MILLER/SPOOLMAN

LIVING IN THE ENVIRONMENT

17TH

Chapter 20

Water Pollution

The Seattle, Washington Area, U.S.

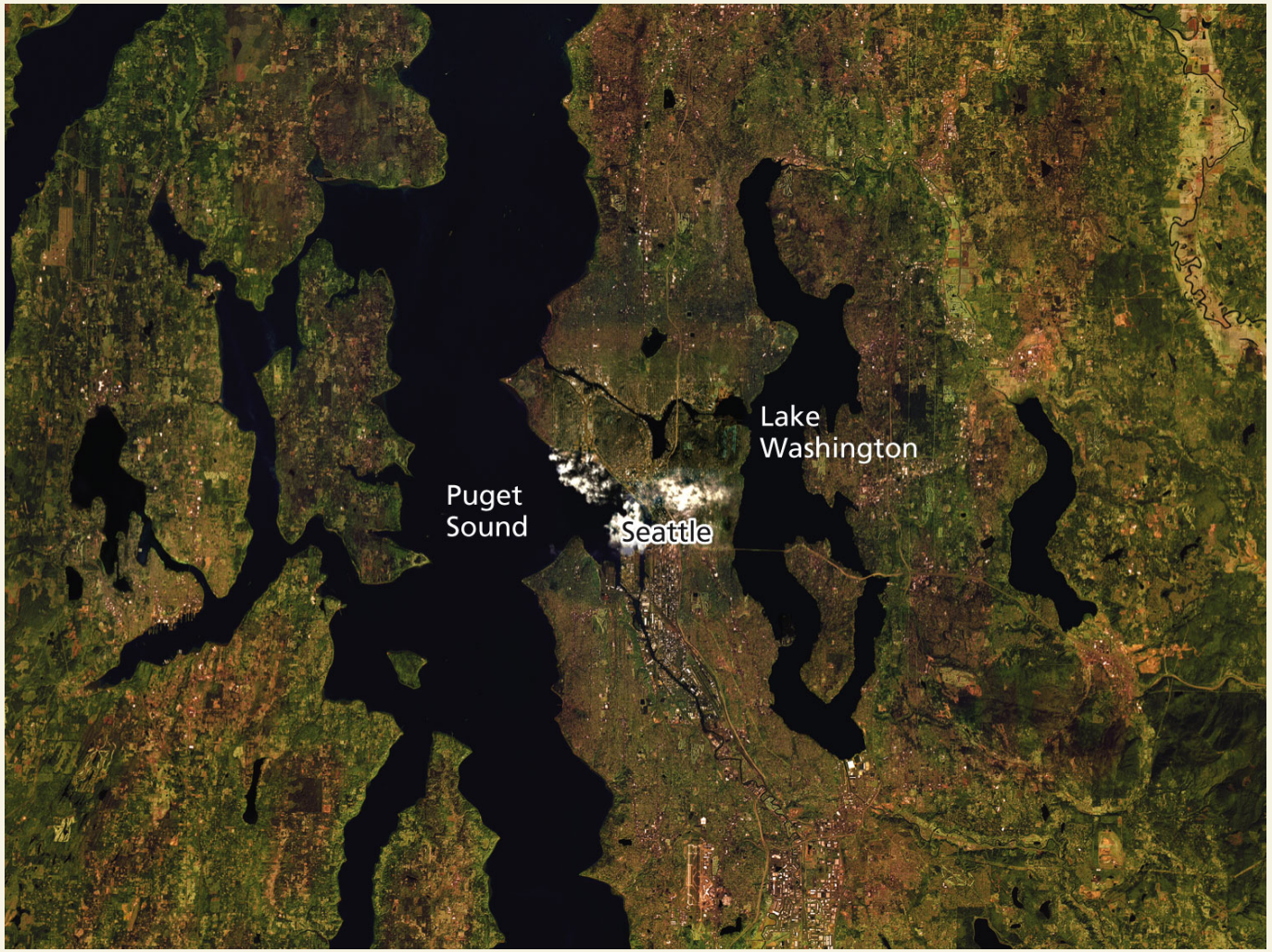


Fig. 20-1, p. 528

Core Case Study: Lake Washington

- Sewage dumped into Lake Washington
- 1955: Edmondson discovered cyanobacteria in the lake
  - Role of phosphorus
- Public pressure led to cleanup of the lake
  - Sewage treatment plant effluent to Puget Sound
- New pollution challenges

Kayaker Enjoys Lake Washington

Fig. 20-2, p. 528

20-1 What Are the Causes and Effects of Water Pollution?

- ***Concept 20-1A*** *Water pollution causes illness and death in humans and other species, and disrupts ecosystems.*

- ***Concept 20-1B*** *The chief sources of water pollution are agricultural activities, industrial facilities, and mining, but growth in population and resource use make it increasingly worse.*

Water Pollution Comes from Point and Nonpoint Sources (1)

- **Water pollution**
  - Change in water quality that can harm organisms or make water unfit for human uses
  - Contamination with chemicals
  - Excessive heat

- **Point sources**
  - Located at specific places
  - Easy to identify, monitor, and regulate
  - Examples

Water Pollution Comes from Point and Nonpoint Sources (2)

- **Nonpoint sources**
  - Broad, diffuse areas
  - Difficult to identify and control
  - Expensive to clean up
  - Examples

Water Pollution Comes from Point and Nonpoint Sources (3)

- Leading causes of water pollution
  1. Agriculture activities
     - Sediment eroded from the lands
     - Fertilizers and pesticides
     - Bacteria from livestock and food processing wastes
  2. Industrial facilities
  3. Mining

Point Source of Polluted Water in Gargas, France

Fig. 20-3, p. 530

Nonpoint Sediment from Unprotected Farmland Flows into Streams

Fig. 20-4, p. 530

Lake Polluted with Mining Wastes

Fig. 20-5, p. 531

Plastic Wastes in Mountain Lake

Fig. 20-6, p. 531

Major Water Pollutants Have Harmful Effects

- Infectious disease organisms: contaminated drinking water

- The World Health Organization (WHO)
  - 1.6 million people die every year, mostly under the age of 5

Major Water Pollutants and Their Sources

Table 20-1 Major Water Pollutants and Their Sources

Type/*Effects*	Examples	Major Sources
Infectious agents (pathogens) *Cause diseases*	Bacteria, viruses, protozoa, parasites	Human and animal wastes
Oxygen-demanding wastes *Deplete dissolved oxygen needed by aquatic species*	Biodegradable animal wastes and plant debris	Sewage, animal feedlots, food-processing facilities, paper mills
Plant nutrients *Cause excessive growth of algae and other species*	Nitrates (NO_3^-) and phosphates (PO_4^{3-})	Sewage, animal wastes, inorganic fertilizers
Organic chemicals *Add toxins to aquatic systems*	Oil, gasoline, plastics, pesticides, fertilizers, cleaning solvents	Industry, farms, households, mining sites, runoff from streets and parking lots
Inorganic chemicals *Add toxins to aquatic systems*	Acids, bases, salts, metal compounds	Industry, households, mining sites, runoff from streets and parking lots
Sediments *Disrupt photosynthesis, food webs, other processes*	Soil, silt	Land erosion from farms and construction and mining sites
Heavy metals *Cause cancer, disrupt immune and endocrine systems*	Lead, mercury, arsenic	Unlined landfills, household chemicals, mining refuse, industrial discharges
Thermal *Make some species vulnerable to disease*	Heat	Electric power and industrial plants

Common Diseases Transmitted to Humans through Contaminated Drinking Water

Table 20-2 Common Diseases Transmitted to Humans through Contaminated Drinking Water

Type of Organism	Disease	Effects
Bacteria	Typhoid fever	Diarrhea, severe vomiting, enlarged spleen, inflamed intestine; often fatal if untreated
	Cholera	Diarrhea, severe vomiting, dehydration; often fatal if untreated
	Bacterial dysentery	Diarrhea, bleeding; rarely fatal except in infants without proper treatment
	Enteritis	Severe stomach pain, nausea, vomiting; rarely fatal
Viruses	Infectious hepatitis (Type B)	Fever, severe headache, loss of appetite, abdominal pain, jaundice, enlarged liver; rarely fatal but may cause permanent liver damage
	Poliomyelitis	Fever, diarrhea, backache, sore throat, aches in limbs; can infect spinal chord and cause paralysis and muscle weakness
Parasitic protozoa	Amoebic dysentery	Severe diarrhea, headache, abdominal pain, chills, fever; if not treated can cause liver abscess, bowel perforation, and death
	Giardiasis	Diarrhea, abdominal cramps, flatulence, belching, fatigue
	Cryptosporidium	Severe diarrhea, cramps for up to 3 weeks, and possible death for people with weakened immune systems
Parasitic worms	Schistosomiasis	Abdominal pain, skin rash, anemia, chronic fatigue, and chronic general ill health
	Ancylostomiasis	Severe anemia and possible symptoms of bronchial infection

Science Focus: Testing Water for Pollutants (1)

- Variety of tests to determine water quality
- Coliform bacteria: *Escherichia coli*, significant levels
- Level of dissolved oxygen (DO)
- Chemical analysis

Science Focus: Testing Water for Pollutants (2)

- Indicator species
  - Examples

- Bacteria and yeast glow in the presence of a particular toxic chemical

- Color and turbidity of the water

Water Quality as Measured by Dissolved Oxygen Content in Parts per Million

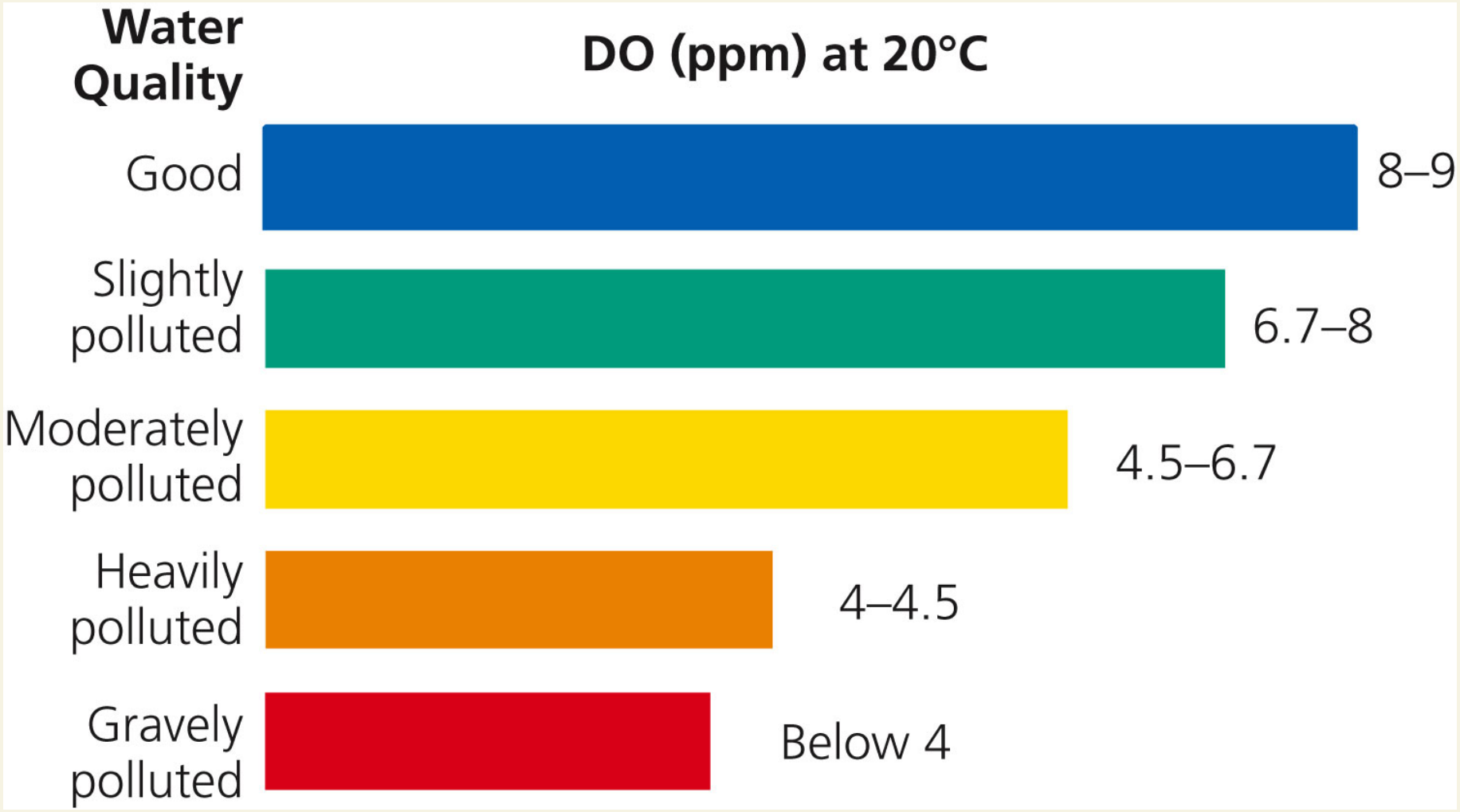


Fig. 20-A, p. 533

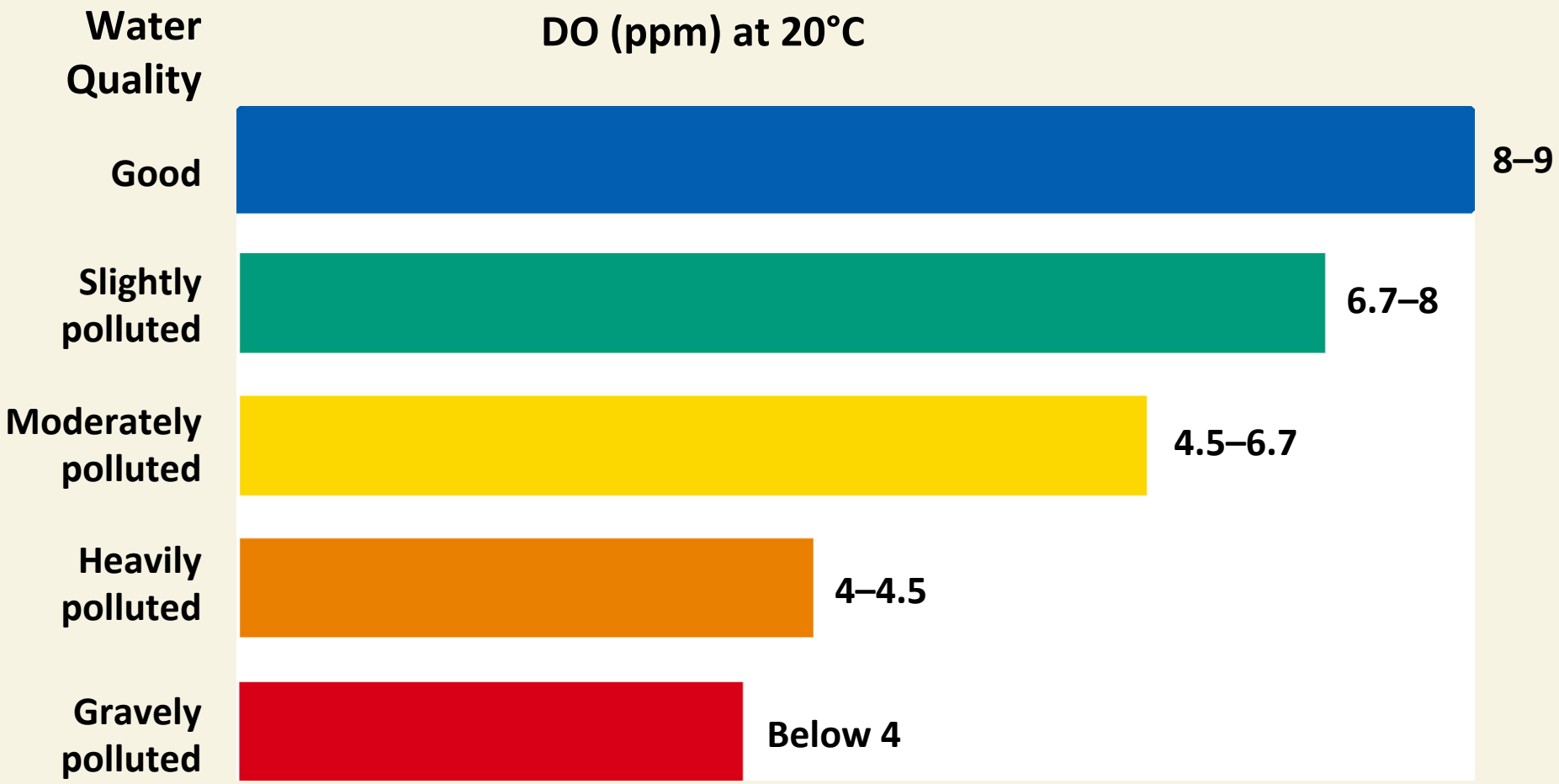

Water Quality
DO (ppm) at 20°C
Good
8–9
Slightly polluted
6.7–8
Moderately polluted
4.5–6.7
Heavily polluted
4–4.5
Gravely polluted
Below 4

Fig. 20-A, p. 533

20-2 What Are the Major Water Pollution Problems in Streams and Lakes?

- ***Concept 20-2A*** *Streams and rivers around the world are extensively polluted, but they can cleanse themselves of many pollutants if we do not overload them or reduce their flows.*

- ***Concept 20-2B*** *The addition of excessive nutrients to lakes from human activities can disrupt their ecosystems, and prevention of such pollution is more effective and less costly than cleaning it up.*

Streams Can Cleanse Themselves If We Do Not Overload Them

- Dilution
- Biodegradation of wastes by bacteria takes time
- Oxygen sag curve

Dilution and Decay of Degradable, Oxygen-Demanding Wastes in a Stream

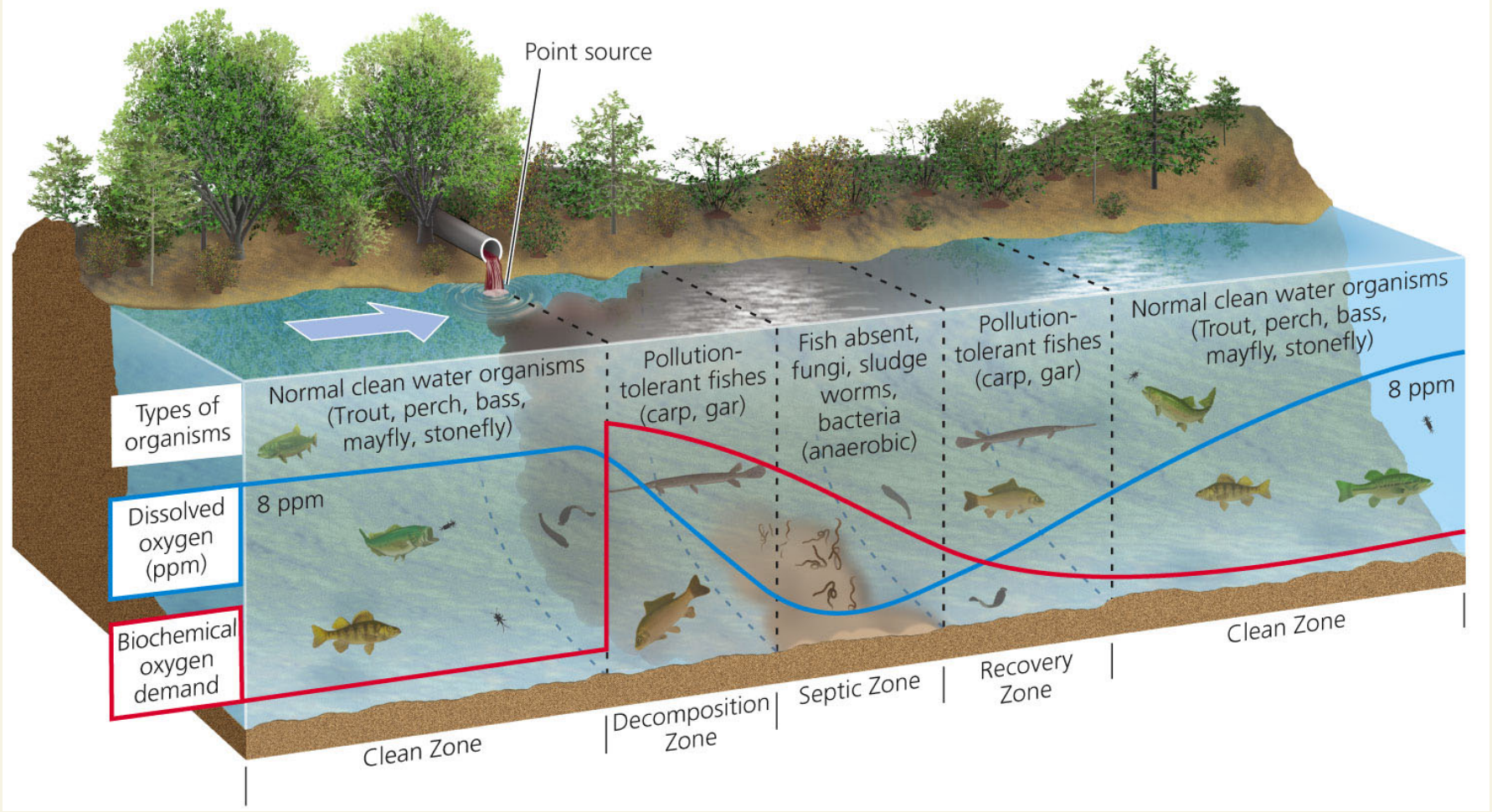


Fig. 20-7, p. 534

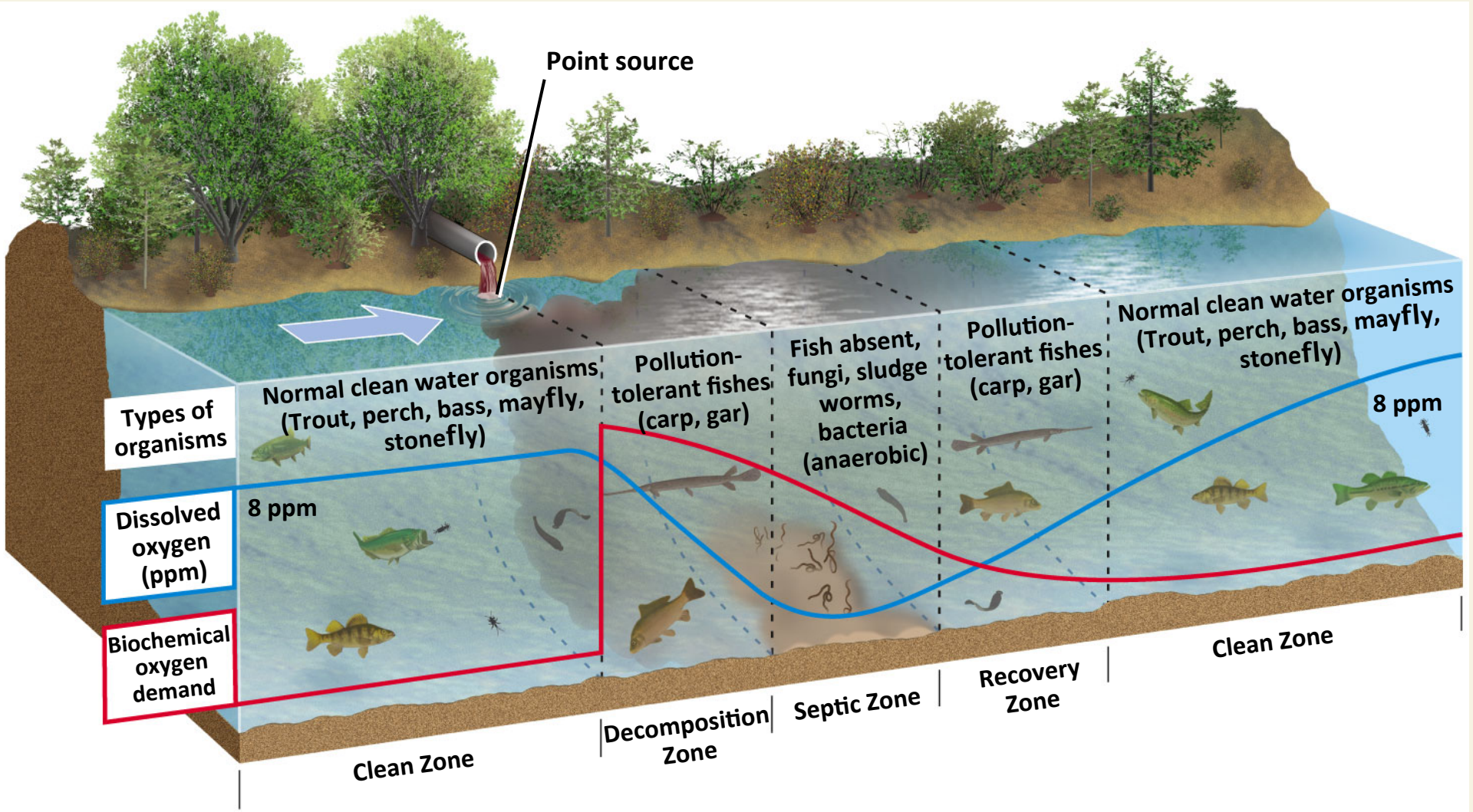

Point source
Types of organisms
Dissolved oxygen (ppm)
Biochemical oxygen demand
Normal clean water organisms (Trout, perch, bass, mayfly, stonefly)
8 ppm
Pollution-tolerant fishes (carp, gar)
Fish absent, fungi, sludge worms, bacteria (anaerobic)
Pollution-tolerant fishes (carp, gar)
Normal clean water organisms (Trout, perch, bass, mayfly, stonefly)
8 ppm
Clean Zone
Decomposition Zone
Septic Zone
Recovery Zone
Clean Zone

Fig. 20-7, p. 534

Stream Pollution in More Developed Countries

- 1970s: Water pollution control laws
- Successful water clean-up stories
  - Ohio Cuyahoga River, U.S.
  - Thames River, Great Britain
- Contamination of toxic inorganic and organic chemicals by industries and mines

Individuals Matter: The Man Who Planted Trees to Restore a Stream

- John Beal: restoration of Hamm Creek, Seattle, WA, U.S.
- Planted trees
- Persuaded companies to stop dumping
- Removed garbage

Global Outlook: Stream Pollution in Developing Countries

- Half of the world's 500 major rivers are polluted
- Untreated sewage
- Industrial waste
- India's rivers
- China's rivers

Natural Capital Degradation: Highly Polluted River in China

Fig. 20-8, p. 535

Trash Truck Disposing of Garbage into a River in Peru

Fig. 20-9, p. 536

Too Little Mixing and Low Water Flow Makes Lakes Vulnerable to Water Pollution

- Less effective at diluting pollutants than streams
  - Stratified layers
    - Little vertical mixing
  - Little of no water flow
  - Can take up to 100 years to change the water in a lake
  - Biological magnification of pollutants

Lake Fish Killed by Water Pollution

Fig. 20-10, p. 536

Cultural Eutrophication Is Too Much of a Good Thing (1)

- **Eutrophication**
  - Natural enrichment of a shallow lake, estuary, or slow-moving stream
  - Caused by runoff into lake that contains nitrates and phosphates

- Oligotrophic lake
  - Low nutrients, clear water

Cultural Eutrophication Is Too Much of a Good Thing (2)

- **Cultural eutrophication**
  - Nitrates and phosphates from human sources
  - Farms, feedlots, streets, parking lots
  - Fertilized lawns, mining sites, sewage plants

- During hot weather or droughts
  - Algal blooms
  - Increased bacteria
  - More nutrients
  - Anaerobic bacteria

Cultural Eutrophication Is Too Much of a Good Thing (3)

- Prevent or reduce cultural eutrophication
  - Remove nitrates and phosphates
  - Diversion of lake water
- Clean up lakes
  - Remove excess weeds
  - Use herbicides and algaecides; down-side?
  - Pump in air

Cultural Eutrophication of Chinese Lake

Fig. 20-11, p. 537

Revisiting Lake Washington and Puget Sound

- Severe water pollution can be reversed
- Citizen action combined with scientific research
- Good solutions may not work forever
  - Wastewater treatment plant effluents sent into Puget Sound
- Now what's happening?

Case Study: Pollution in the Great Lakes (1)

- 1960s: Many areas with cultural eutrophication

- 1972: Canada and the United States: Great Lakes pollution control program
  - Decreased algal blooms
  - Increased dissolved oxygen
  - Increased fishing catches
  - Swimming beaches reopened
  - Better sewage treatment plants
  - Fewer industrial wastes
  - Bans on phosphate-containing household products

Case Study: Pollution in the Great Lakes (2)

- Problems still exist
  - Raw sewage
  - Nonpoint runoff of pesticides and fertilizers
  - Biological pollution
  - Atmospheric deposition of pesticides and Hg

Case Study: Pollution in the Great Lakes (3)

- 2007 State of the Great Lakes report
  - New pollutants found
  - Wetland loss and degradation
  - Declining of some native species
  - Native carnivorous fish species declining
  - What should be done?

The Great Lakes of North America

Fig. 20-12, p. 538

20-3 Pollution Problems Affecting Groundwater, Other Water Sources

- ***Concept 20-3A*** *Chemicals used in agriculture, industry, transportation, and homes can spill and leak into groundwater and make it undrinkable.*

- ***Concept 20-3B*** *There are both simple an complex ways to purify groundwater used as a source of drinking water, but protecting it through pollution prevention is the least expensive and most effective strategy.*

Ground Water Cannot Cleanse Itself Very Well (1)

- Source of drinking water
- Common pollutants
  - Fertilizers and pesticides
  - Gasoline
  - Organic solvents
- Pollutants dispersed in a widening plume

Ground Water Cannot Cleanse Itself Very Well (2)

- Slower chemical reactions in groundwater due to
  - Slow flow: contaminants not diluted
  - Less dissolved oxygen
  - Fewer decomposing bacteria
  - Low temperatures

Principal Sources of Groundwater Contamination in the U.S.

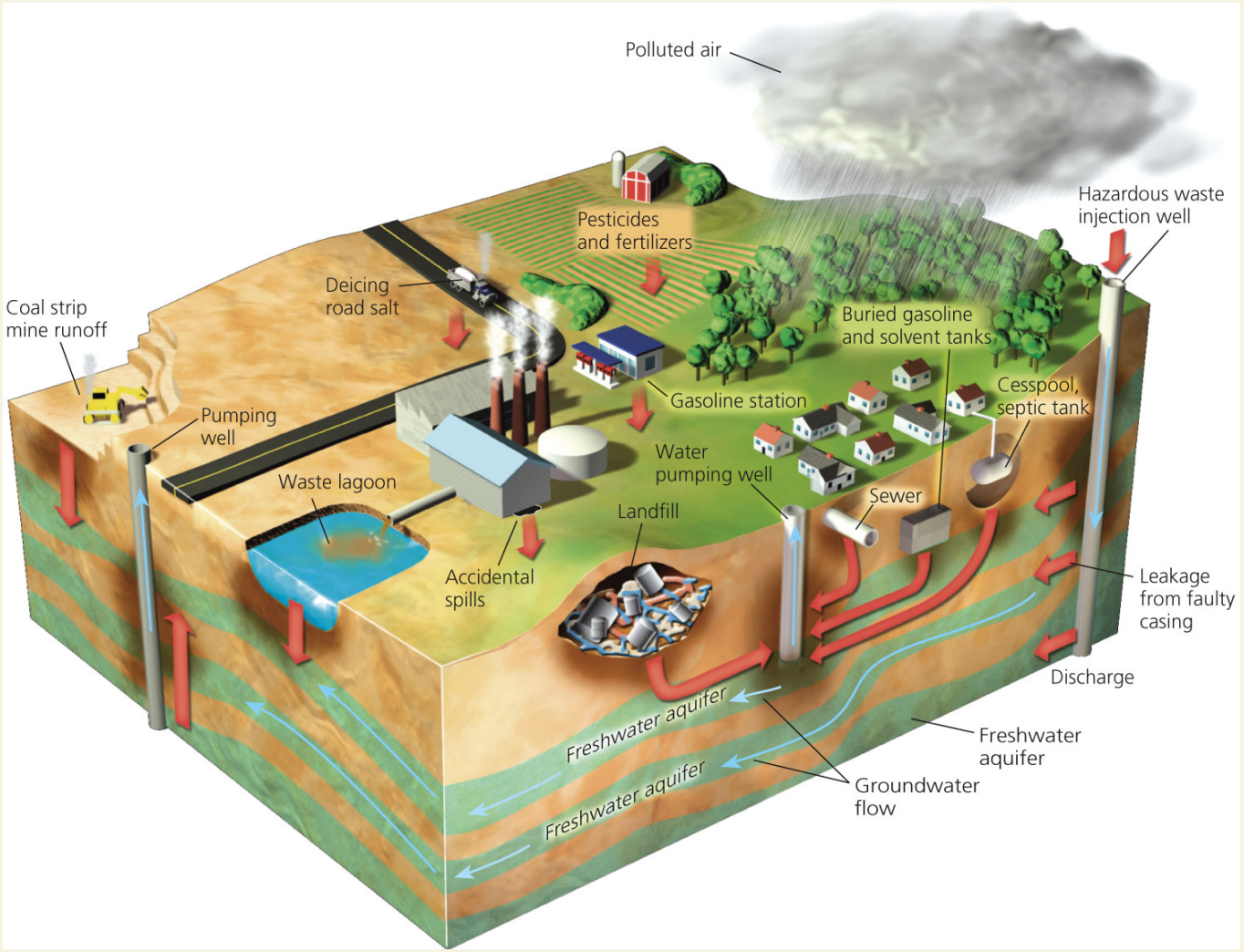


Fig. 20-13, p. 540

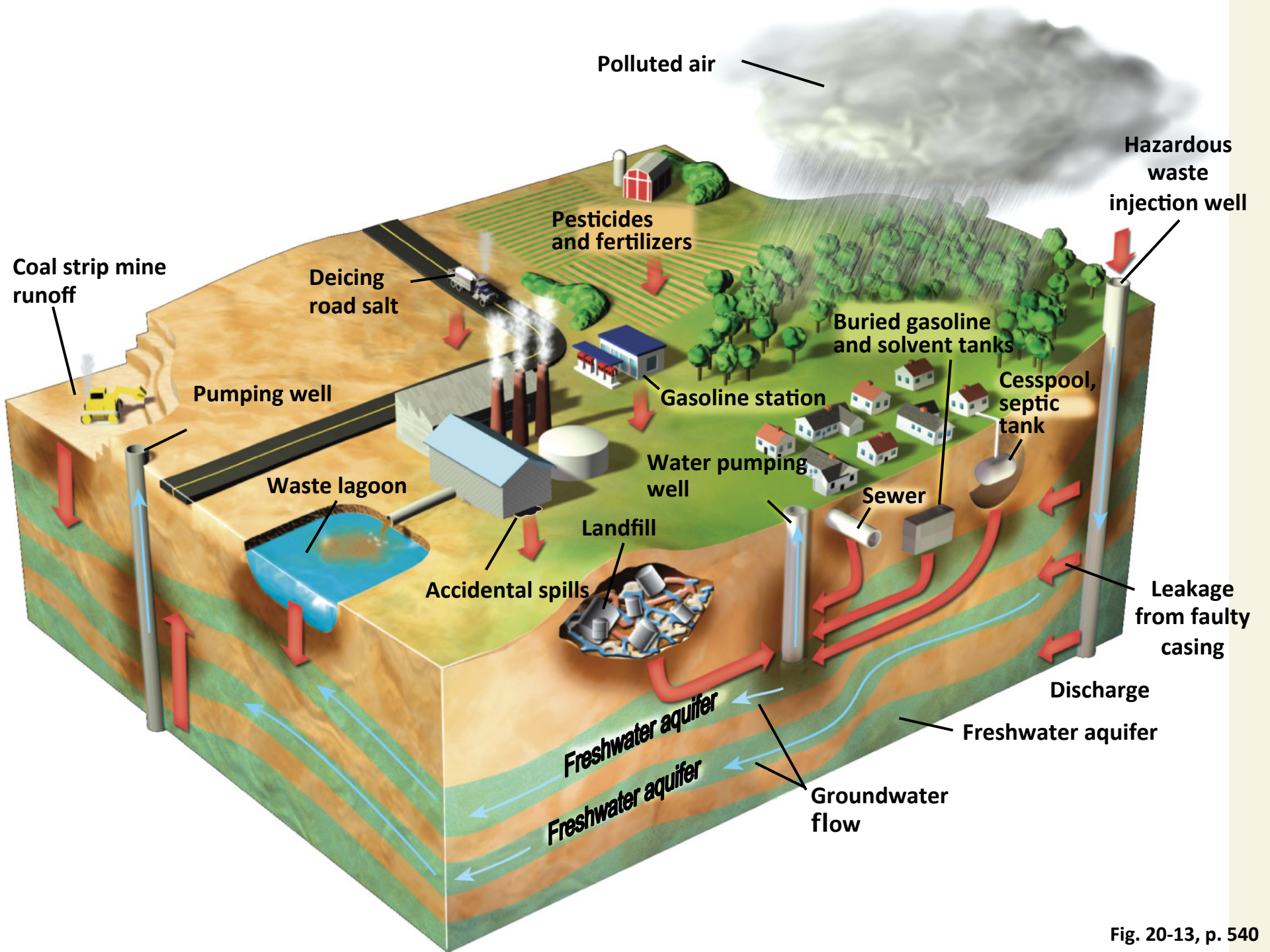


Fig. 20-13, p. 540

Groundwater Pollution Is a Serious Hidden Threat in Some Areas

- China: 90% of urban aquifers are contaminated or overexploited
- U.S.: FDA reports of toxins found in many aquifers
- Threats
  - Gasoline, oil
  - Nitrate ions
  - Arsenic

Pollution Prevention Is the Only Effective Way to Protect Groundwater

- Prevent contamination of groundwater
- Cleanup: expensive and time consuming

Solutions: Groundwater Pollution, Prevention and Cleanup

Solutions

Groundwater Pollution

Prevention

Find substitutes for toxic chemicals

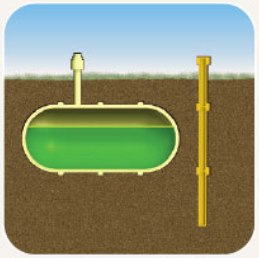
Keep toxic chemicals out of the environment

Install monitoring wells near landfills and underground tanks

Require leak detectors on underground tanks

Ban hazardous waste disposal in landfills and injection wells

Store harmful liquids in aboveground tanks with leak detection and collection systems



Cleanup

Pump to surface, clean, and return to aquifer (very expensive)

Inject microorganisms to clean up contamination (less expensive but still costly)

Pump nanoparticles of inorganic compounds to remove pollutants (still being developed)

Fig. 20-14, p. 541

Solutions

Groundwater Pollution

Prevention

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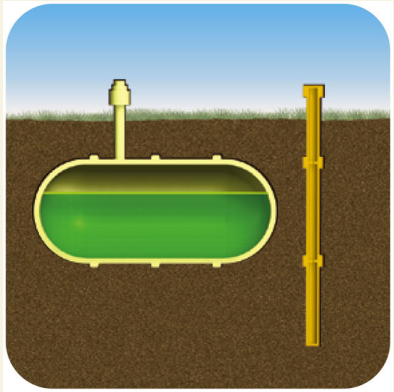

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Fig. 20-14, p. 541

There Are Many Ways to Purify Drinking Water

- Reservoirs and purification plants
- Process sewer water to drinking water
- Expose clear plastic containers to sunlight (UV)
- The LifeStraw
- PUR: chlorine and iron sulfate powder

The LifeStraw: Personal Water Purification Device

Fig. 20-15, p. 542

Case Study: Protecting Watersheds Instead of Building Water Purification Plants

- New York City water
  - Reservoirs in the Catskill Mountains
  - Paid towns, farmers, and others in the watershed to restore forests, wetlands, and streams
  - Saved the cost of building a plant: $6 billion

Using Laws to Protect Drinking Water Quality

- 1974: U.S. Safe Drinking Water Act
  - Sets maximum contaminant levels for any pollutants that affect human health
- Health scientists: strengthen the law
- Water-polluting companies: weaken the law

Case Study: Is Bottled Water the Answer?

- U.S.: some of the cleanest drinking water

- Bottled water
  - Some from tap water
  - 40% bacterial contamination
  - Fuel cost to manufacture the plastic bottles
  - Recycling of the plastic
  - 240-10,000x the cost of tap water

- Growing back-to-the-tap movement

20-4 What Are the Major Water Pollution Problems Affecting Oceans?

- ***Concept 20-4A*** *The great majority of ocean pollution originates on land and includes oil and other toxic chemicals as well as solid waste, which threaten fish and wildlife and disrupt marine ecosystems.*

- ***Concept 20-4B*** *The key to protecting the oceans is to reduce the flow of pollution from land and air and from streams emptying into these waters.*

Ocean Pollution Is a Growing and Poorly Understood Problem (1)

- 2006: State of the Marine Environment
  - 80% of marine pollution originates on land
  - Sewage
  - Coastal areas most affected

- Deeper ocean waters
  - Dilution
  - Dispersion
  - Degradation

Ocean Pollution Is a Growing and Poorly Understood Problem (2)

- Cruise line pollution: what is being dumped?

- U.S. coastal waters
  - Raw sewage
  - Sewage and agricultural runoff: NO_3^- and PO_4^{3-}
  - Harmful algal blooms
  - Oxygen-depleted zones

- Huge mass of plastic in North Pacific Ocean

Residential Areas, Factories, and Farms Contribute to Pollution of Coastal Waters

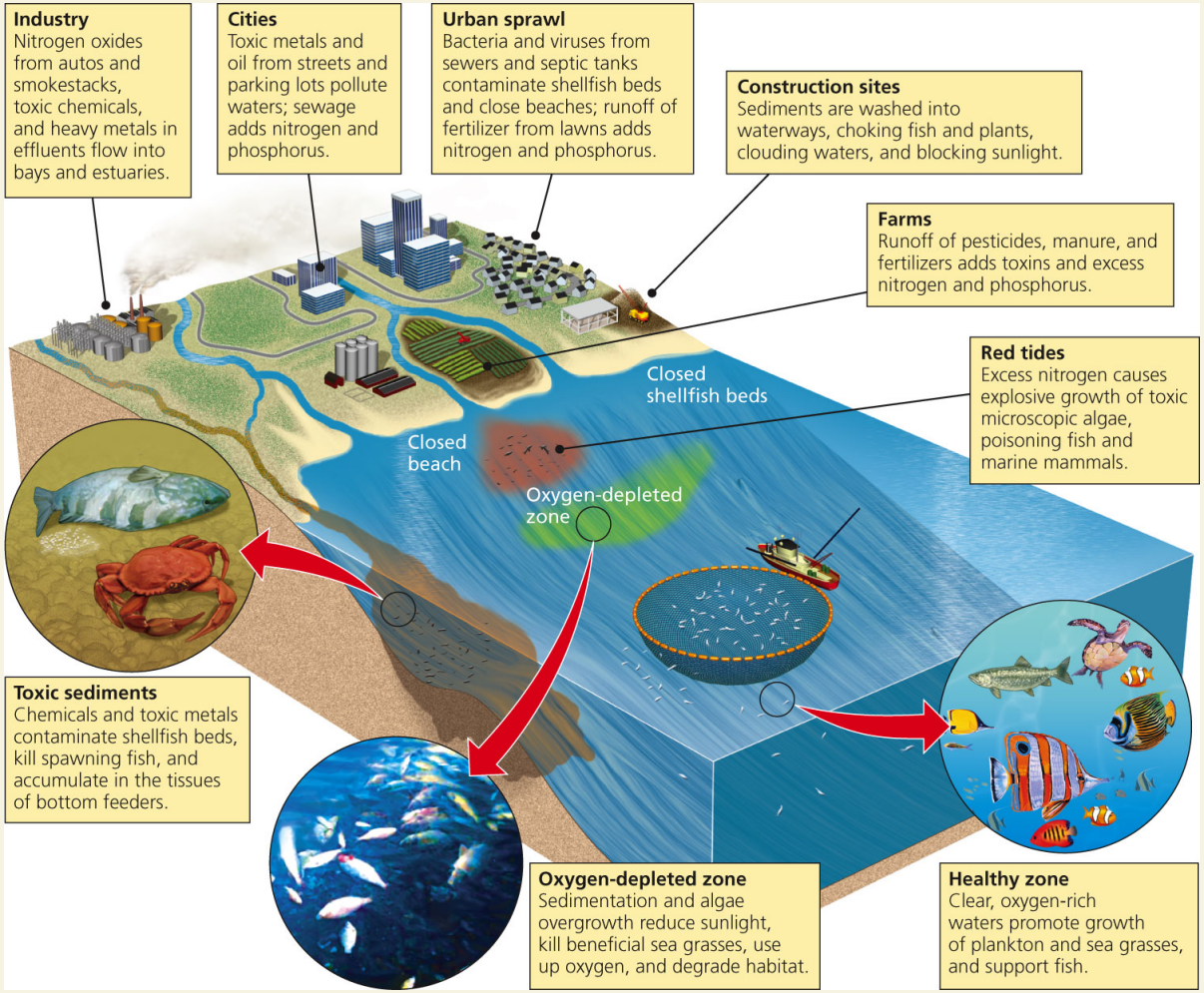


Fig. 20-16, p. 545

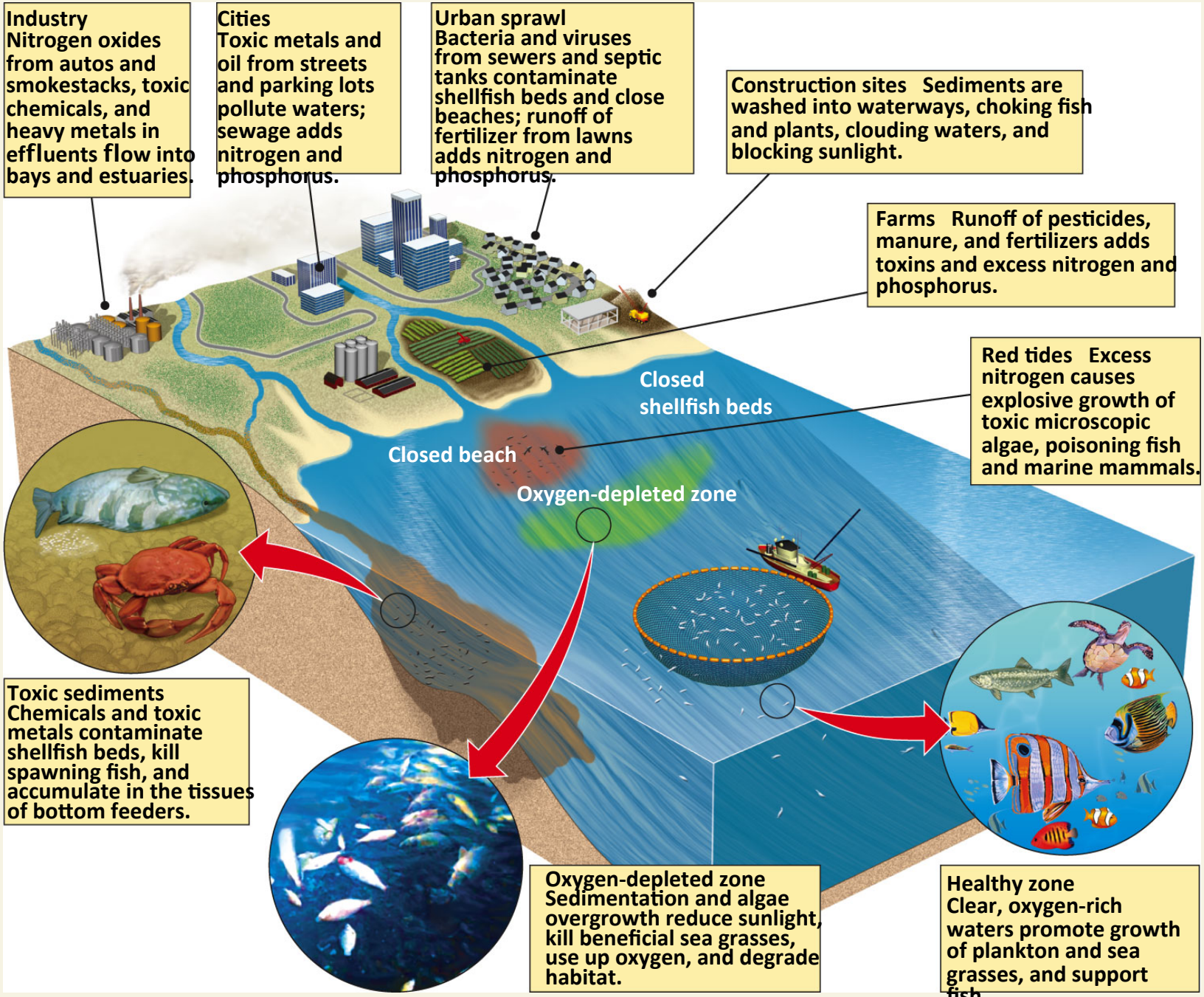


Fig. 20-16, p. 545

Science Focus: Oxygen Depletion in the Northern Gulf Of Mexico

- Severe cultural eutrophication
- Oxygen-depleted zone
- Overfertilized coastal area
- Preventive measures
- Will it reach a tipping point?

A Large Zone of Oxygen-Depleted Water in the Gulf of Mexico Due to Algal Blooms

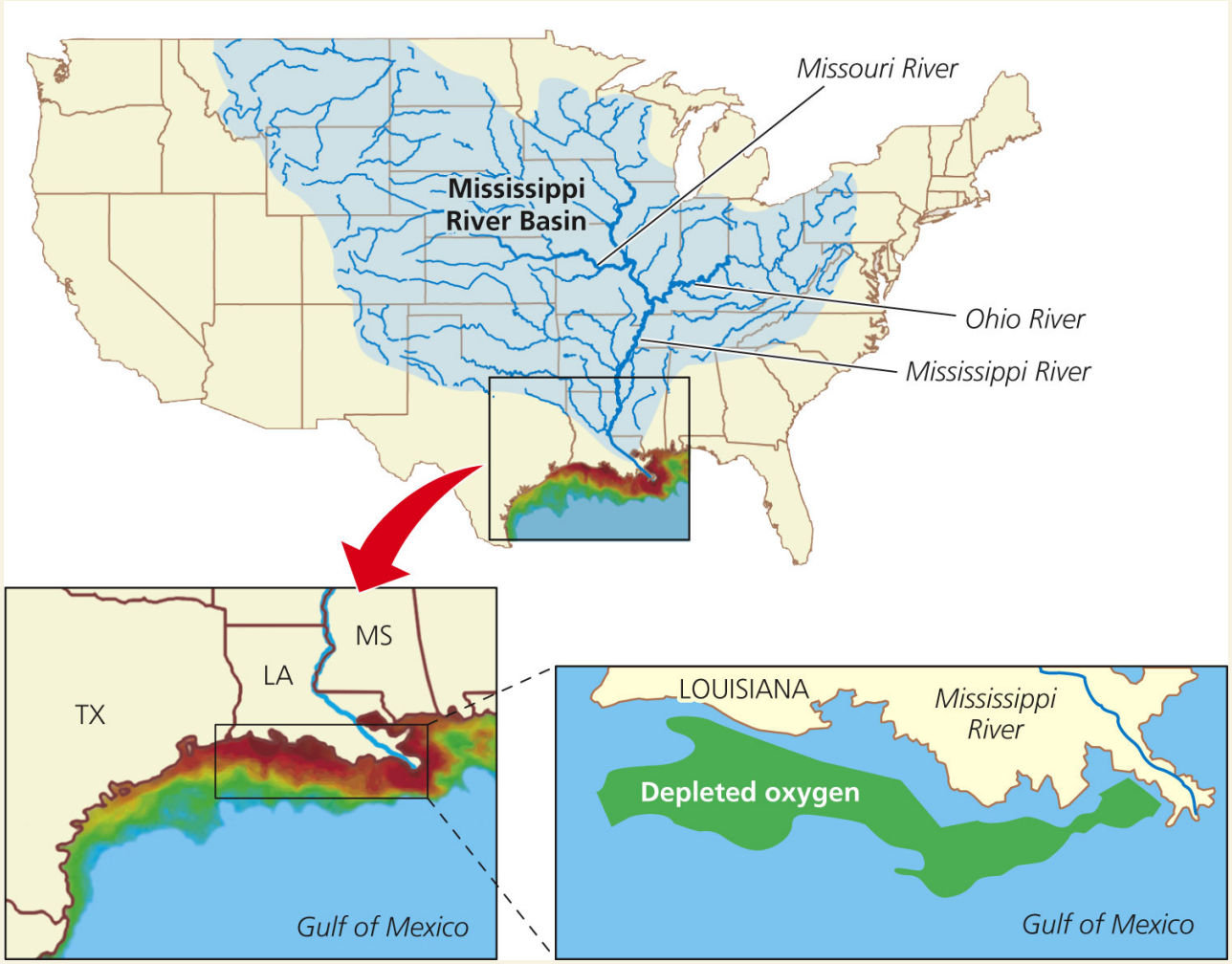


Fig. 20-B, p. 546

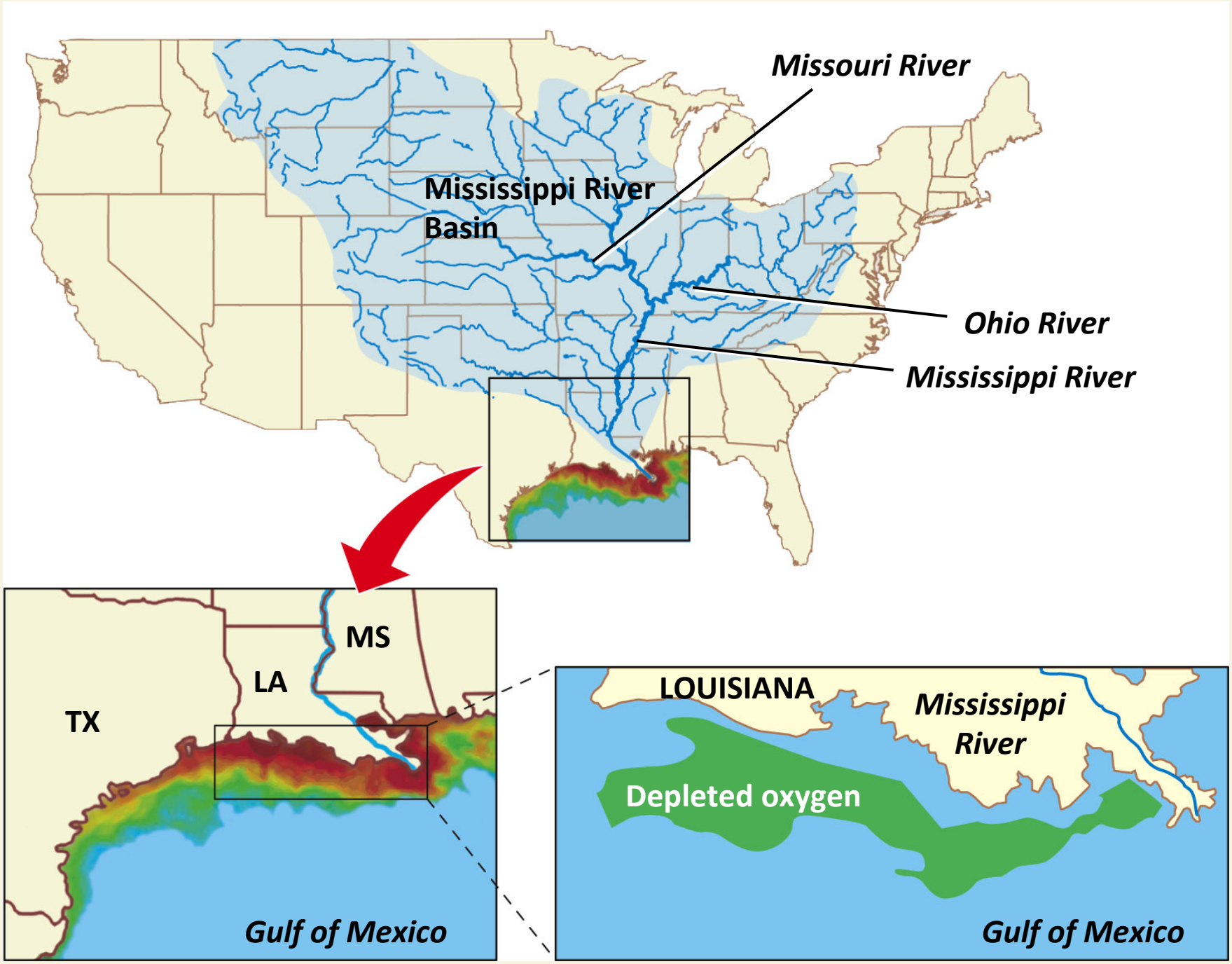
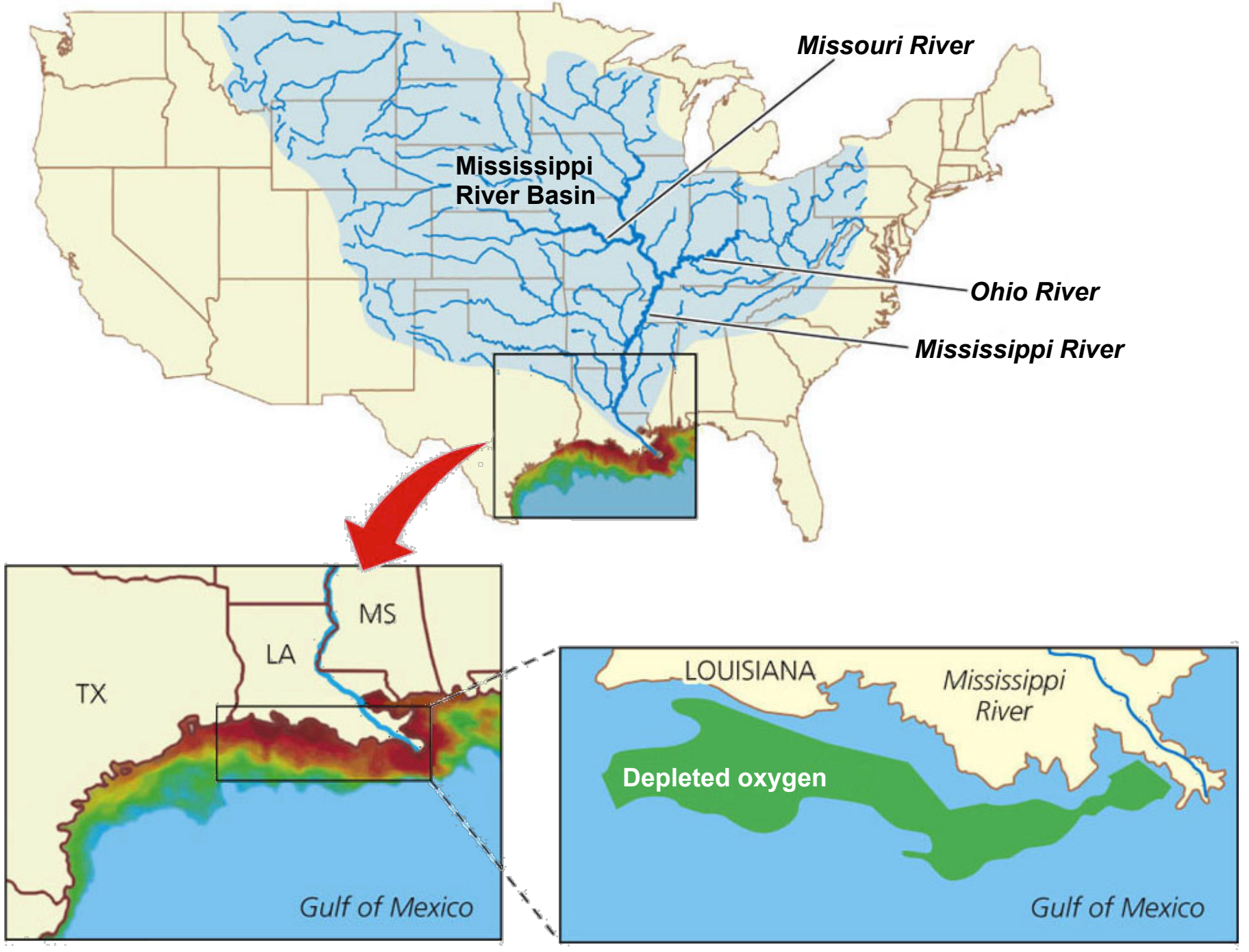

Missouri River
Mississippi River Basin
Ohio River
Mississippi River
MS
LA
TX
Gulf of Mexico
LOUISIANA
Mississippi River
Depleted oxygen
Gulf of Mexico

Fig. 20-B, p. 546



Stepped Art Fig. 20-B, p. 546

Ocean Pollution from Oil (1)

- Crude and refined petroleum
  - Highly disruptive pollutants
- Largest source of ocean oil pollution
  - Urban and industrial runoff from land
- 1989: Exxon Valdez, oil tanker
- 2010: BP explosion in the Gulf of Mexico

Ocean Pollution from Oil (2)

- Volatile organic hydrocarbons
  - Kill many aquatic organisms
- Tar-like globs on the ocean's surface
  - Coat animals
- Heavy oil components sink
  - Affect the bottom dwellers

Ocean Pollution from Oil (3)

- Faster recovery from crude oil than refined oil
- Cleanup procedures
- Methods of preventing oil spills

Solutions: Coastal Water Pollution, Prevention and Cleanup

Solutions

Coastal Water Pollution

Prevention

Reduce input of toxic pollutants

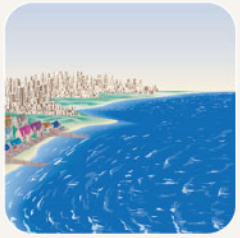
Separate sewage and storm water lines

Ban dumping of wastes and sewage by ships in coastal waters

Ban dumping of hazardous material

Strictly regulate coastal development, oil drilling, and oil shipping

Require double hulls for oil tankers



Cleanup

Improve oil-spill cleanup capabilities

Use nanoparticles on sewage and oil spills to dissolve the oil or sewage (still under development)

Require secondary treatment of coastal sewage

Use wetlands, solar-aquatic, or other methods to treat sewage

Fig. 20-17, p. 547

Solutions

Coastal Water Pollution

Prevention

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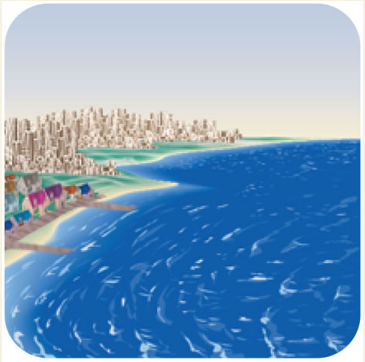

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Fig. 20-17, p. 547

Deepwater Horizon Blowout in the Gulf of Mexico, April 20, 2010

Fig. 20-18, p. 547

Case Study: The Exxon Valdez Oil Spill

- 1989: Alaska's Prince William Sound
  - 41 million liters of crude oil
  - 5200 km of coastline
  - Killed 250,000 seabirds
  - $15 billion in damages to economy
  - Exxon paid $3.8 billion in damages and clean-up costs
  - Led to improvements in oil tanker safety and clean-up strategies

20-5 How Can We Best Deal with Water Pollution?

- ***Concept 20-5*** *Reducing water pollution requires we prevent it, work with nature to treat sewage, cut resource use and waste, reduce poverty, and slow population growth.*

Reducing Surface Water Pollution from Nonpoint Sources

- Agriculture
  - Reduce erosion
  - Reduce the amount of fertilizers
  - Plant buffer zones of vegetation
  - Use organic farming techniques
  - Use pesticides prudently
  - Control runoff
  - Tougher pollution regulations for livestock operations
  - Deal better with animal waste

Laws Can Help Reduce Water Pollution from Point Sources

- 1972: Clean Water Act
  1987: Water Quality Act

- EPA: experimenting with a discharge trading policy that uses market forces
  - Cap and trade system
  - Could this allow pollutants to build up?

Case Study: The U.S. Experience with Reducing Point-Source Pollution (1)

- Numerous improvements in water quality
- Some lakes and streams are not safe for swimming or fishing
- Treated wastewater still produces algal blooms
- High levels of Hg, pesticides, and other toxic materials in fish

Case Study: The U.S. Experience with Reducing Point-Source Pollution (2)

- Leakage of gasoline storage tanks into groundwater
- Many violations of federal laws and regulations
- Need to strengthen the Clean Water Act

Sewage Treatment Reduces Water Pollution (1)

- **Septic tank system**

- Wastewater or sewage treatment plants
  - **Primary sewage treatment**
    - Physical process
  - **Secondary sewage treatment**
    - Biological process with bacteria
  - Tertiary or advance sewage treatment
    - Special filtering processes
    - Bleaching, chlorination

Sewage Treatment Reduces Water Pollution (2)

- Many cities violate federal standards for sewage treatment plants
- Should there be separate pipes for sewage and storm runoff?
- Health risks of swimming in water with blended sewage wastes

Solutions: Septic Tank System

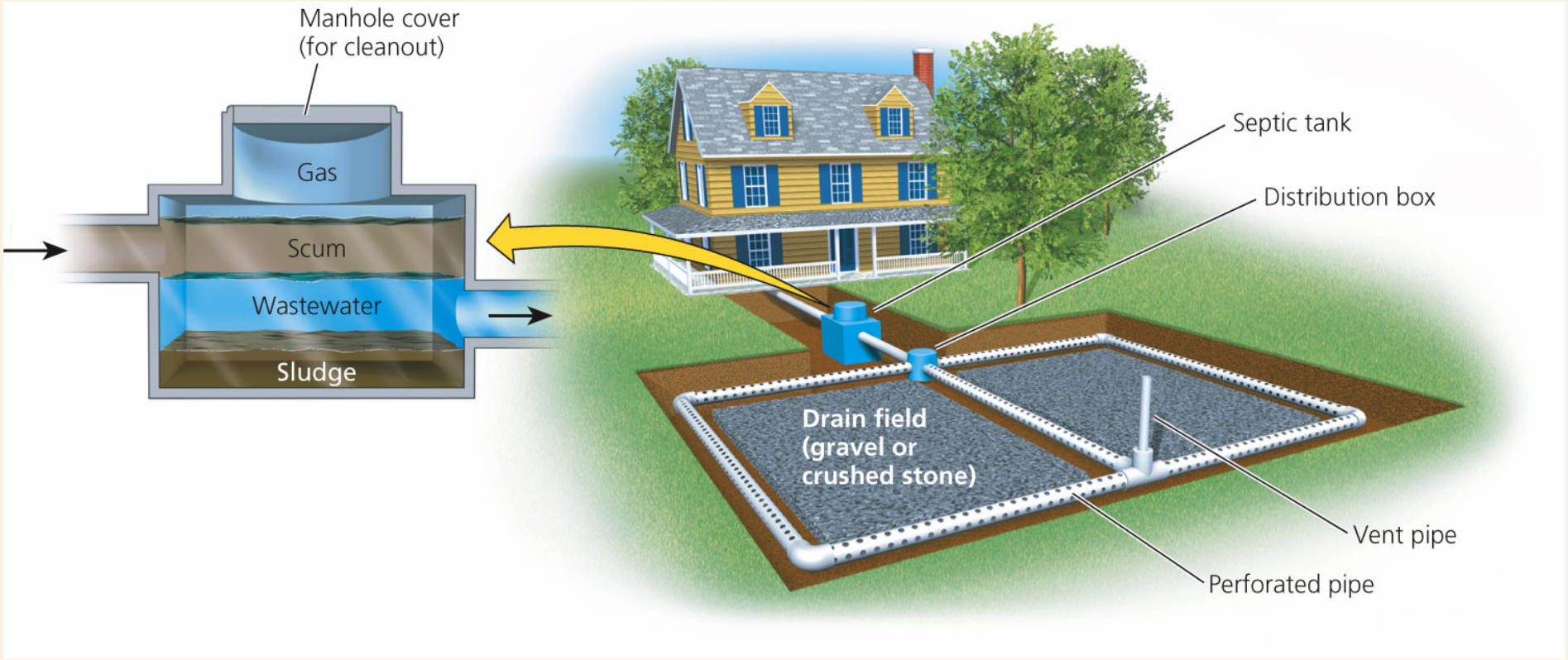


Fig. 20-19, p. 550

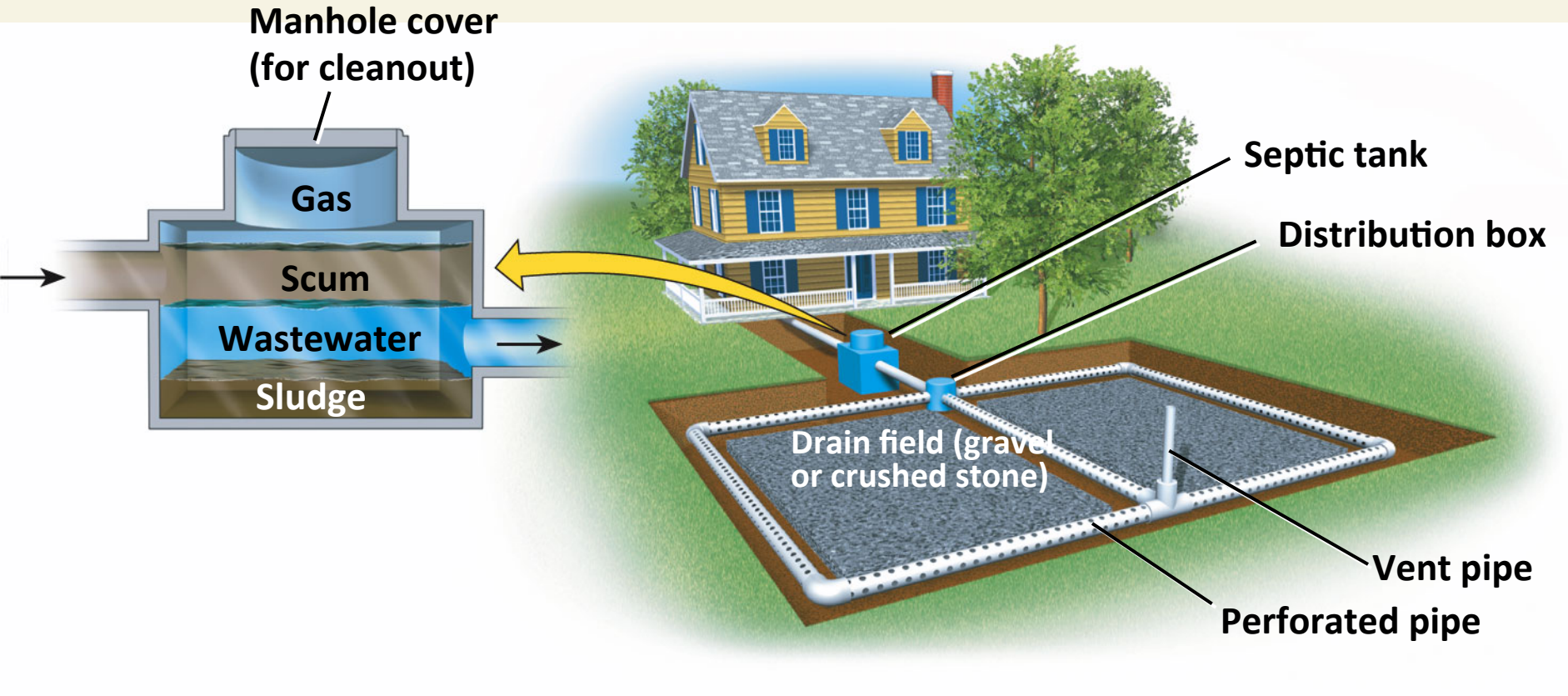


Fig. 20-19, p. 550

Solutions: Primary and Secondary Sewage Treatment

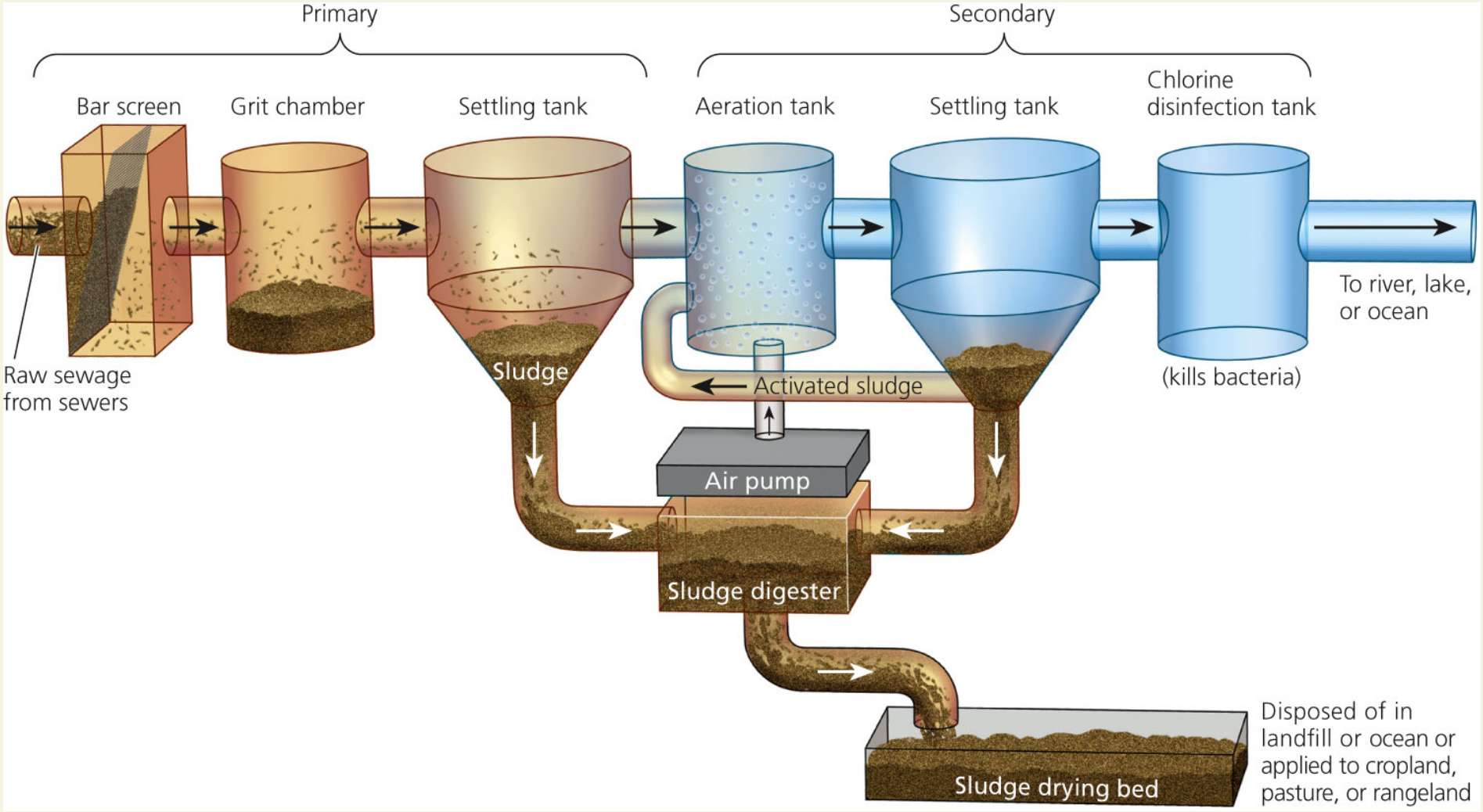


Fig. 20-20, p. 551

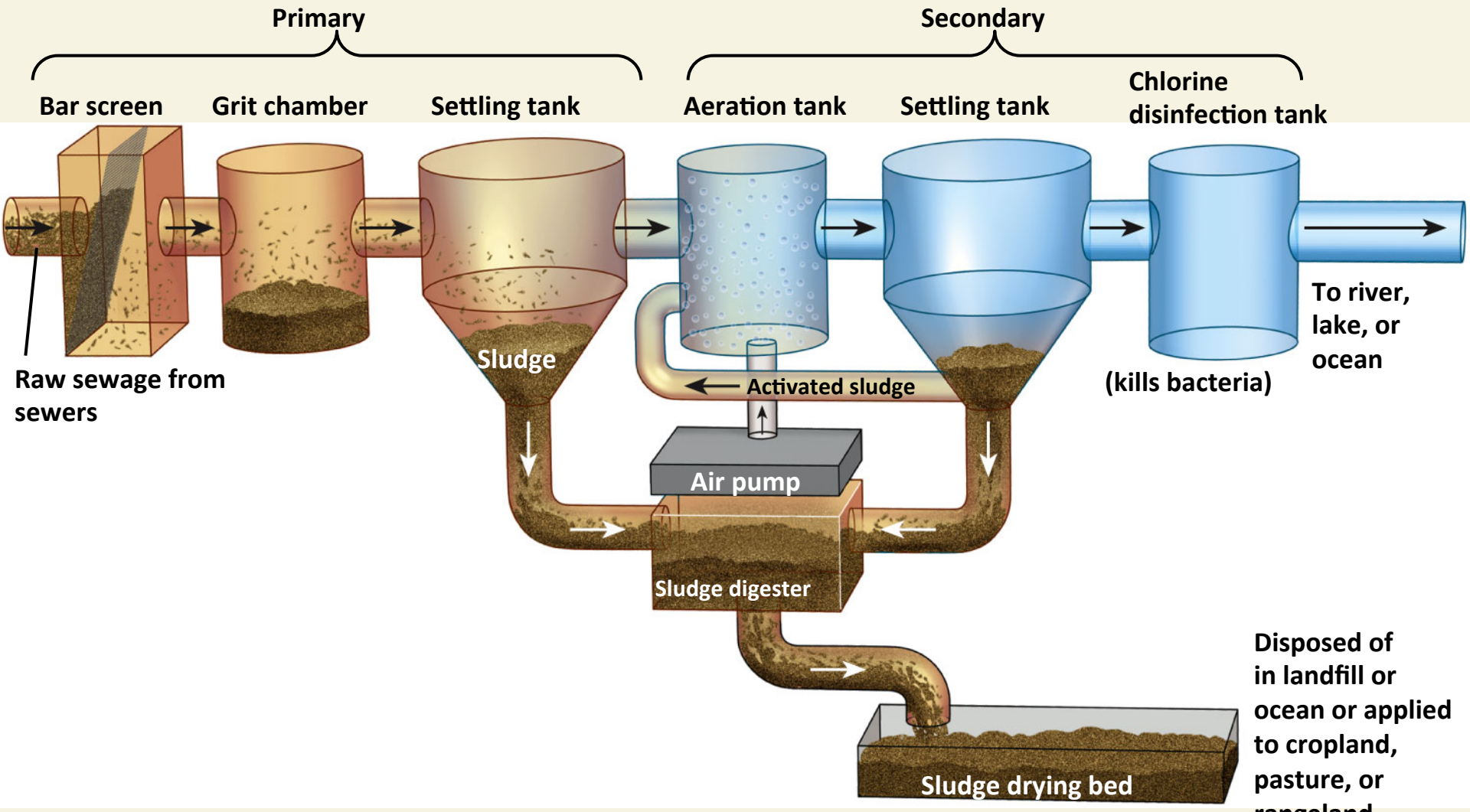
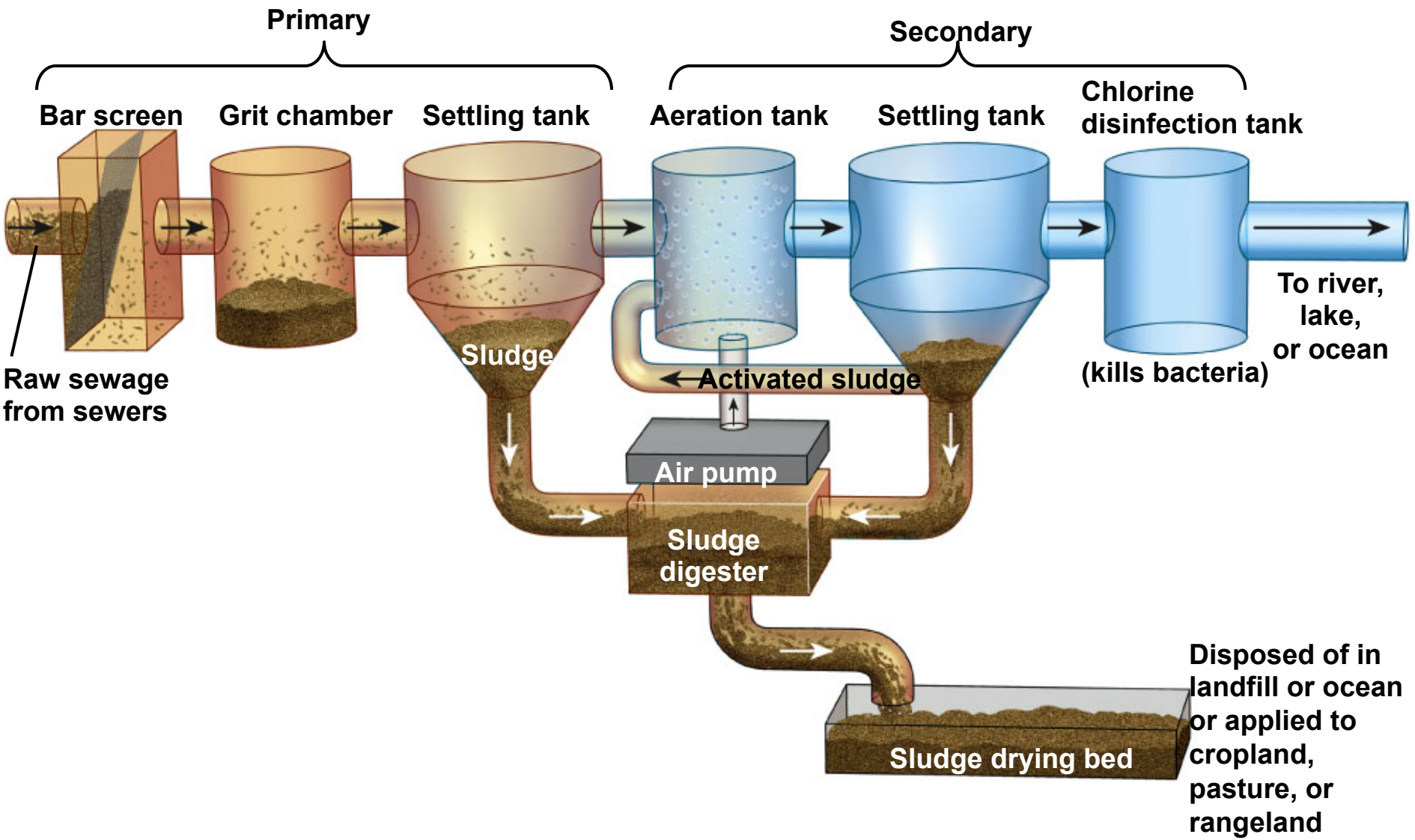


Fig. 20-20, p. 551



Stepped Art

Fig. 20-20, p. 551

We Can Improve Conventional Sewage Treatment

- Peter Montague: environmental scientist
  - Remove toxic wastes before water goes to the municipal sewage treatment plants
  - Reduce or eliminate use and waste of toxic chemicals
  - Use composting toilet systems

- Wetland-based sewage treatment systems

Science Focus: Treating Sewage by Working with Nature

- John Todd: biologist

- Natural water purification system
  - Sewer water flows into a passive greenhouse
  - Solar energy and natural processes remove and recycle nutrients
  - Diversity of organisms used

Solutions: Ecological Wastewater Purification by a Living Machine, RI, U.S.

Fig. 20-C, p. 553

There Are Sustainable Ways to Reduce and Prevent Water Pollution

- Developed countries
  - Bottom-up political pressure to pass laws
- Developing countries
  - Little has been done to reduce water pollution
  - China : ambitious plan

Solutions: Methods for Preventing and Reducing Water Pollution

Fig. 20-21, p. 553

What Can You Do? Reducing Water Pollution

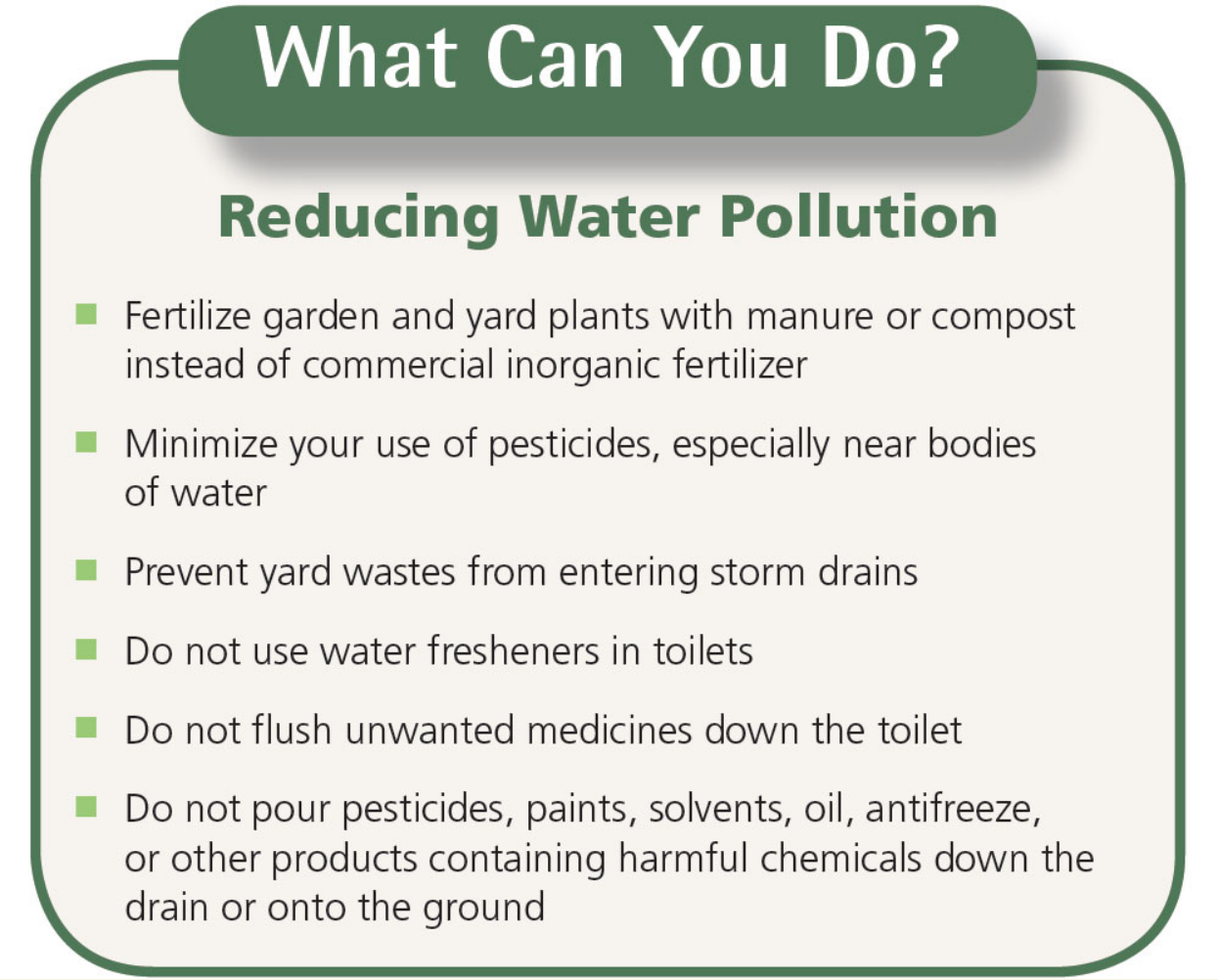


Fig. 20-22, p. 554

Three Big Ideas

1. There are a number of ways to purify drinking water, but the most effective and cheapest strategy is pollution control.

2. The key to protecting the oceans is to reduce the flow of pollution from land and air, and from streams emptying into ocean waters.

Three Big Ideas

3. Reducing water pollution requires that we prevent it, work with nature in treating sewage, cut resource use and waste, reduce poverty, and slow population growth.