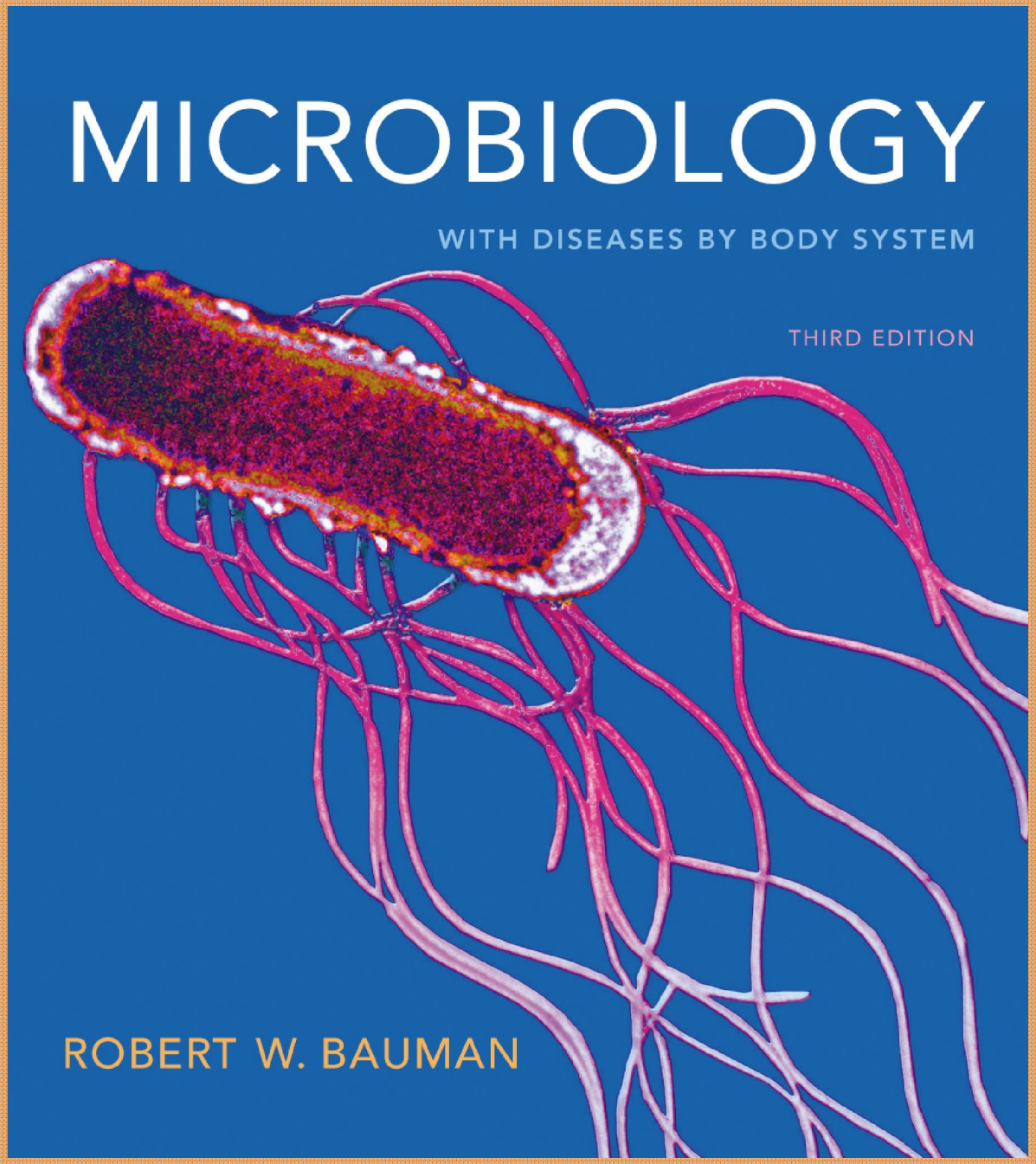


# Chapter 25

# Applied and Environmental Microbiology

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# Food Microbiology

- **Microorganisms are involved in producing many foods and beverages**
- **Fermentation produces desirable characteristics of various foods**
- **Microbial metabolism has other functions**
  - Acts as a preservative
  - Destroys many pathogenic microbes and toxins
  - Can add nutritional value in form of vitamins or other nutrients
- **Microbes are used in food production**
- **Microbes can help control food spoilage**

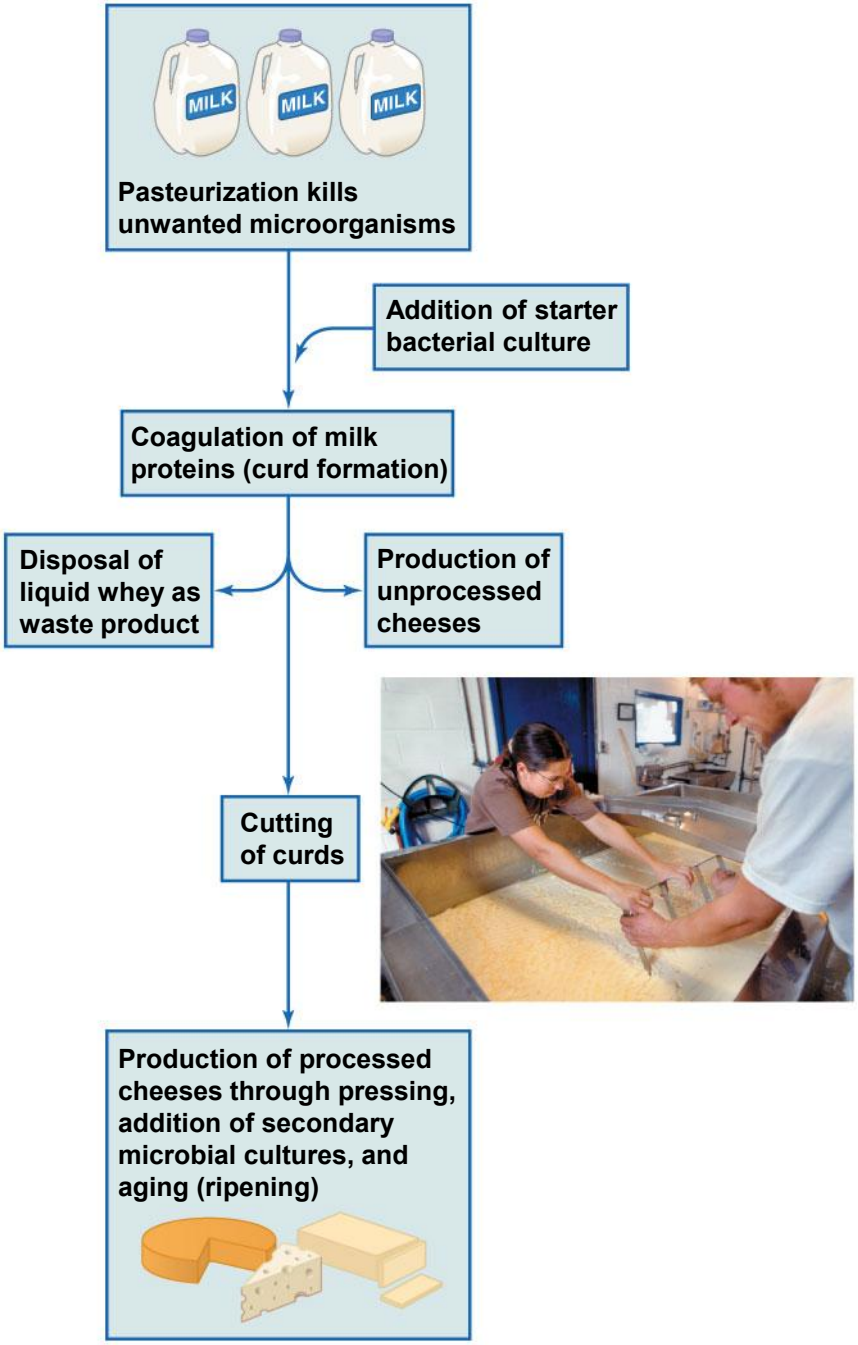
# Food Microbiology

- **The Roles of Microorganisms in Food Production**
  - Fermentation
    - Any desirable change to a food or beverage that occurs as a result of microbial growth
  - Spoilage is unwanted change to a food due to various reasons
    - Undesirable metabolic reactions
    - Growth of pathogens
    - Presence of unwanted microorganisms in the food

# Food Microbiology

- **The Roles of Microorganisms in Food Production**
  - Use starter cultures in commercial food and beverage production
    - Composed of known microorganisms
      - Consistently perform specific fermentations
  - Many common products result from fermentation of vegetables, meats, and dairy products

**Figure 25.1 The cheese-making process**



# Food Microbiology

- **The Roles of Microorganisms in Food Production**
  - Products of alcoholic fermentation
    - Alcoholic fermentation
      - Microorganisms convert simple sugars into alcohol and carbon dioxide
    - Specific starter cultures used in commercial applications of alcohol fermentation
    - Various alcoholic products made through fermentation

**Figure 25.2 The wine-making process**

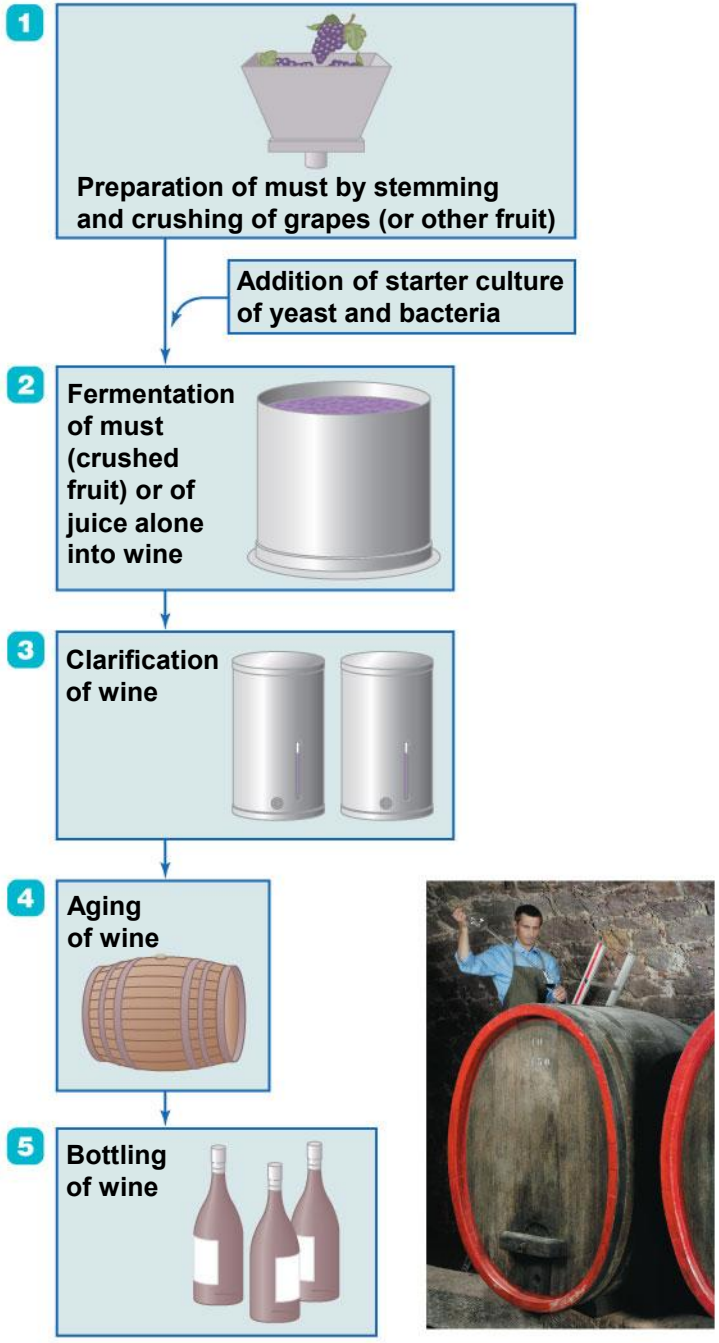
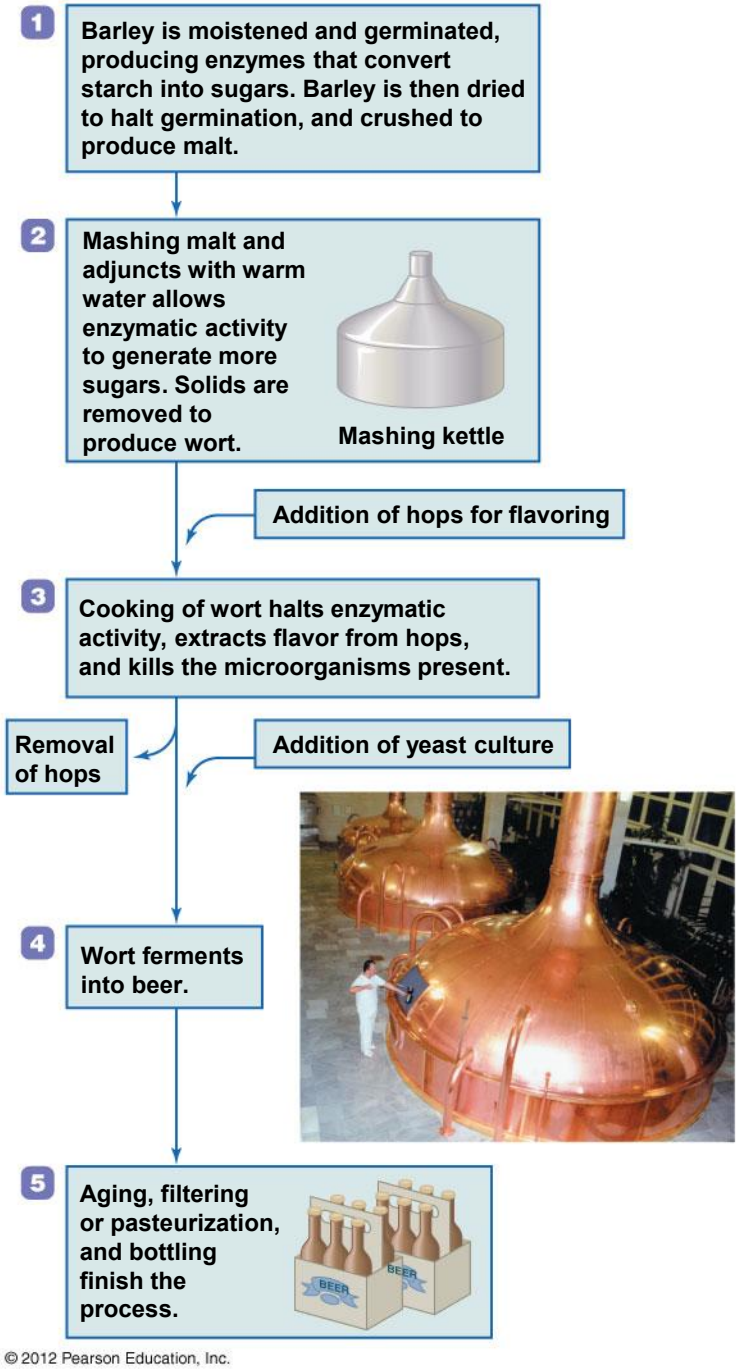


**Figure 25.3 The beer-brewing process**



- **The Causes of Food Spoilage**
  - Food spoilage results from intrinsic or extrinsic factors
    - Intrinsic factors are inherent properties of the food itself
    - Extrinsic factors involved with processing or handling of food

**Table 25.2 Factors Affecting Food Spoilage**

TABLE 25.2

## Factors Affecting Food Spoilage

| | Foods at Greatest Risk of Spoilage | Food at Least Risk of Spoilage |
|---|---|---|
| **Intrinsic Factors** | | |
| **Nutritional composition** | Chemically rich or fortified foods (steak, bread, yogurt) | Chemically limited foods (flour, cereals, grains) |
| **Water activity** | Moist foods (meat, milk) | Dry foods or those with low water activity (pasta, jam) |
| **pH** | Foods with neutral pH (bread) | Foods with low pH (orange juice, pickles) |
| **Physical structure** | Foods without rinds, skins, or shells; ground meat | Foods with rinds, skins, or shells; intact foods |
| **Microbial competition** | Foods that lack natural microbe populations (ground beef) | Foods with resident microbial populations (pickles) |
| **Extrinsic Factors** | | |
| **Degree of processing** | Unprocessed foods (raw milk, fruit) | Processed foods (pasteurized foods) |
| **Amount of preservatives** | Foods without preservatives (meats, natural foods) | Foods with either naturally occurring or added preservatives (garlic, spices, sulfur dioxide) |
| **Storage temperature** | Foods left in warm conditions | Foods kept cold |
| **Storage packaging** | Foods stored exposed | Foods wrapped or sealed |

- **The Causes of Food Spoilage**
  - Classifying foods in terms of potential for spoilage
    - Three categories based on likelihood of spoilage
      - Perishable
        - Nutrient rich, moist, and unprotected by coverings
      - Semi-perishable
        - Can store sealed for months without spoiling
        - Many fermented foods are semi-perishable
      - Nonperishable
        - Dry or canned foods that can be stored indefinitely
        - Often nutrient poor, dried, fermented, or preserved

# Food Microbiology

- **The Causes of Food Spoilage**
  - The prevention of food spoilage
    - Food-processing methods
      - Industrial canning
        - Eliminates mesophilic bacteria and endospores
      - Pasteurization
        - Lowers microbe numbers, but some microbes survive
      - Lyophilization
        - A vacuum draws off ice crystals from frozen foods
      - Gamma radiation
        - Can achieve complete sterilization

**Figure 25.4 Industrial canning**

# Food Microbiology

- **The Causes of Food Spoilage**
  - The prevention of food spoilage
    - Use of preservatives
      - Salt and sugar remove water from the food
      - Garlic contains allicin, which inhibits enzyme function
      - Benzoic acid interferes with enzymatic function
      - Certain spices and herbs interfere with the functions of membranes of microorganisms
      - Chemical preservatives can be purposely added to foods

# Food Microbiology

- **The Causes of Food Spoilage**
  - The prevention of food spoilage
    - Attention to temperature during processing and storage
      - High temperatures desirable to prevent food spoilage
        - Proteins and enzymes become denatured
      - Low temperatures are desirable for food storage
        - Cold slows metabolism and retards microbial growth
        - *Listeria monocytogenes* can grow in cold storage
        - Found in certain dairy products

# Food Microbiology

- **Foodborne Illnesses**
  - Consumption of spoiled foods or foods containing harmful microbes or their products
  - Two categories of food poisoning
    - Food infections
      - Consumption of living microorganisms
    - Food intoxications
      - Consumption of microbial toxins rather than the microbe
  - Symptoms include nausea, vomiting, diarrhea, fever, fatigue, and muscle cramps

# Industrial Microbiology

- **Important field within the microbiological sciences**
- **Industrial microbiology used in various applications**
  - Microbes in fermentation
  - Microbes in the production of several industrial products
  - Treatment of water and wastewaters
  - Disposal and cleanup of biological wastes
  - Treatment of mine drainage

# Industrial Microbiology

- **The Roles of Microbes in Industrial Fermentations**
  - Industrial fermentations
    - Large-scale growth of particular microbes for producing beneficial compounds
    - Examples include amino acids and vitamins

# Industrial Microbiology

- **The Roles of Microbes in Industrial Fermentations**
  - Primary metabolites
    - Produced during active growth and metabolism
    - Required for reproduction or are by-products of metabolism
  - Secondary metabolites
    - Produced after the culture has entered stationary growth
    - Substances are not immediately needed for growth

**Figure 25.5 Fermentation vats**

# Industrial Microbiology

- **Industrial Products of Microorganisms**
  - Microorganisms produce array of industrially useful chemicals
  - Recombinant organisms add to this diversity
    - Produce substances not normally made by microbial cells

# Industrial Microbiology

- **Industrial Products of Microorganisms**
  - Enzymes and other industrial products
    - Microbial products used as food additives and supplements
    - Include vitamins, amino acids, organic acids, dyes
  - Alternative fuels
    - Some microbes produce carbohydrates used as fuels
    - Other microbes convert biomass into renewable fuels
  - Pharmaceuticals
    - Includes antimicrobials, recombinant hormones, and other cell regulators

**Figure 25.6 Burning methane gas released from a landfill**

# Industrial Microbiology

- **Industrial Products of Microorganisms**
  - Pesticides and agricultural products
    - Microbes used to help crop management
  - Biosensors and bioreporters
    - Use of microorganisms to solve environmental problems
    - Biosensors
      - Bacteria or microbial products combined with electronic measuring devices
    - Bioreporters
      - Composed of microbes with innate signaling capabilities

# Industrial Microbiology

- **Water Treatment**
  - Water pollution
    - Water pollution can occur three ways
      - Physically
      - Chemically
      - Biologically
    - Polluted waters support a greater than normal microbial load

# Industrial Microbiology

- **Water Treatment**
  - Waterborne illnesses
    - Consuming contaminated water can cause various diseases
      - Diarrheal diseases occur worldwide
    - Waterborne diseases rare in the United States
      - Outbreaks are point-source infections
    - Water treatment removes most waterborne pathogens

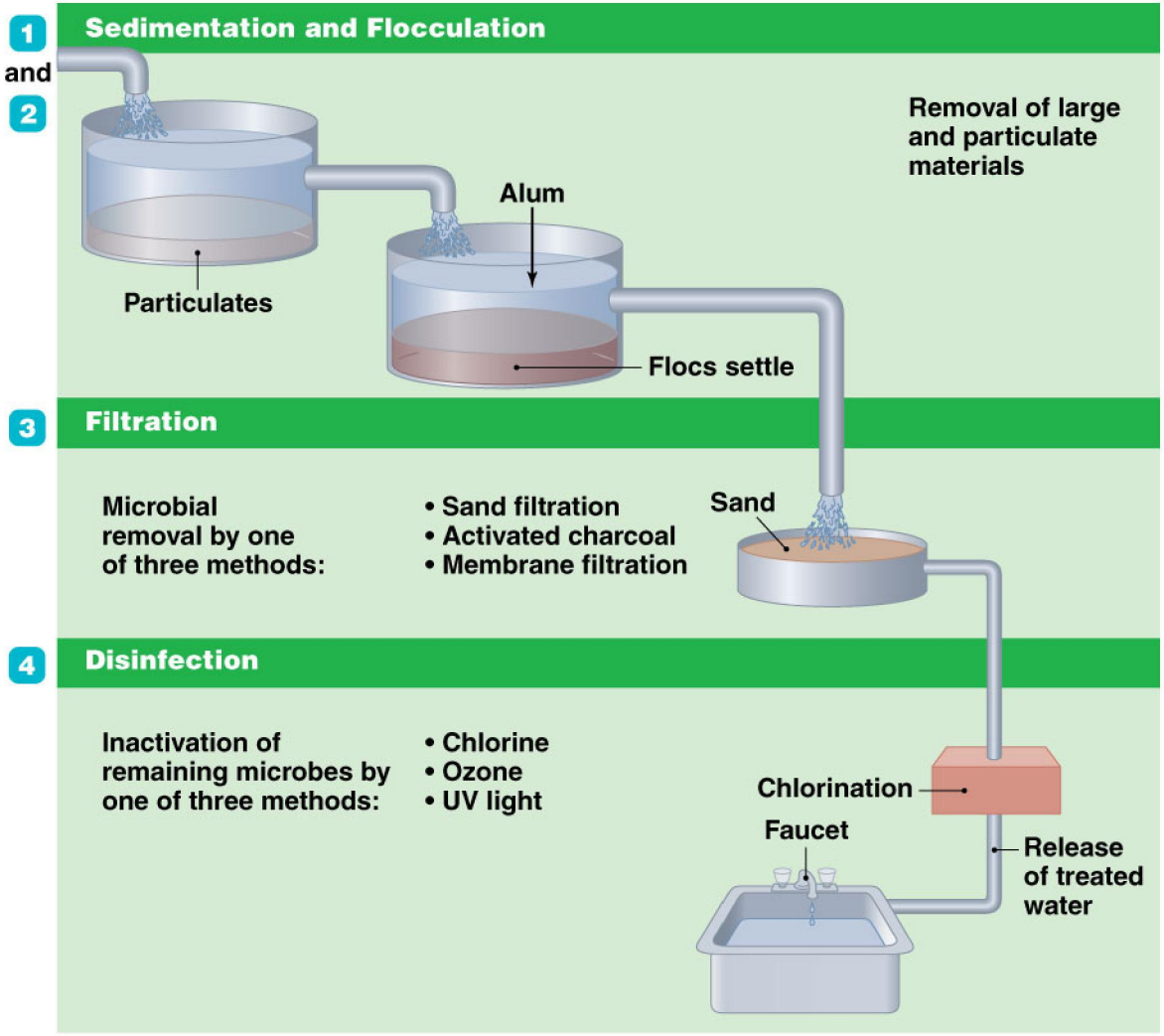
# Industrial Microbiology

- **Water Treatment**
  - Treatment of drinking water
    - Potable water is water considered safe to drink
      - Water is not devoid of microorganisms and chemicals
        - Levels are low enough that they are not a health concern
    - Presence of coliforms in water indicates fecal contamination
      - Increased likelihood that disease-causing microbes are present
    - Treatment of drinking water involves four stages

**Figure 25.7 The treatment of drinking water-overview**

(a)



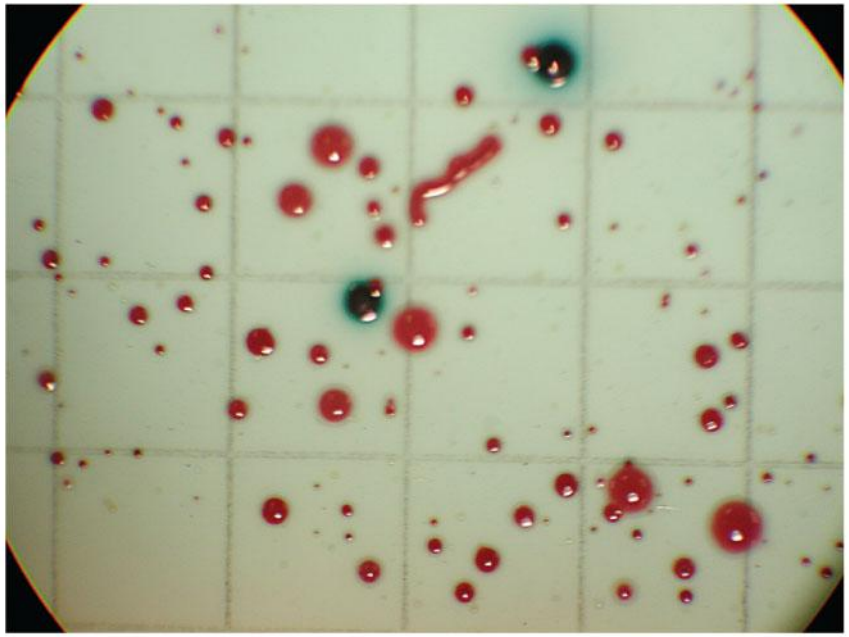



(b)

# Industrial Microbiology

- **Water Treatment**
  - Water quality testing
    - Majority of waterborne illnesses caused by fecally contaminated water
    - Indicator organisms signal possible presence of pathogens
      - *E. coli* or other coliforms used as indicator organisms
      - *E. coli* is a good indicator organism
        - Consistently found in human waste
        - Survives in water as long as most pathogens
        - Easily detected by simple tests

**Figure 25.8 Two water quality tests-overview**



(a)

(b)

# Industrial Microbiology

- **Water Treatment**
  - Treatment of wastewater
    - Wastewater
      - Water that leaves homes or businesses after use
    - Wastewater contains a variety of contaminants
    - Treatment intended to remove or reduce contaminants
    - Processed to reduce the biochemical oxygen demand (BOD)
      - Oxygen needed by aerobic bacteria to metabolize wastes
      - Levels reduced so unable to support microbial growth

## Figure 25.9 Traditional sewage treatment-overview

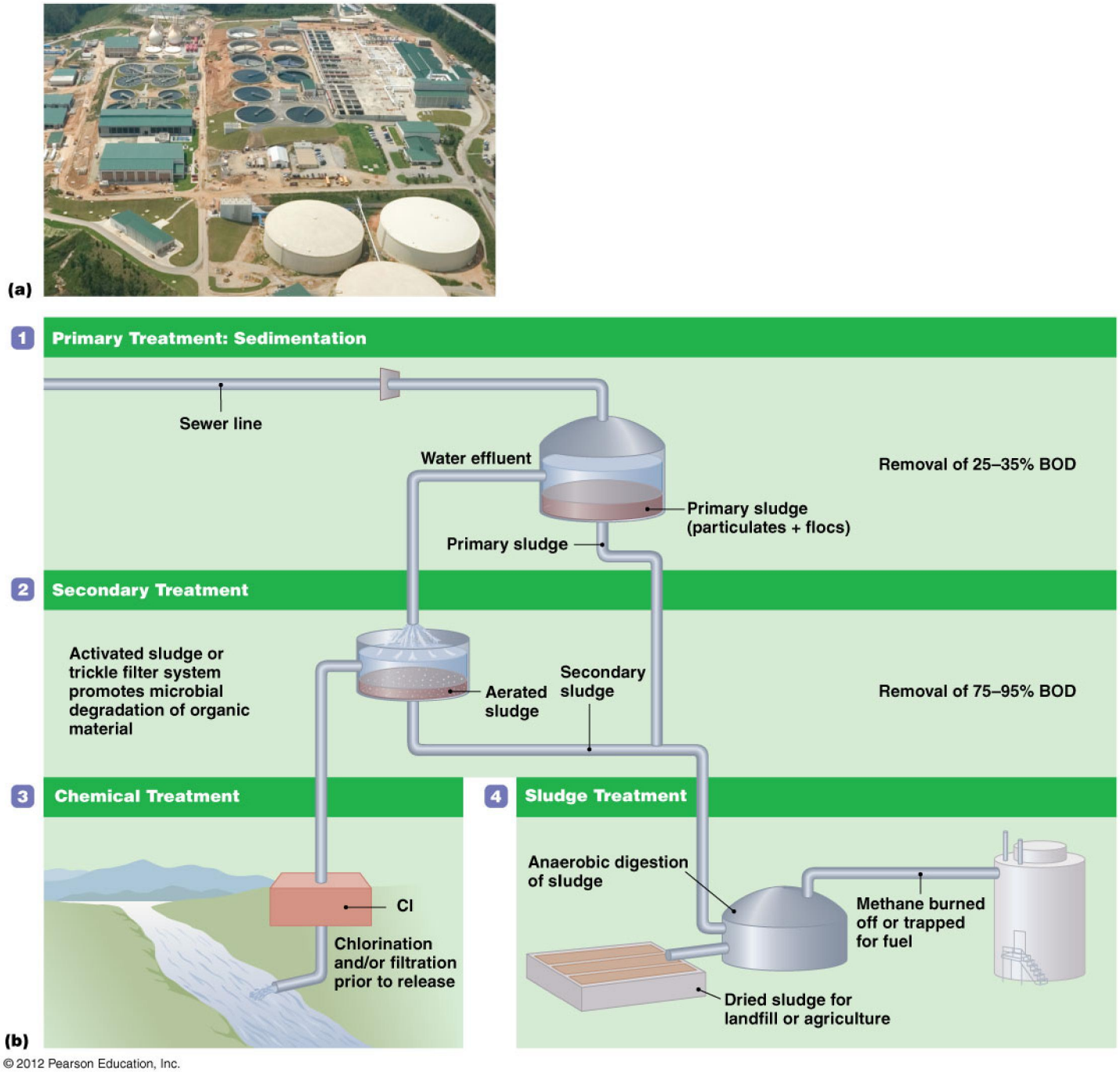


**Figure 25.10 A home septic system**

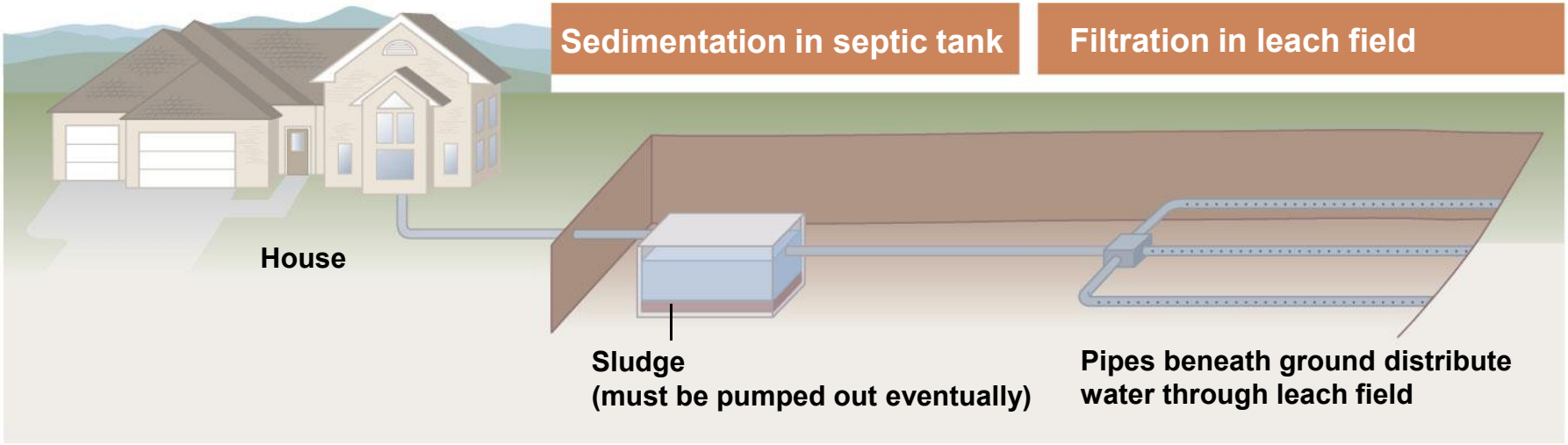


**Figure 25.11 Wastewater treatment in an artificial wetland**

Houses and businesses of planned community release sewage

**Pond 1: Aeration**
- Aerobic digestion of wastes in water column
- Anaerobic digestion of wastes in sludge

Water

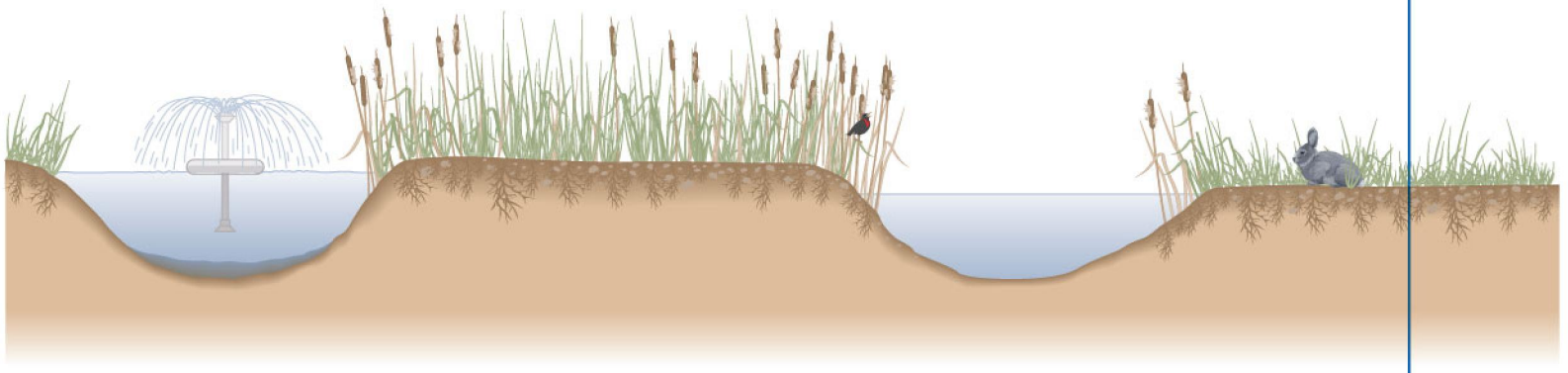
**Marsh**
- Soil microbes digest organics

Water

**Pond 2: Still water**
- Algae continue digestion of organics

Water

**Meadow**
- Grasses filter out pollutants



Water release into third pond or waterway

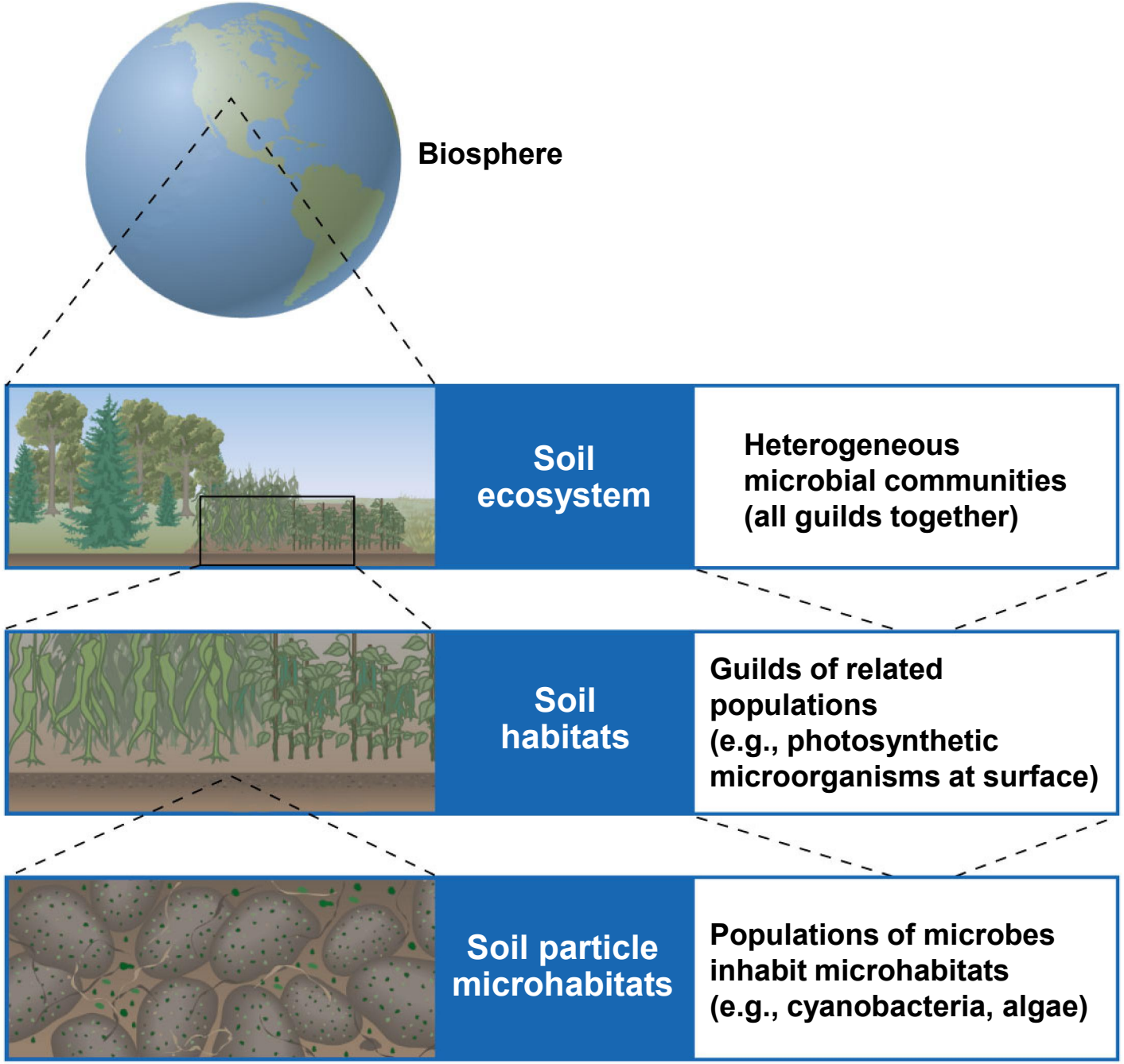
# Environmental Microbiology

- Studies the microorganisms as they occur in their natural habitats
- Microbes flourish in every habitat on Earth
- Microbes are important to the cycling of chemical elements

# Environmental Microbiology

- **Microbial Ecology**
  - Study of the interrelationships among microorganisms and the environment
  - Two aspects to consider
    - Levels of microbial associations in the environment
    - Role of adaptation in microbial survival

**Figure 25.12 The basic relationships among microorganisms and between microorganisms and the environment**



# Environmental Microbiology

- **Microbial Ecology**
  - Role of adaptation in microbial survival
    - Most microorganisms live in harsh environments
      - Microbes must be specially adapted to survive
    - Microbes must adapt to constantly varying conditions
    - Extremophiles
      - Adapted to extremely harsh conditions
        - Can survive only in these habitats

# Environmental Microbiology

- **Microbial Ecology**
  - Role of adaptation in microbial survival
    - Biodiversity held in balance by various checks
      - Competition
      - Antagonism
      - Cooperation

# Environmental Microbiology

- **Bioremediation**
  - Uses organisms to clean up toxic, hazardous, or recalcitrant compounds by degrading them to harmless compounds
  - Most known application is use of bacteria to clean oil spills

# Industrial Microbiology

- **Two Types of Bioremediation**
  - Natural bioremediation
    - Microbes “encouraged” to degrade toxic substances in soil or water
    - Addition of nutrients stimulate microbe growth
  - Artificial bioremediation
    - Genetically modified microbes degrade specific pollutants

# Industrial Microbiology

- **The Problem of Acid Mine Drainage**
  - Drainage results from exposure of certain metal ores to oxygen and microbial action
  - Resulting compounds are carried into streams and rivers
    - Causes decrease in pH
      - Can kill fish, plants, and other organisms
      - Acidic water unfit for human consumption
  - Some microbes flourish in these acidic conditions

**Figure 25.13 The effects of acid mine drainage**

**Figure 25.14 An acid-loving microbe**

# Environmental Microbiology

- **Role of Microorganisms in Biogeochemical Cycles**
  - Biogeochemical cycles
    - Processes by which organisms convert elements from one form to another
    - Elements often converted between oxidized and reduced forms
    - Involve the recycling of elements by organisms

# Environmental Microbiology

- **Role of Microorganisms in Biogeochemical Cycles**
  - Biogeochemical cycling entails three processes
    - Production
      - Inorganic compounds converted into organic compounds
    - Consumption
      - Organisms feed on producers and other consumers
    - Decomposition
      - Organic compounds in dead organisms converted into inorganic compounds

Figure 25.15 Simplified carbon cycle

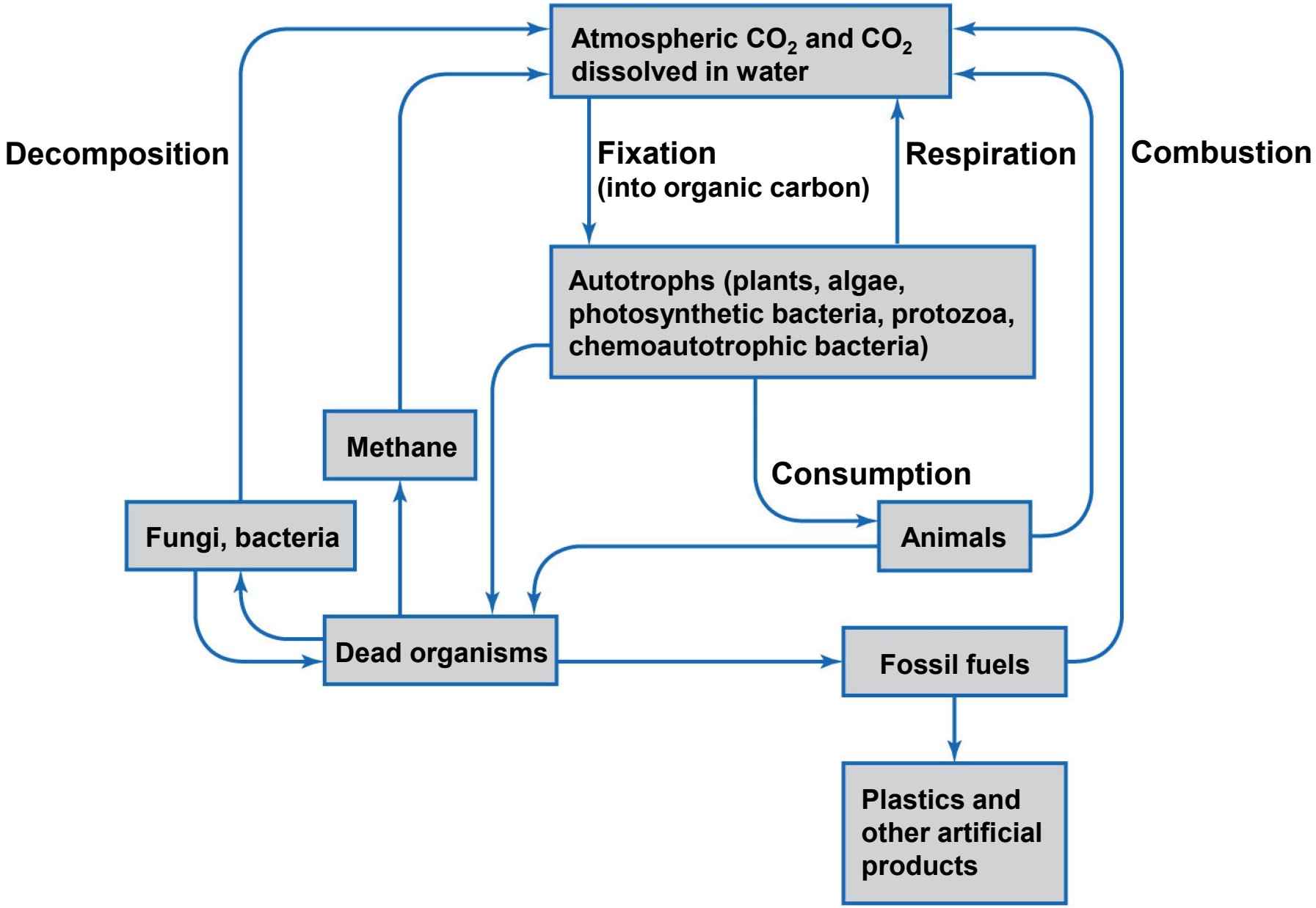


Figure 25.16 Simplified nitrogen cycle

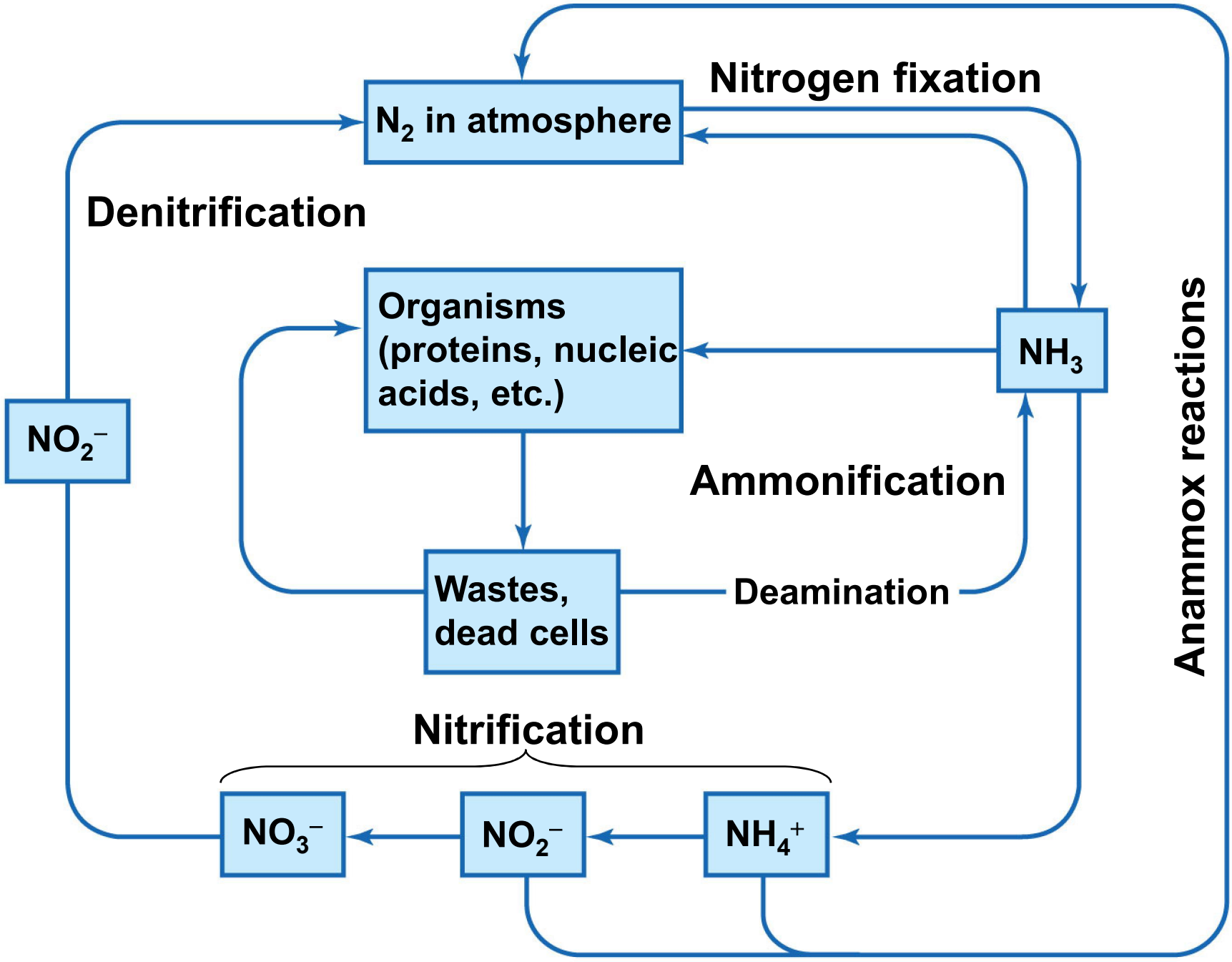
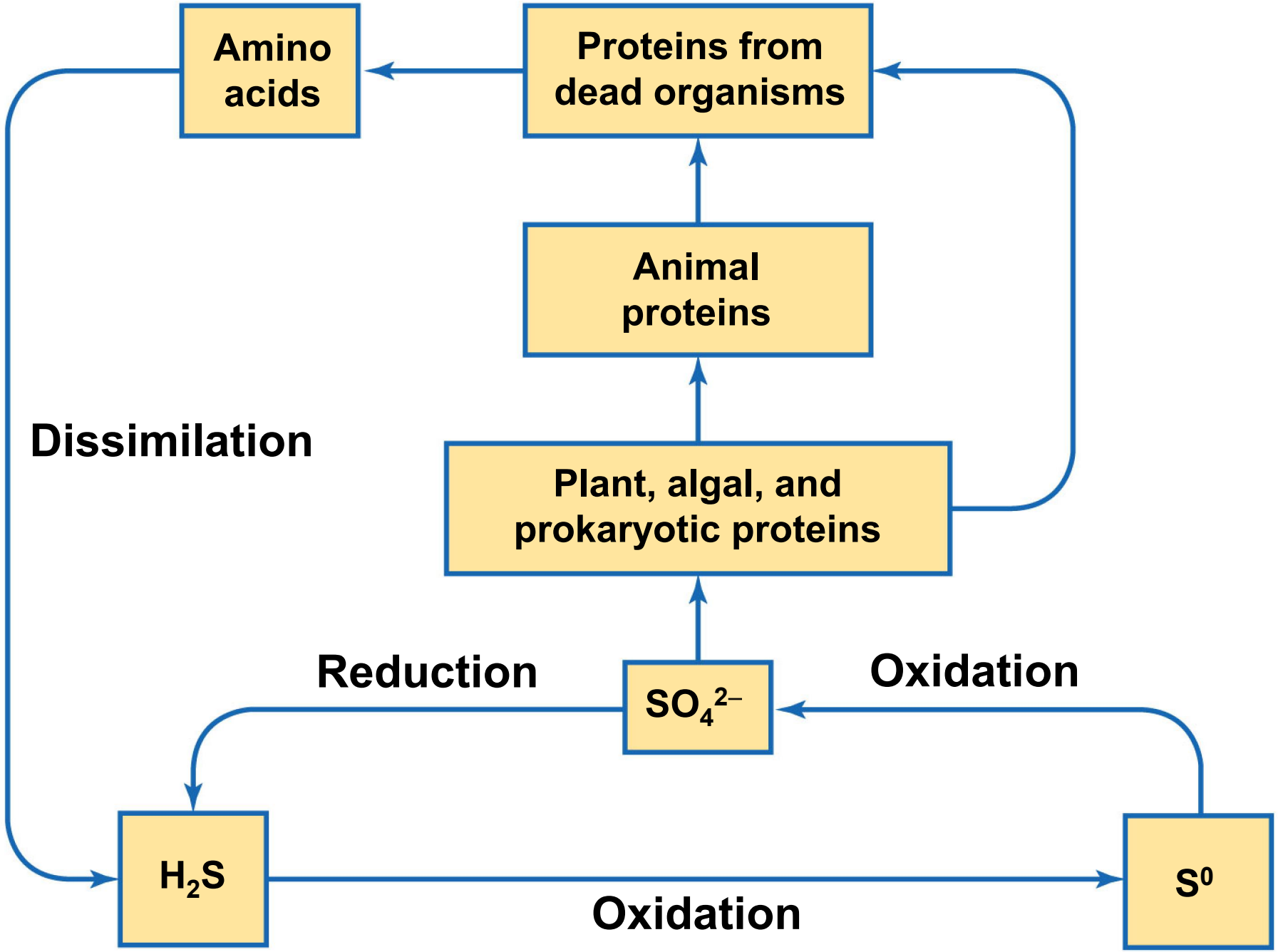


Figure 25.17 Simplified sulfur cycle



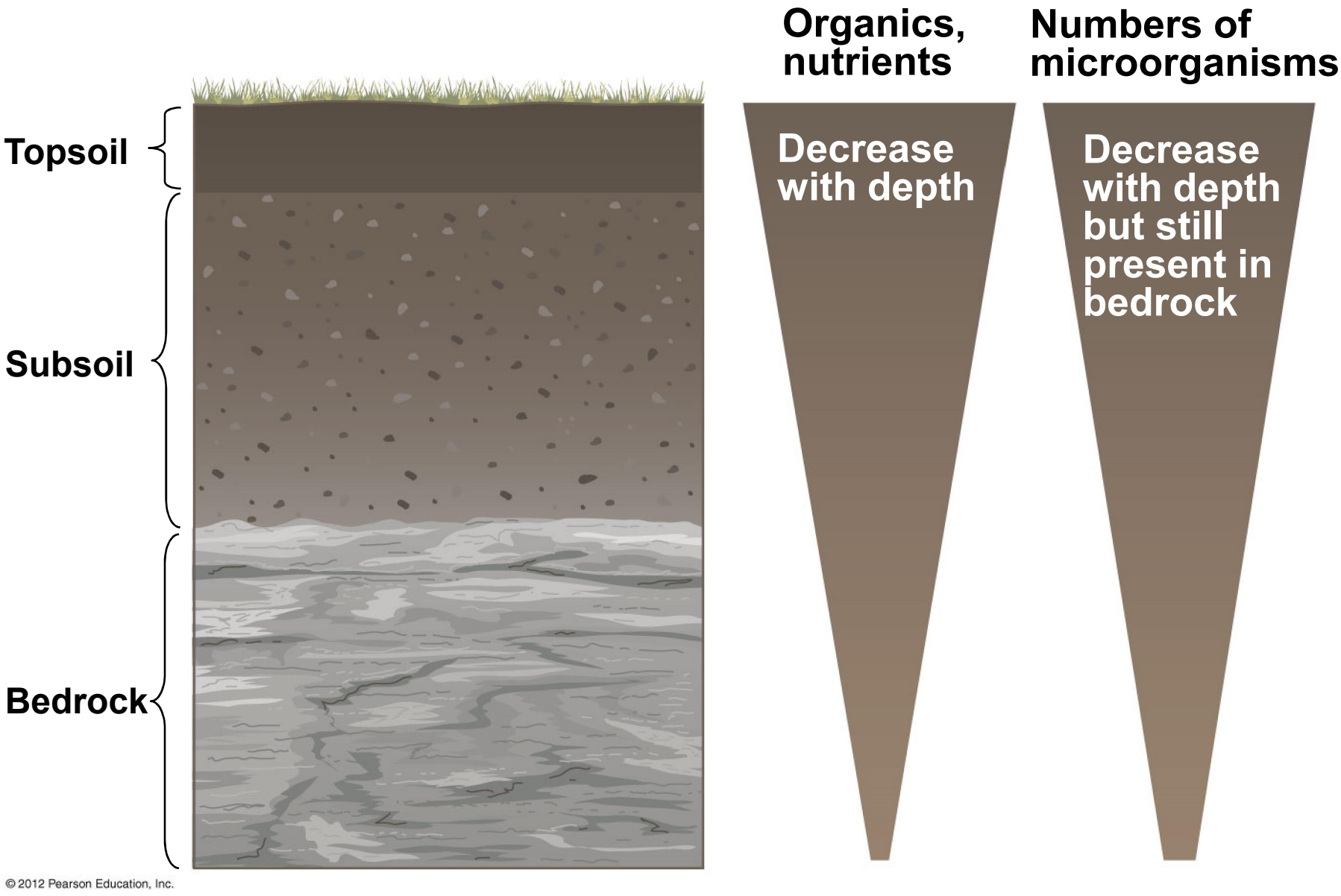
- **Role of Microorganisms in Biogeochemical Cycle**
  - Phosphorus cycle
    - Environmental phosphorus undergoes little change in oxidation state
    - Phosphorus converted from insoluble to soluble forms
      - Becomes available for uptake by organisms
    - Conversion of phosphorus from organic to inorganic forms
      - Occurs by pH–dependent processes

- **Role of Microorganisms in Biogeochemical Cycle**
  - The cycling of metals
    - Metal ions are important microbial nutrients
    - Primarily involves transition from insoluble to soluble forms
      - Allows trace metals to be be used by organisms

# Environmental Microbiology

- **Soil Microbiology**
  - Examines the roles played by organisms living in soil
  - Nature of soils
    - Soil arises from the weathering of rocks
    - Soil also produced through the actions of microorganisms

**Figure 25.18 The soil layers and the distributions of nutrients and microorganisms within them**



# Environmental Microbiology

- **Soil Microbiology**
  - Environmental factors affecting microbial abundance in soils
    - Moisture content
      - Moist soils support microbial growth better than dry soils
    - Oxygen
      - Moist soils are lower in oxygen than dry soils
        - Oxygen dissolves poorly in water
    - pH
      - Highly acidic and highly basic soils favor fungi

# Environmental Microbiology

- **Soil Microbiology**
  - Environmental factors affecting microbial abundance in soils
    - Temperature
      - Most soil organisms are mesophiles
    - Nutrient availability
      - Microbial community size determined by how much organic material is available