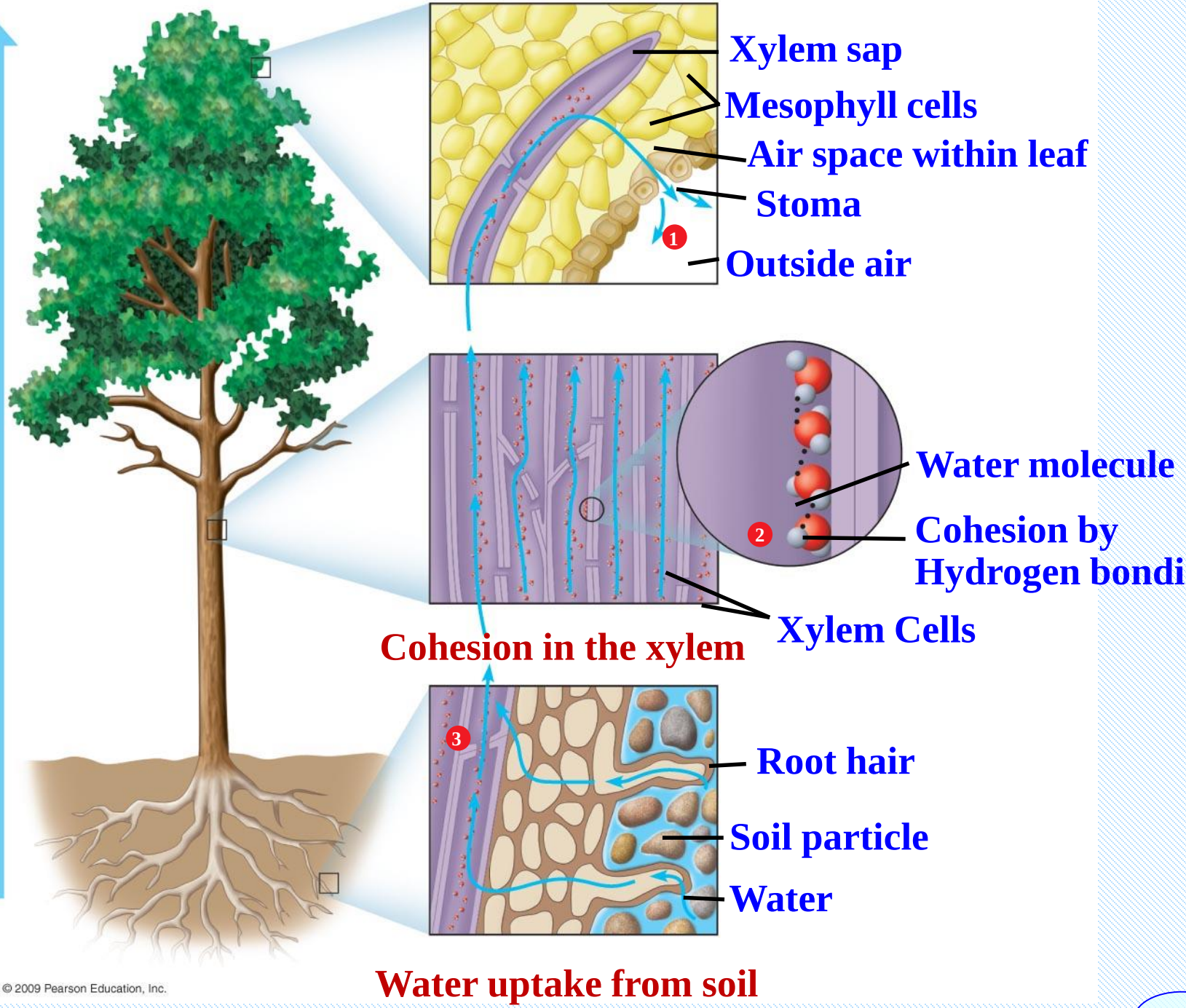


Transpiration pulls water up in xylem vessels

- Evaporation of water from the surface of leaves, called transpiration, is the driving force for the movement of xylem sap
- Xylem sap is the solution carried up through a plant in tracheids and vessel elements
- Xylem sap is pulled up through roots and shoots to the leaves
- Water's cohesion and adhesion allow water to be pulled up to the top of the highest trees

Transpiration pulls water up xylem vessels

- **Transpiration-cohesion-tension mechanism**
  - Water's cohesion describes its ability to stick to itself
  - Water's adhesion describes its ability to stick to other surfaces; water adheres to the inner surface of xylem cells
  - A steep diffusion gradient pulls water molecules from the surface of leaves into much drier air
  - The air's pull on water creates a tension that pulls on water in the xylem; since water is cohesive, it is pulled along, much as when a person sucks on a straw



Guard cells control transpiration

- Plants must open pores in leaves called stomata to allow CO_2 to enter for photosynthesis
- Water evaporates from the surface of leaves through stomata
- Paired guard cells surround each stoma
- Guard cells can regulate the amount of water lost from leaves by changing shape and closing the stomata pore

Guard cells control transpiration

- Stomata open as a result of a rise in potassium levels, and close when the levels fall.
- Stomata open when guard cells take up water
  - 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 causes 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

Stoma opening

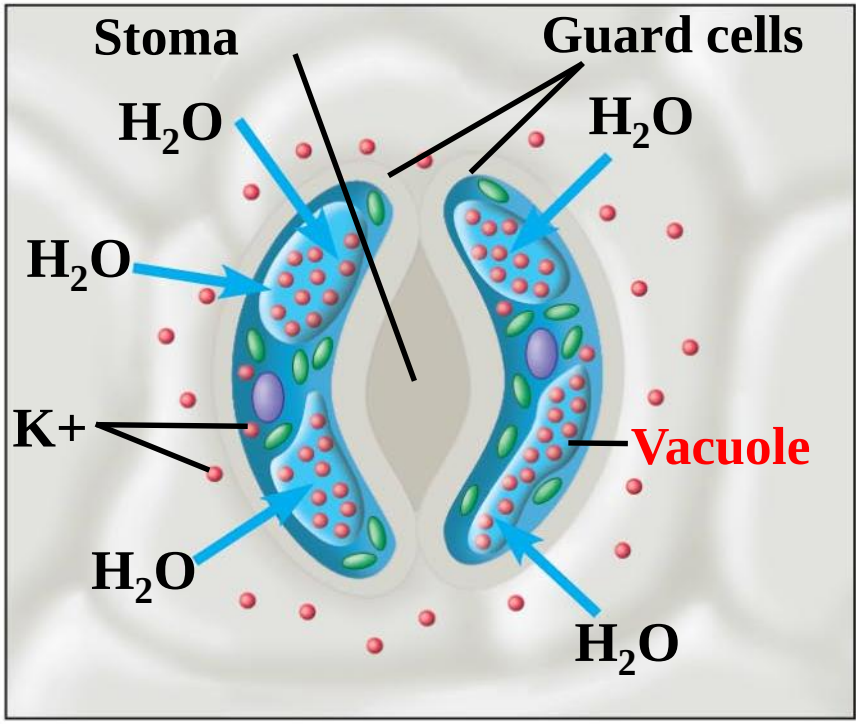
More K^+ inside guard cell

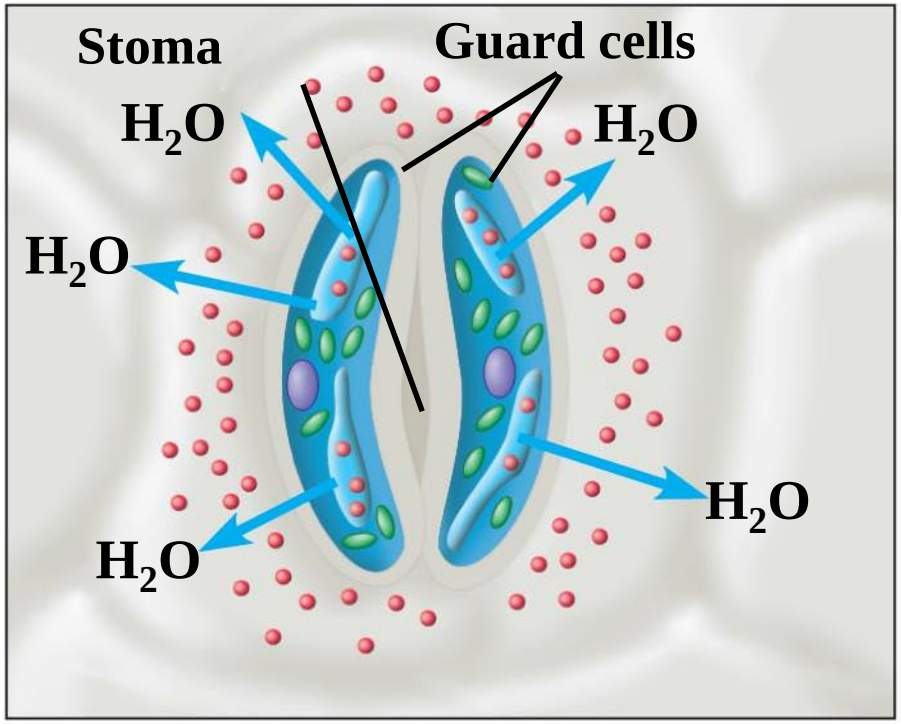
Day time
Low CO_2
Natural Rhythms

Stoma closing

Less K^+ inside guard cell

Night time
High CO_2
Natural Rhythms





How guard cells control stomata

Phloem transports sugars

- **Phloem transports the products of photosynthesis throughout the plant**
  - **Phloem is composed of long tubes of sieve tube members stacked end to end**
  - **Phloem sap moves through sieve plates in sieve tube members**
  - **Phloem sap is composed of sucrose and other solutes such as ions, amino acids, and hormones**
  - **Sugars are carried through phloem from sources to sinks**

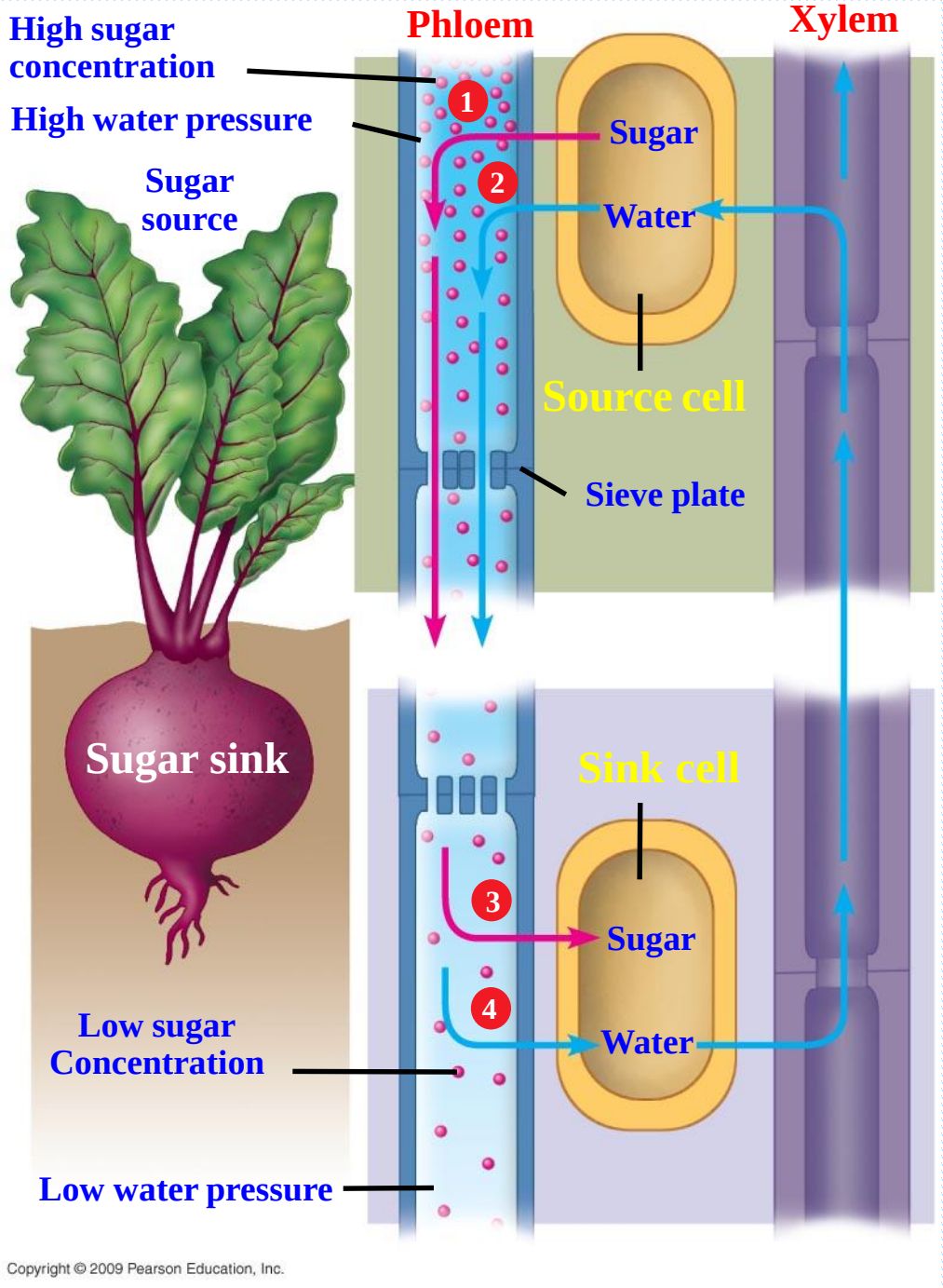
Sugar source and Sugar sink

- A sugar source is a plant organ that is a net producer of sugar via photosynthesis or breakdown of starch
  - Leaves produce sugars via photosynthesis
  - Roots and other storage organs produce sugar via breakdown of starch
- A sugar sink is a plant organ that is a net consumer of sugar or one that stores starch
  - Growing organs use sugar in cellular respiration
  - Roots and other organs store unused sugars as starch

The pressure flow mechanism that transports sugars in the Phloem from source to sink

- **The pressure flow mechanism**
  - At sources, sugars are actively loaded into sieve tube members
  - High solute concentration caused by the sugar in sieve tubes causes water to rush in from nearby xylem cells
  - Flow of water into sieve tubes increases pressure at sources
  - At sinks, sugars are unloaded from sieve tubes and solute concentration decreases; water is lost and pressure is low
  - The pressure gradient drives rapid movement of sugars from sources to sinks

Pressure flow in plant phloem from a sugar source to a sugar sink (and the return of water to the source via xylem)



PLANT NUTRIENTS AND THE SOIL

8-6 Plant health depends on a complete diet of essential inorganic nutrients

- **Essential elements** are those that a plant must obtain to complete its life cycle of growth and reproductive success
- There are 17 elements essential to plant growth and reproduction
  - **Macronutrients** — plants require relatively large amounts of these elements
  - **Micronutrients** — plants require relatively small amounts of these elements
  - Both types of nutrients have vital functions

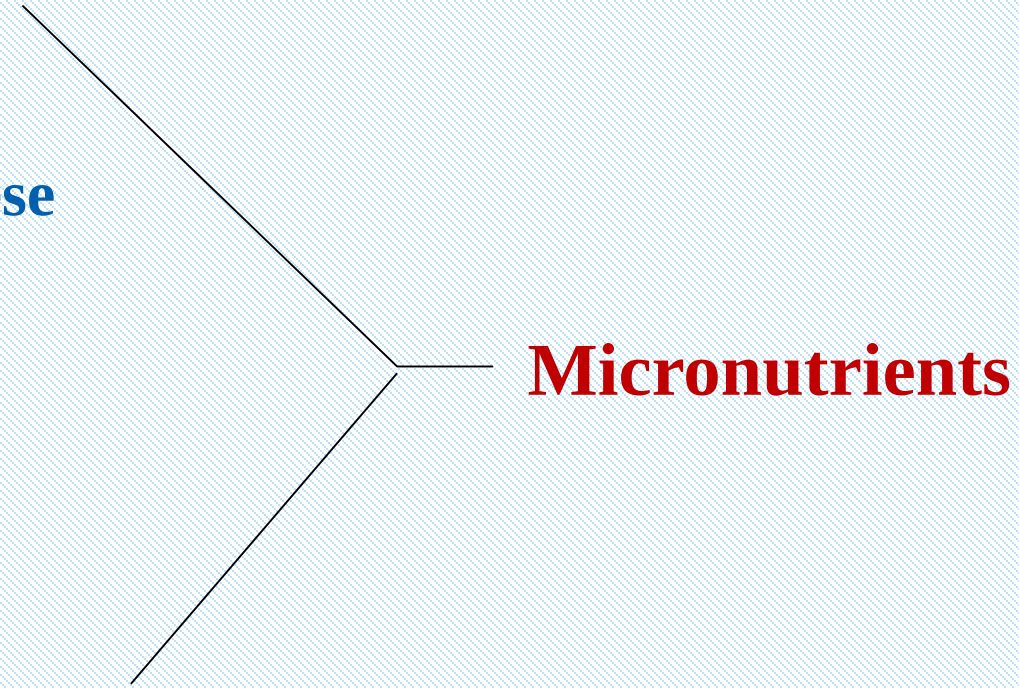
8-6 Plant health depends on a complete diet of essential inorganic nutrients

- **Macronutrients — components of organic molecules**
  - Carbon
  - Hydrogen
  - Oxygen
  - Nitrogen
  - Sulfur
  - Phosphorus
  - Potassium
  - Calcium
  - Magnesium

Make up 98% of plant dry weight

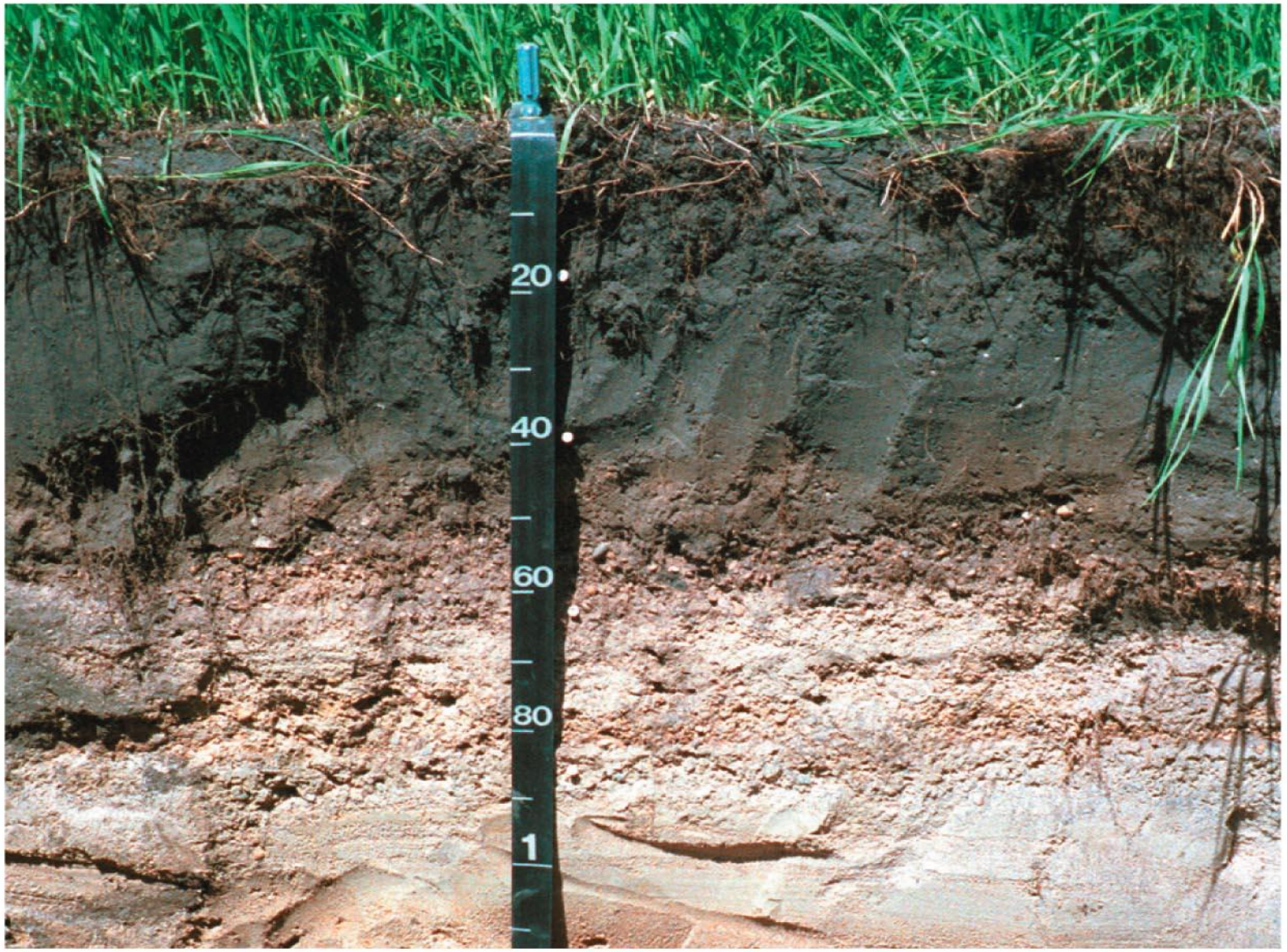
8.6 Plant health depends on a complete diet of essential inorganic nutrients

- **Micronutrients — often act as cofactors**
  - Chlorine
  - Iron
  - Manganese
  - Boron
  - Zinc
  - Copper
  - Nickel
  - Molybdenum



Fertile soil supports plant growth

- Soils are affected by geography and climate
- Soil horizons are layers of soil with different characteristics
  - A horizon — topsoil subject to weathering; layer contains humus (decayed organic matter) and many soil organisms
  - B horizon — clay and dissolved elements
  - C horizon — rocks of the "parent material" from which soil is formed



Three soil horizons visible beneath grass

PLANT NUTRITION AND SYMBIOSIS WITH BACTERIA

Most plants depend on bacteria to supply nitrogen

- Most of the nitrogen in the biosphere is in the atmosphere as N_2 gas
- Plants can only absorb nitrogen as ammonium or nitrates from the soil; they cannot absorb it from air

Most plants depend on bacteria to supply nitrogen

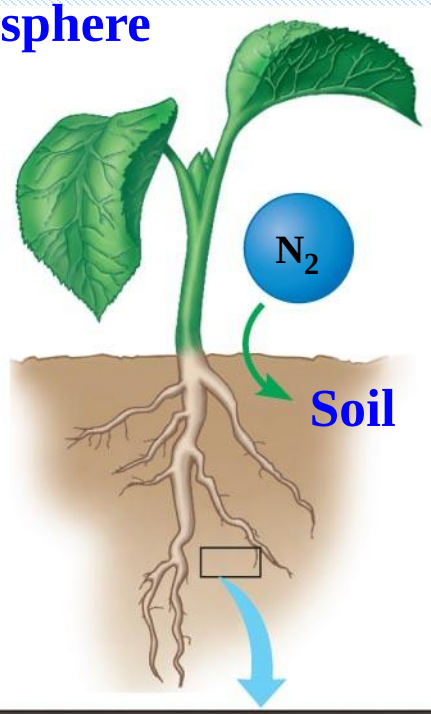
- **Soil bacteria can convert N_2 gas from the air into forms usable by plants via several processes**

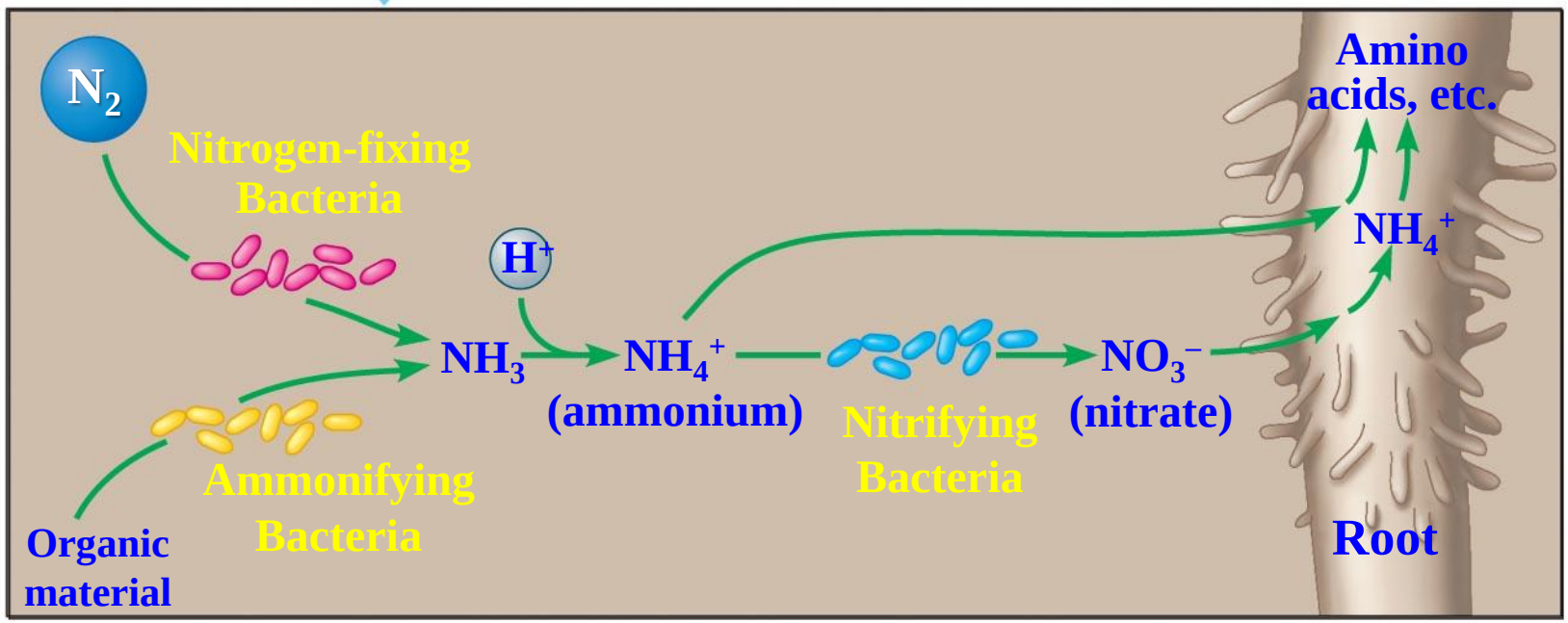
1) **Nitrogen fixation — N_2 is converted to ammonia**

2) **Ammonification — conversion of organic matter into ammonium**

3) **Nitrification — conversion of ammonium to nitrates, the form most often taken up by plants**

The roles of bacteria in supplying nitrogen to plants





The plant kingdom includes epiphytes, parasites and carnivores

1. Epiphytes

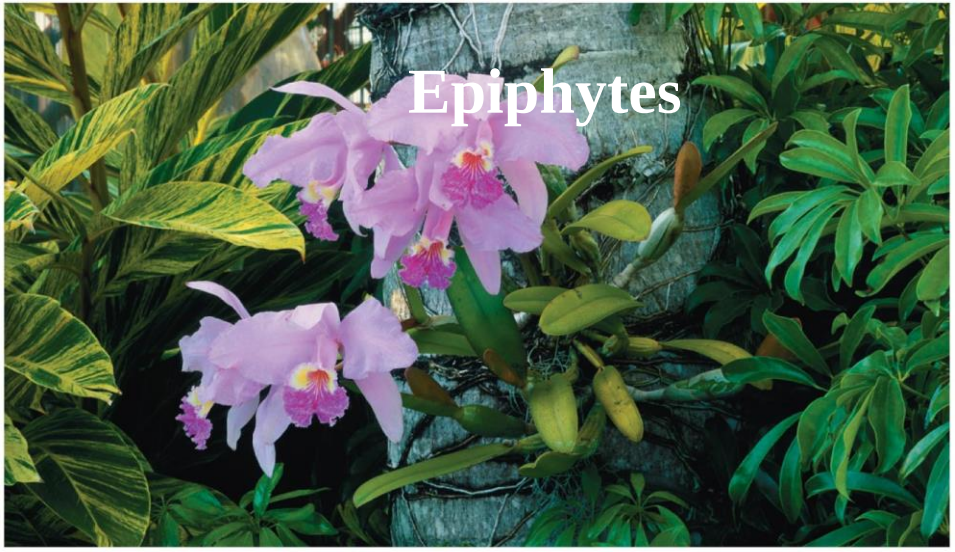
- Grow anchored on other plants
- Absorb water and minerals from rain

2. Parasites

- Roots tap into the host plant's vascular system
- Incapable of photosynthesis
- Absorb organic molecules from host plant

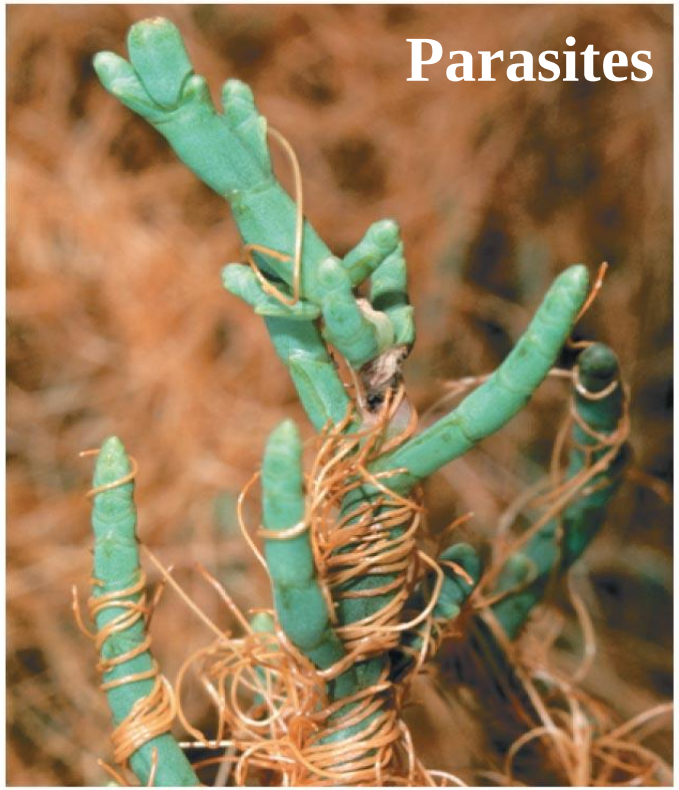
3. Carnivores

- Trap and digest small animals such as insects
- Absorb inorganic elements from prey
- Found in nutrient poor environments



Orchids, a type of epiphyte, growing on the trunk of a tree

A Venus' flytrap digesting a fly



Dodder growing on a pickle weed