

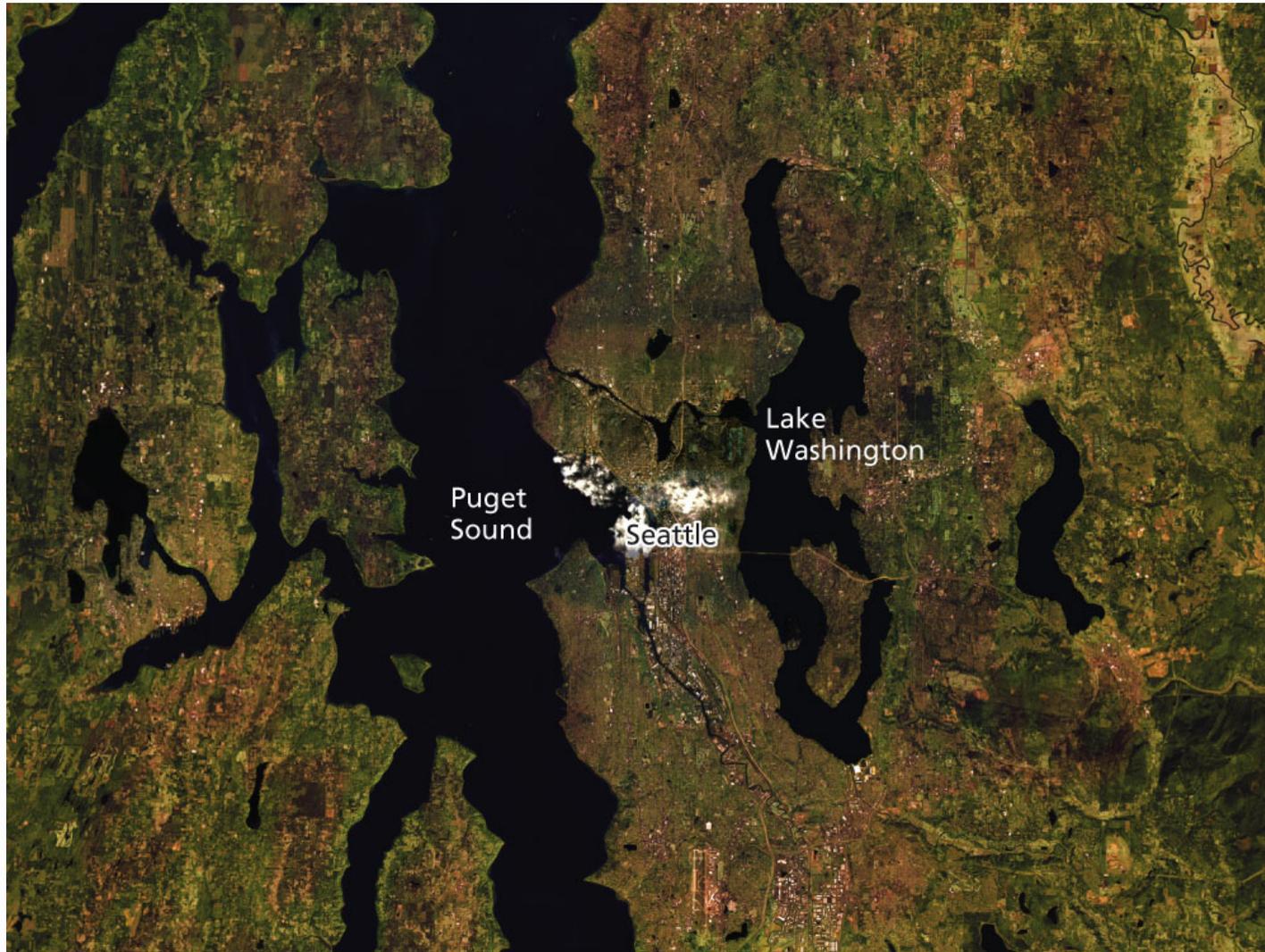


# **Water Pollution**

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## **Chapter 20**

# The Seattle, Washington Area, U.S.



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# 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
  - New pollution challenges
-

# Kayaker Enjoys Lake Washington



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## *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**
  - **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)

- Agriculture activities: leading cause of water pollution
    - Sediment eroded from the lands
    - Fertilizers and pesticides
    - Bacteria from livestock and food processing wastes
  
  - Industrial facilities
  
  - Mining
-

# Water Pollution Comes from Point and Nonpoint Sources (4)

- Other sources of water pollution
    - Parking lots
    - Human-made materials
      - E.g., plastics
    - Climate change due to global warming
-

# Point Source of Polluted Water in Gargas, France



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# Nonpoint Sediment from Unprotected Farmland Flows into Streams



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# Major Water Pollutants Have Harmful Effects

- Infectious disease organisms: contaminated drinking water
  - The World Health Organization (WHO)
    - 3 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 and Effects	Examples	Major sources
Infectious agents (pathogens) <i>Cause diseases</i>	Bacteria, viruses, protozoa, parasites	Human and animal wastes
Oxygen-demanding wastes <i>Deplete dissolved oxygen needed by aquatic species</i>	Biodegradable animal wastes and plant debris	Sewage, animal feedlots, food processing facilities, pulp mills
Plant nutrients <i>Cause excessive growth of algae and other species</i>	Nitrates ( $\text{NO}_3^-$ ) and phosphates ( $\text{PO}_4^{3-}$ )	Sewage, animal wastes, inorganic fertilizers
Organic chemicals <i>Add toxins to aquatic systems</i>	Oil, gasoline, plastics, pesticides, cleaning solvents	Industry, farms, households
Inorganic chemicals <i>Add toxins to aquatic systems</i>	Acids, bases, salts, metal compounds	Industry, households, surface runoff
Sediments <i>Disrupt photosynthesis, food webs, other processes</i>	Soil, silt	Land erosion
Heavy metals <i>Cause cancer, disrupt immune and endocrine systems</i>	Lead, mercury, arsenic	Unlined landfills, household chemicals, mining refuse, industrial discharges
Thermal <i>Make some species vulnerable to disease</i>	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
<b>Bacteria</b>	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
<b>Viruses</b>	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
<b>Parasitic protozoa</b>	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
<b>Parasitic worms</b>	Schistosomiasis	Abdominal pain, skin rash, anemia, chronic fatigue, and chronic general ill health
	Ancylostomiasis	Severe anemia and possible symptoms of bronchial infection

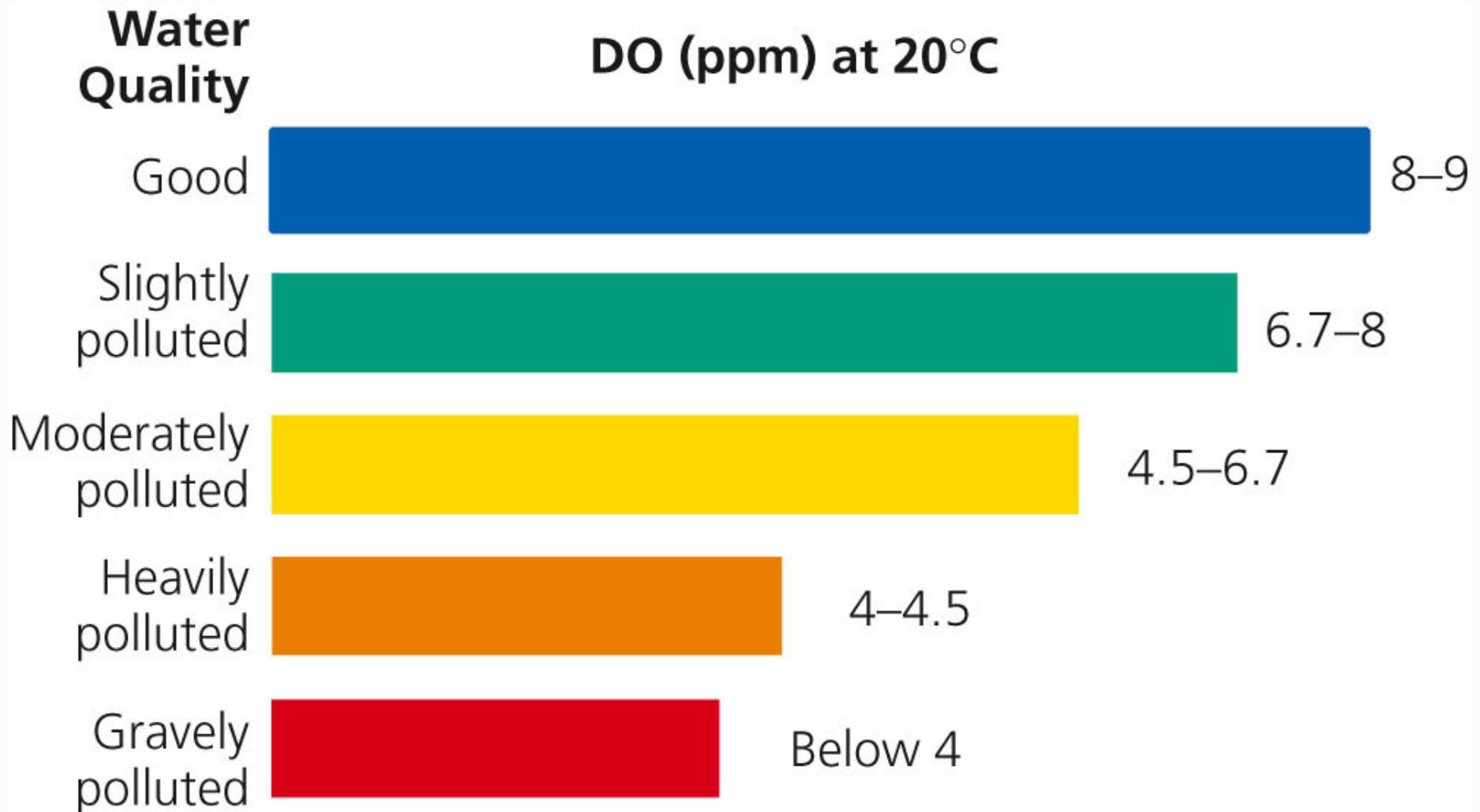
# Science Focus: Testing Water for Pollutants (1)

- 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)

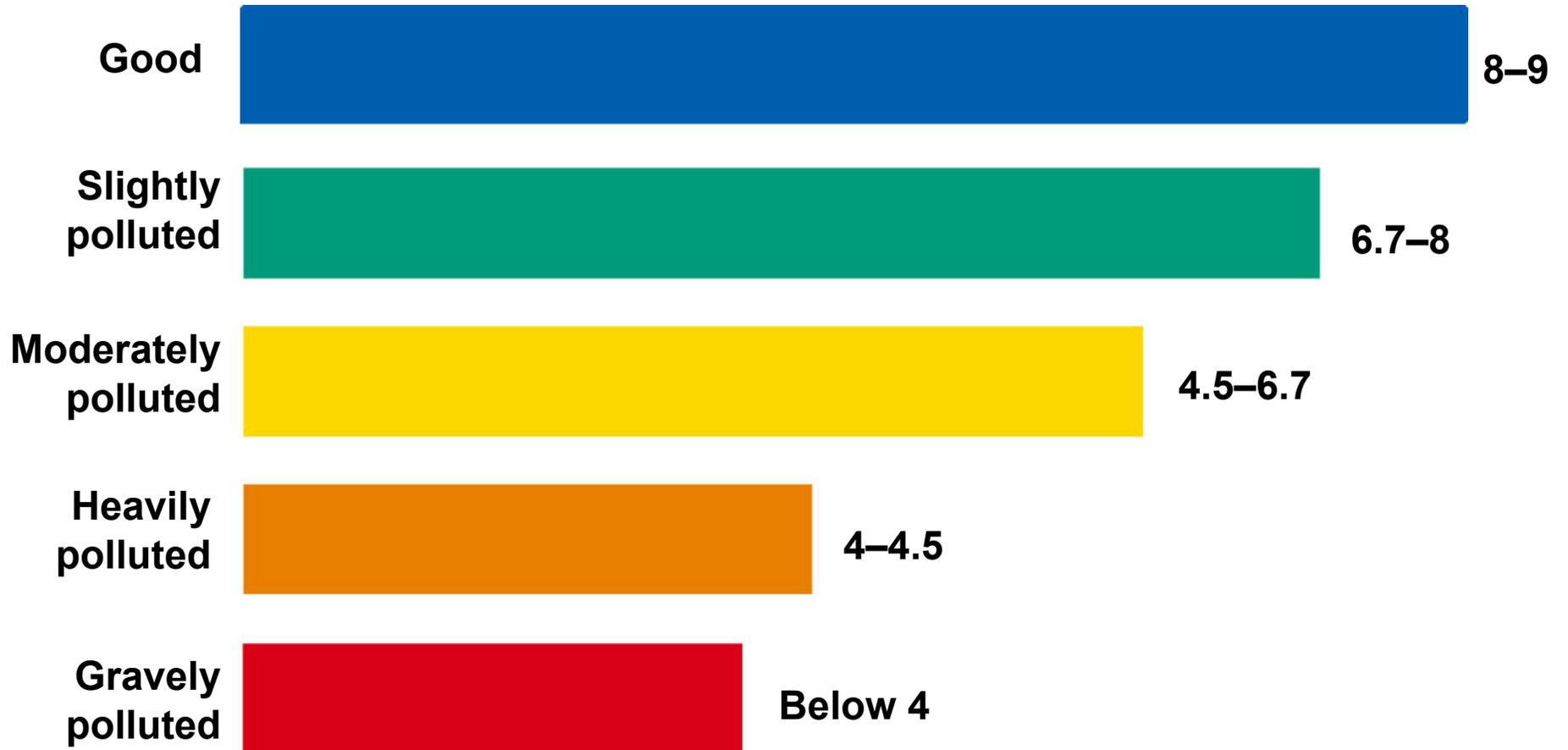
- Indicator species
    - Examples
  - Bacteria and yeast glow in the presence of a particular toxic chemical
  - Color and turbidity of the water
-

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



**Water  
Quality**

**DO (ppm) at 20°C**



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Fig. 20-A, p. 535

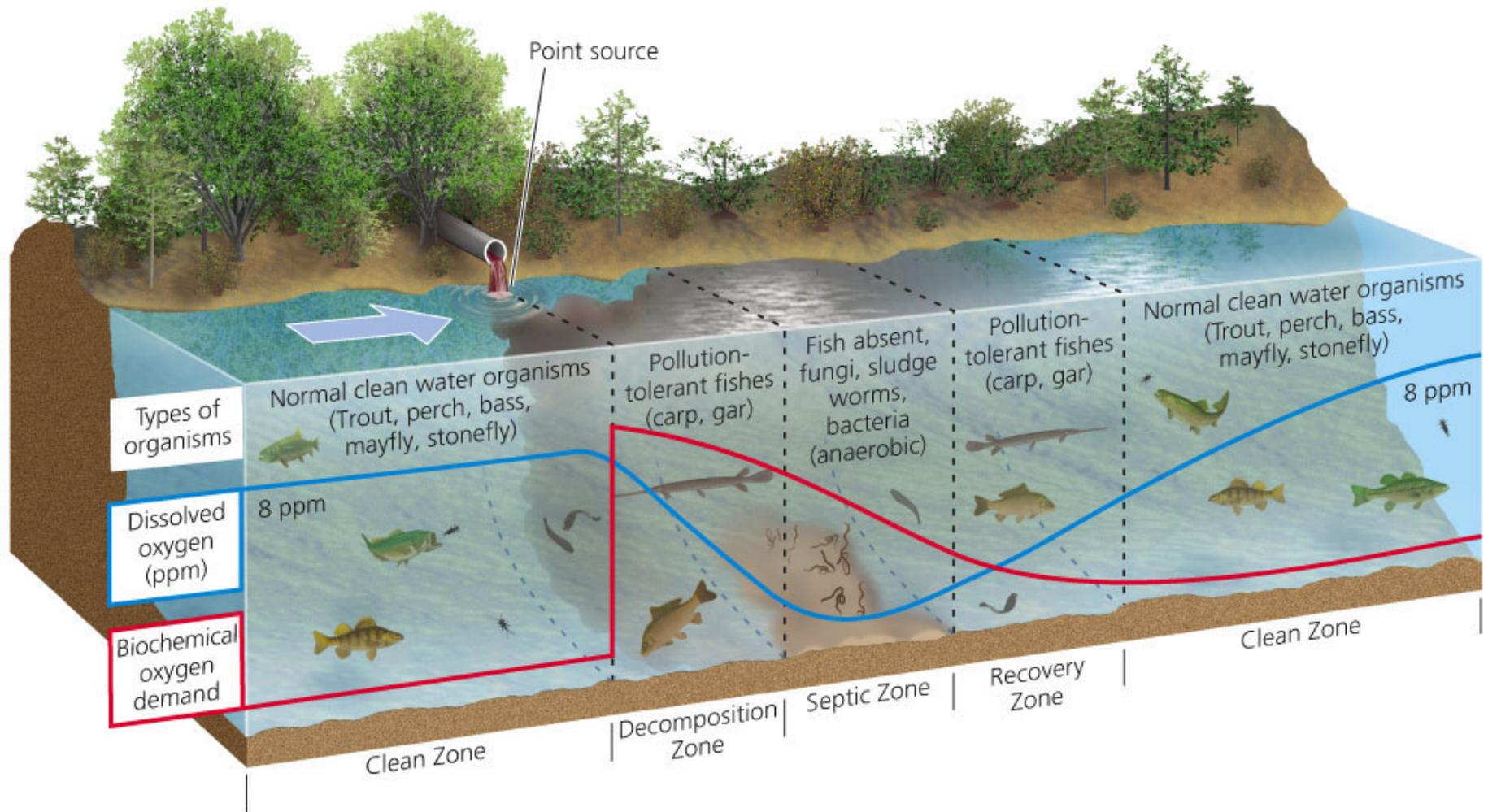
## ***20-2 What Are the Major Water Pollution Problems in Streams and Lakes?***

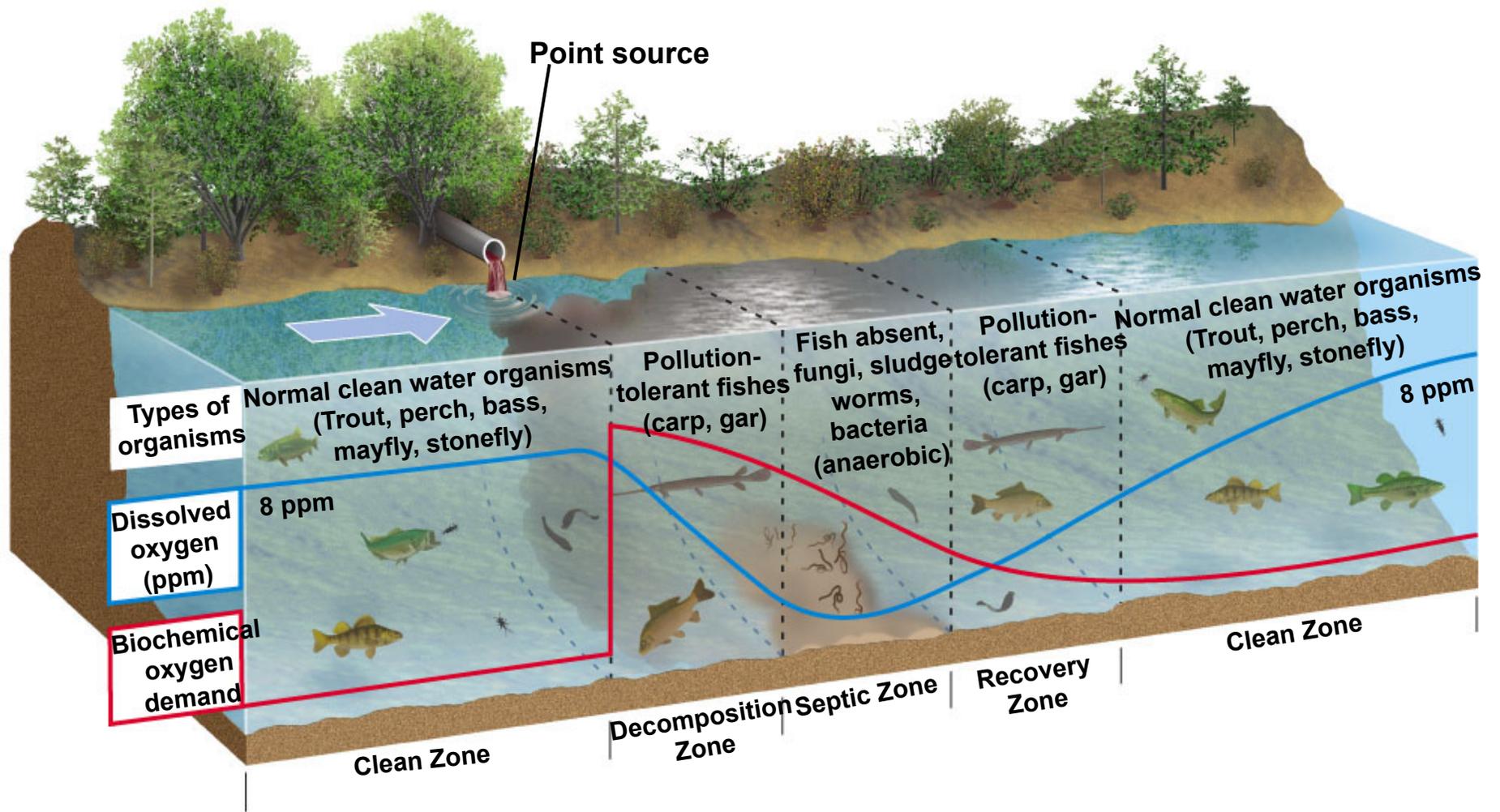
- ***Concept 20-2A*** *While streams are extensively polluted worldwide by human activities, they can cleanse themselves of many pollutants if we do not overload them or reduce their flows.*
  - ***Concept 20-2B*** *Addition of excessive nutrients to lakes from human activities can disrupt lake ecosystems, 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





# Stream Pollution in 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 rivers are polluted
  - Untreated sewage
  - Industrial waste
  - India's rivers
  - China's rivers
-

# Girl Sits on the Edge of a Road beside a Stream Loaded with Raw Sewage in Iraq



© Brooks/Cole, Cengage Learning

# Natural Capital Degradation: Highly Polluted River in China



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---

# Trash Truck Disposing of Garbage into a River in Peru



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# Case Study: India's Ganges River: Religion, Poverty, Population Growth, and Health (1)

- Holy river: religious customs
  - Sewage
  - Human remains
  - Government intervention
    - Waste treatment plants
    - Crematoriums
-

# Case Study: India's Ganges River: Religion, Poverty, Population Growth, and Health (2)

- Adding to the pollution
    - Religious custom
      - Painted statues
    - Global warming
      - Gangotri Glacier
-

# India's Ganges River



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# Makes Lakes Vulnerable to Water Pollution

- Less effective at diluting pollutants than streams
    - Stratified layers
      - Little vertical mixing
    - Little or no water flow
-

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

- **Eutrophication**
  - **Oligotrophic lake**
    - Low nutrients, clear water
  - **Cultural eutrophication**
-

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

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

# 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
-

# 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
    - What was done?
  - 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 (2)

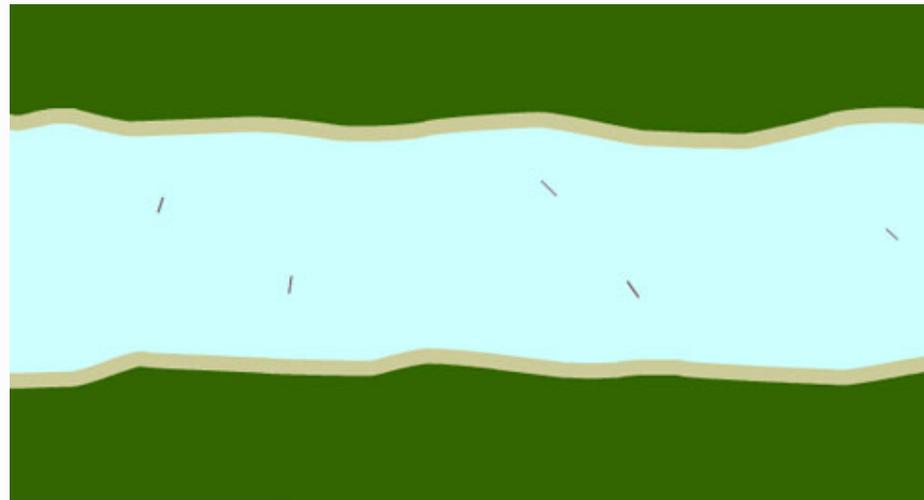
- 2007 State of the Great Lakes report
    - New pollutants found
    - Wetland loss and degradation; significance?
    - Declining of some native species
    - Native carnivorous fish species declining
    - What should be done?
-

# The Great Lakes of North America



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# Active Figure: Stream pollution



## ***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 simple ways and complex ways to purify drinking water, but protecting it through pollution prevention is the least expensive and most effective strategy.*
-

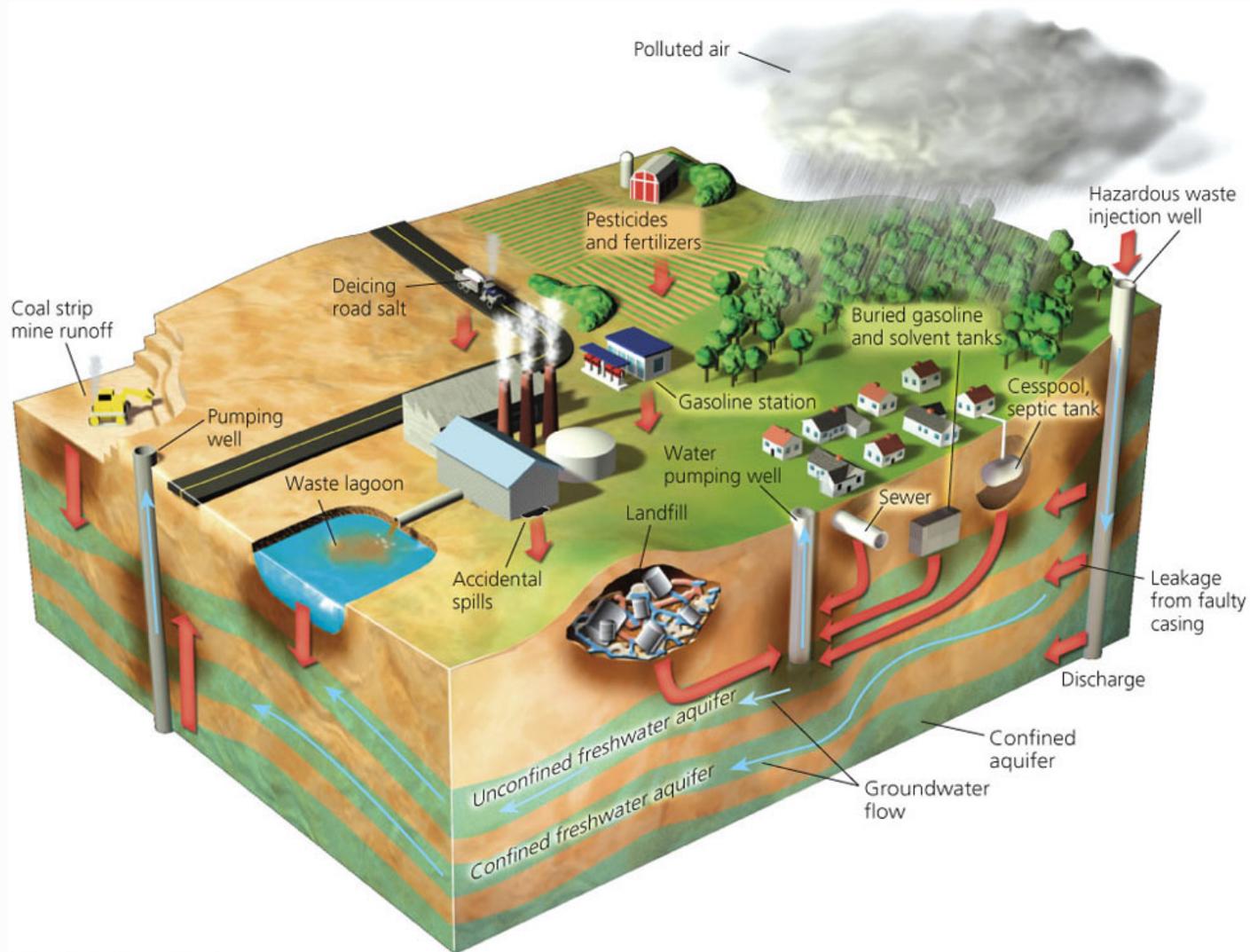
# Ground Water Cannot Cleanse Itself Very Well (1)

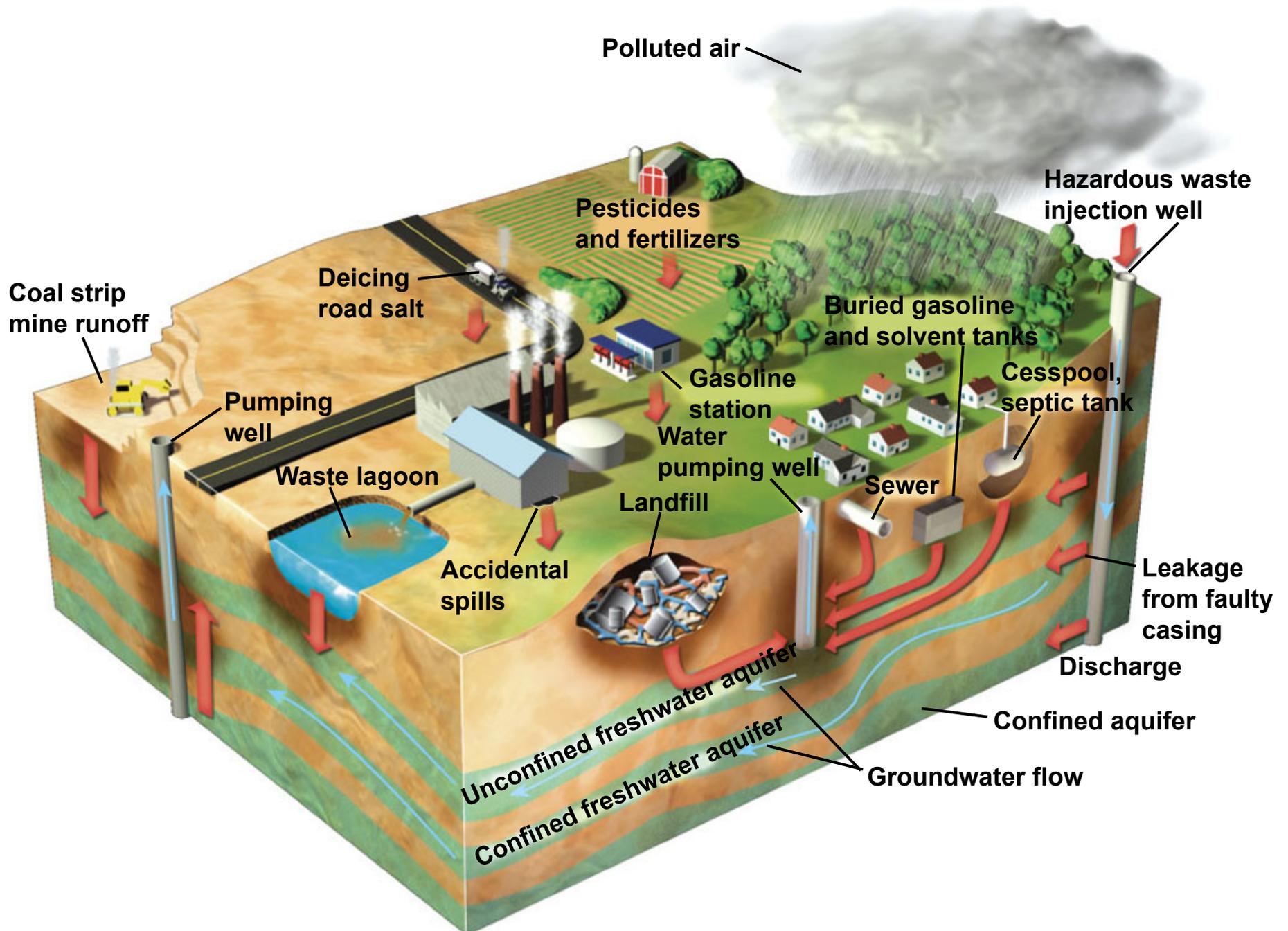
- Source of drinking water
  - Common pollutants
    - Fertilizers and pesticides
    - Gasoline
    - Organic solvents
  - Pollutants dispersed in a widening **plume**
-

# Ground Water Cannot Cleanse Itself Very Well (2)

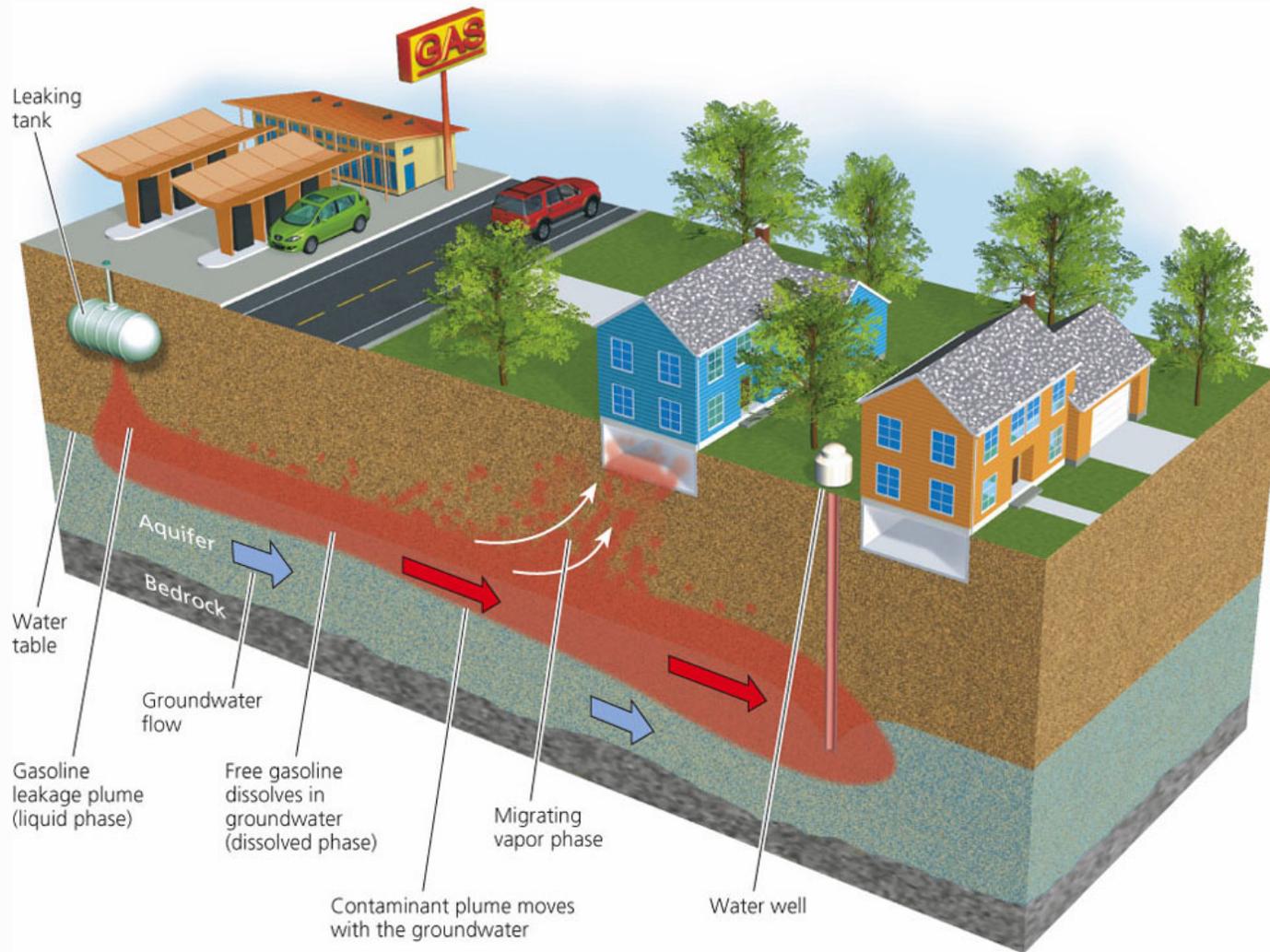
- Slower chemical reactions in groundwater due to
    - Slow flow: contaminants not diluted
    - Less dissolved oxygen
    - Fewer decomposing bacteria
  - How long will it take to cleans itself of
    - Slowly degradable wastes
      - E.g., DDT
    - Nondegradable wastes
      - E.g., Pb and As
-

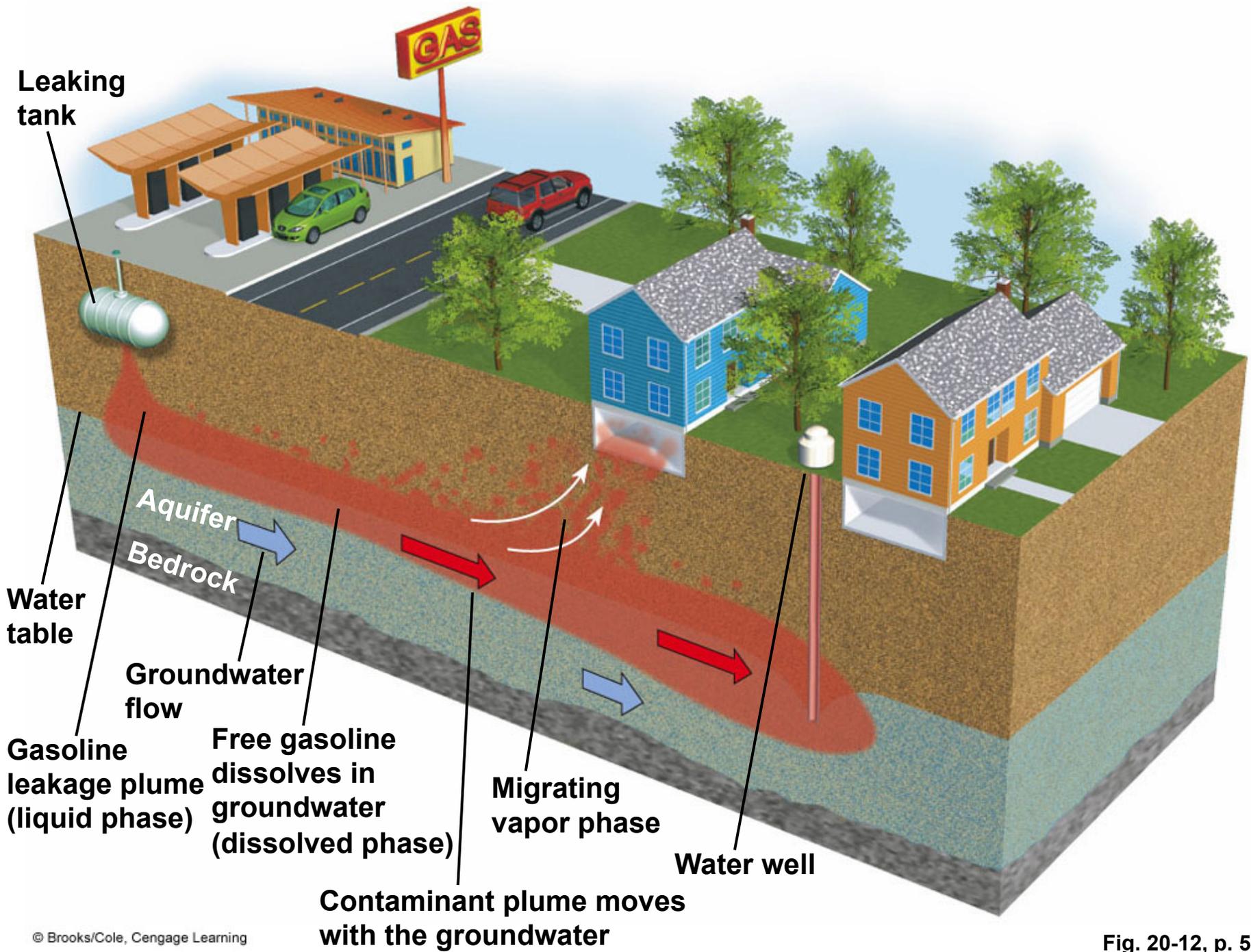
# Principal Sources of Groundwater Contamination in the U.S.





# Groundwater Contamination from a Leaking Gasoline Tank





# Groundwater Pollution Is a Serious Threat

- China: many contaminated or overexploited aquifers
  - U.S.: FDA reports of toxins found in many aquifers
  - What about leaking underground storage tanks:
    - Gasoline
    - Oil
    - Methyl tertiary butyl ether (MTBE)
    - Nitrate ions
-

# Case Study: A Natural Threat from Arsenic in Groundwater

- Source of As in the groundwater
  - Human health hazards: cancer
    - Skin
    - Lungs
    - Bladder
  - 2006 research: Rice University, TX, U.S.
    - Purification system to remove As
-

# 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

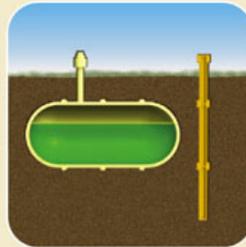
Keep toxic chemicals out of the environment

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)

# SOLUTIONS

## Groundwater Pollution

### Prevention

Find substitutes for toxic chemicals

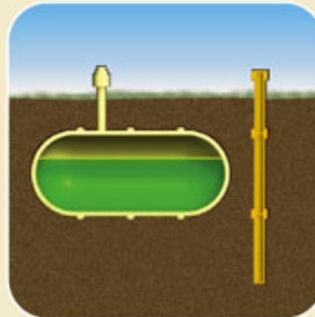
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Pump nanoparticles of inorganic compounds to remove pollutants (still being developed)

# 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)
  - Nanofilters
  - The LifeStraw
-

# The LifeStraw: Personal Water Purification Device



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# Case Study: Protecting Watersheds Instead of Building Water Purification Plants

- New York City water
    - Reservoirs in the Catskill Mountains
  - Protect the watershed instead of water purification plants
-

# 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
-

# 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
  - Growing back-to-the-tap movement
-

# ABC Video: MTBE pollution



▶ **PLAY**

---

## ***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 and solid wastes, which threaten aquatic species and other wildlife and disrupt marine ecosystems.*
  - **Concept 20-4B** *The key to protecting the oceans is to reduce the flow of pollutants from land and air and from streams emptying into these waters.*
-

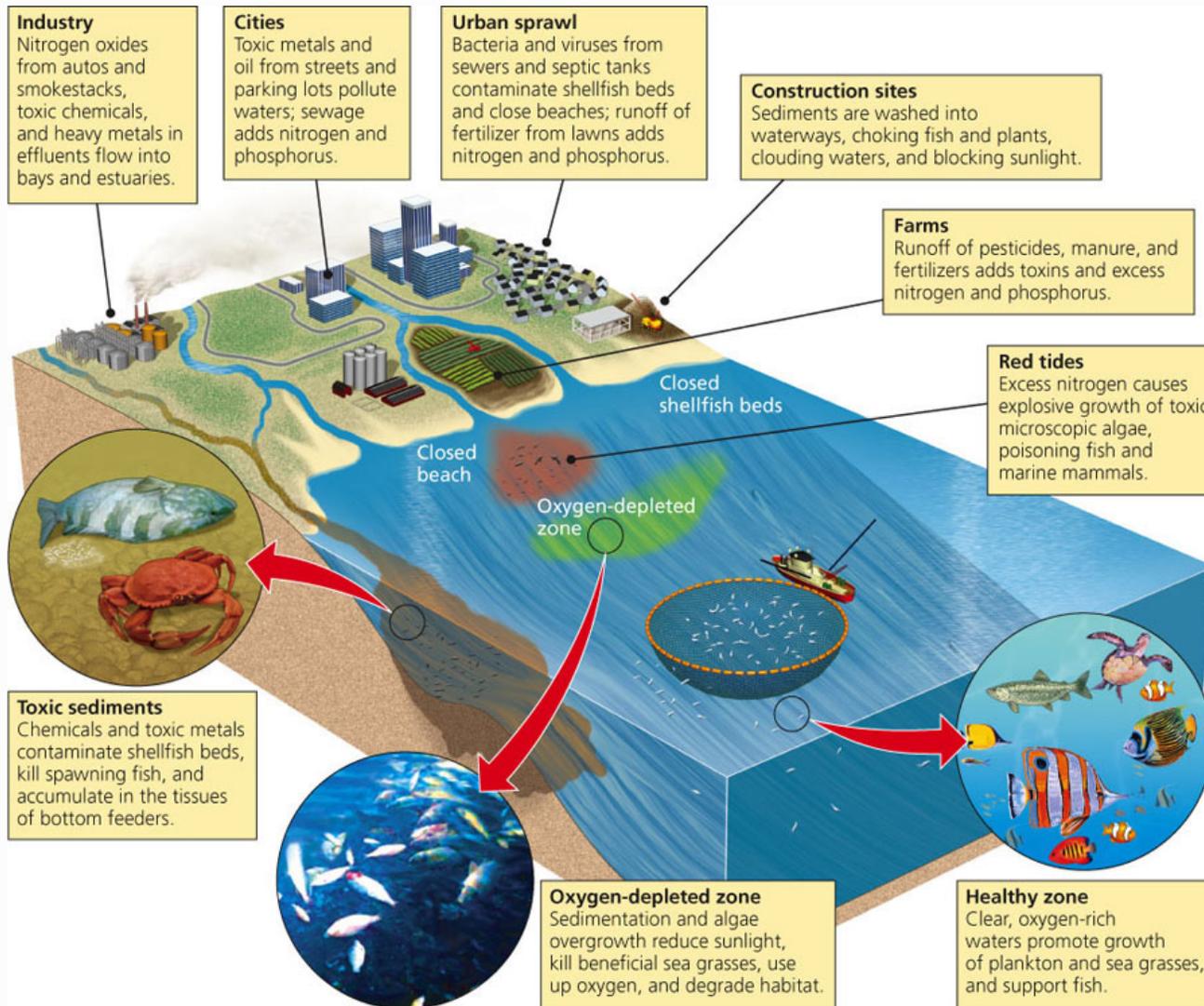
# Ocean Pollution Is a Growing and Poorly Understood Problem (1)

- 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:  $\text{NO}_3^-$  and  $\text{PO}_4^{3-}$
    - Harmful algal blooms
    - Oxygen-depleted zones
-

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



**Industry Nitrogen oxides from autos and smokestacks, toxic chemicals, and heavy metals in effluents flow into bays and estuaries.**

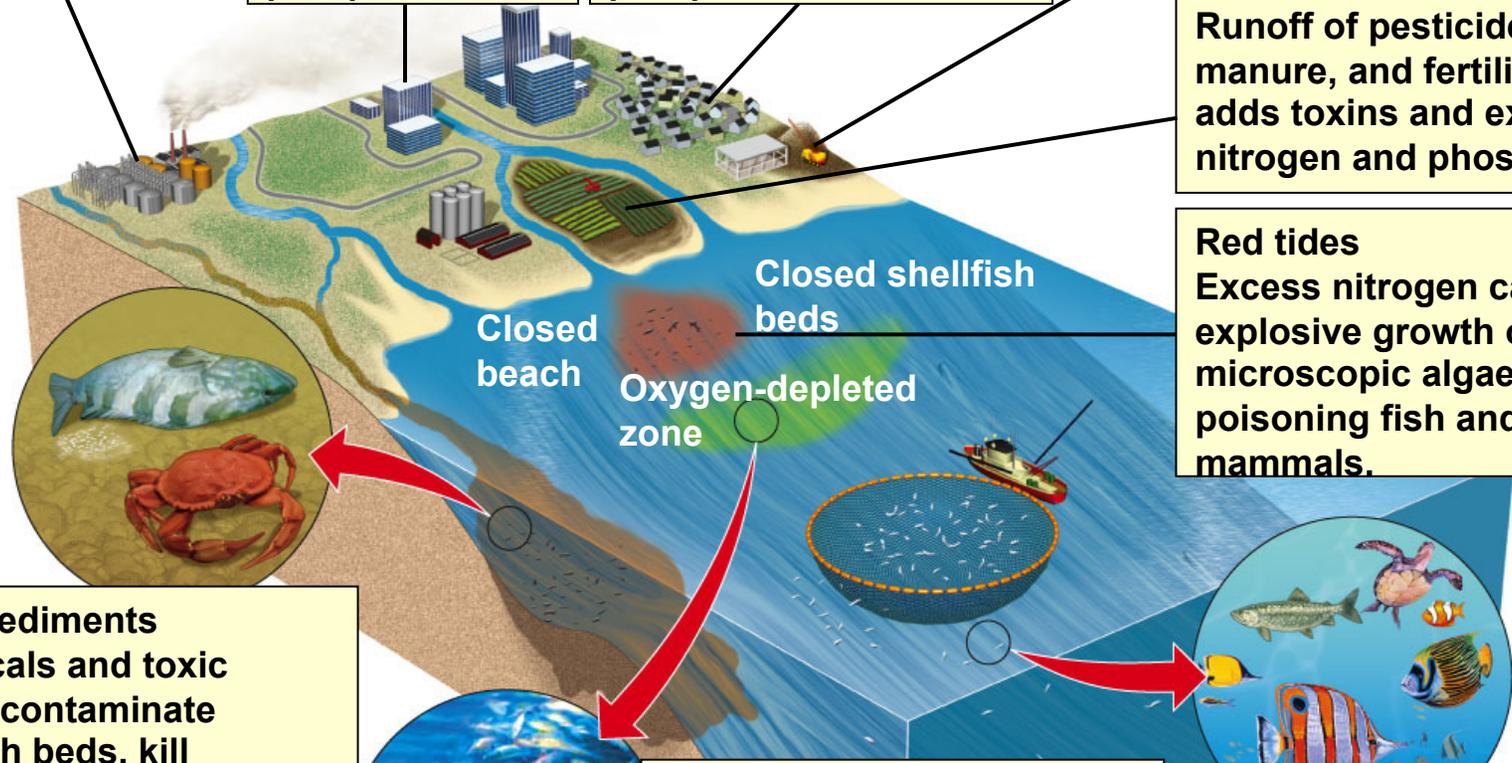
**Cities Toxic metals and oil from streets and parking lots pollute waters; sewage adds nitrogen and phosphorus.**

**Urban sprawl Bacteria and viruses from sewers and septic tanks contaminate shellfish beds and close beaches; runoff of fertilizer from lawns adds nitrogen and phosphorus.**

**Construction sites Sediments are washed into waterways, choking fish and plants, clouding waters, and blocking sunlight.**

**Farms Runoff of pesticides, manure, and fertilizers adds toxins and excess nitrogen and phosphorus.**

**Red tides Excess nitrogen causes explosive growth of toxic microscopic algae, poisoning fish and marine mammals.**



**Toxic sediments Chemicals and toxic metals contaminate shellfish beds, kill spawning fish, and accumulate in the tissues of bottom feeders.**

**Oxygen-depleted zone Sedimentation and algae overgrowth reduce sunlight, kill beneficial sea grasses, use up oxygen, and degrade habitat.**

**Healthy zone Clear, oxygen-rich waters promote growth of plankton and sea grasses, and support fish.**

# A Red Tide

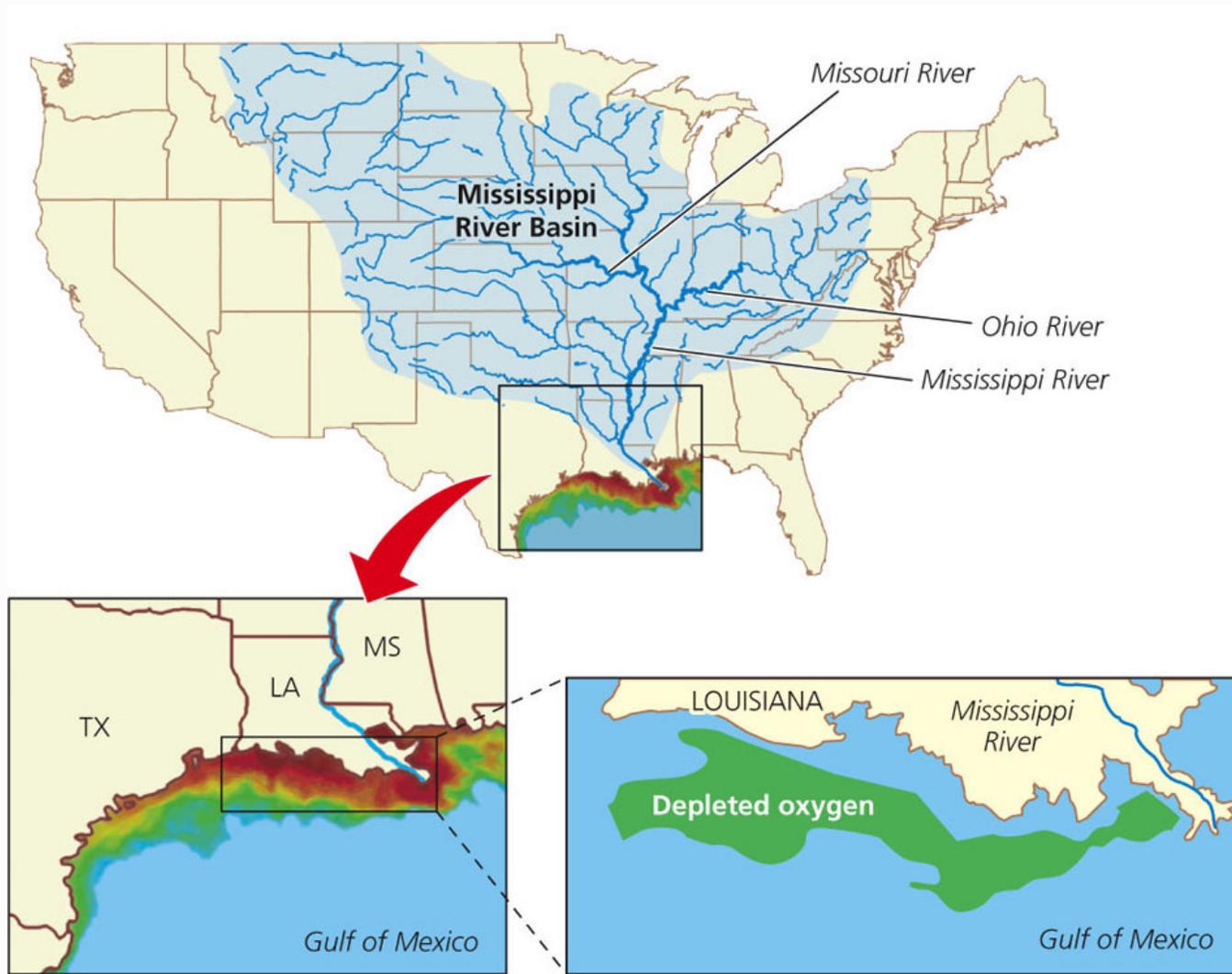


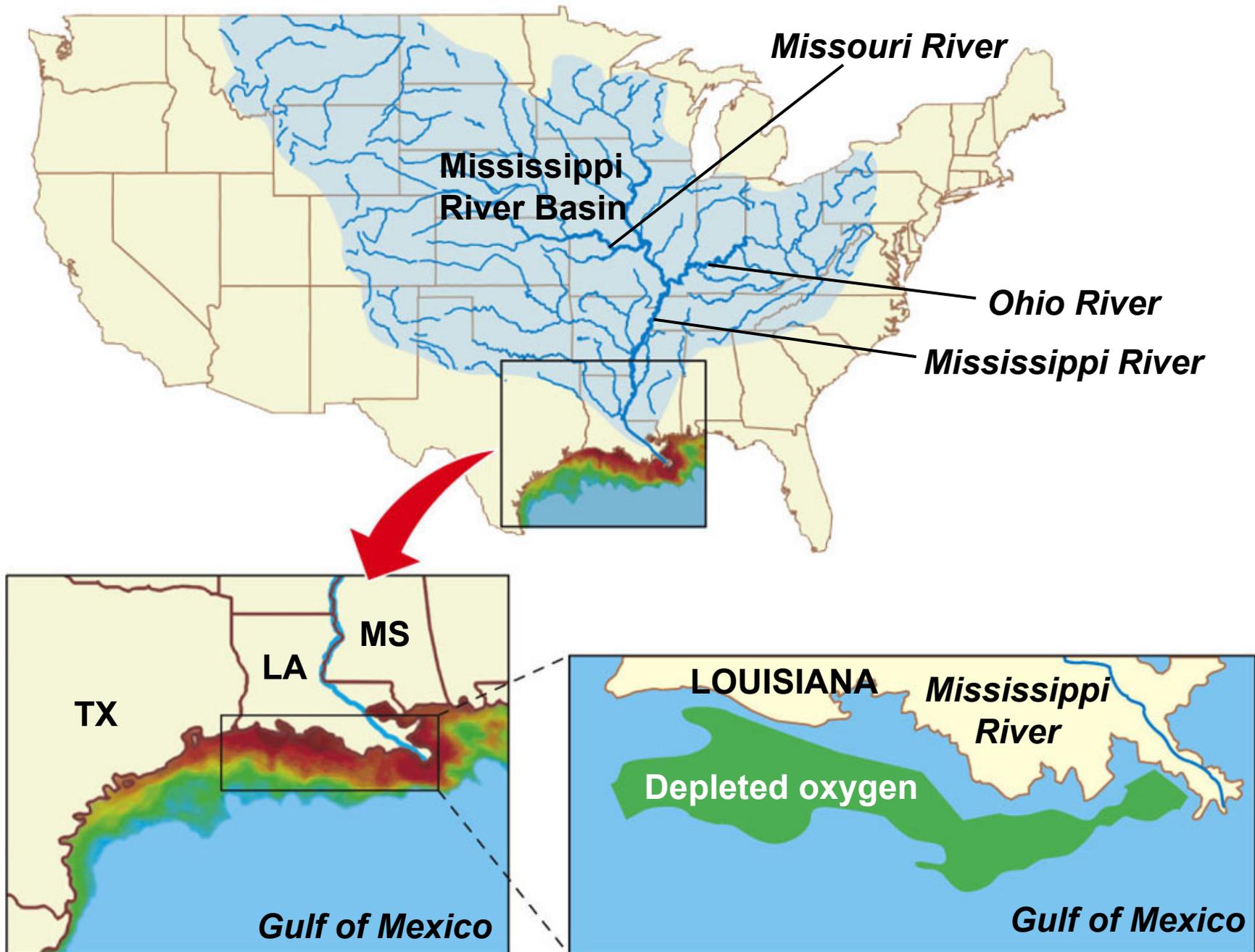
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# Science Focus: Oxygen Depletion in the Northern Gulf Of Mexico

- 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





# Ocean Oil Pollution Is a Serious Problem (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
  - 2002: Prestige, oil tanker
-

# Ocean Oil Pollution Is a Serious Problem (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 Oil Pollution Is a Serious Problem (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 lines

Ban dumping of wastes and sewage by ships in coastal waters

Ban ocean dumping of sludge and hazardous dredged material

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

# SOLUTIONS

## Coastal Water Pollution

### Prevention

Reduce input of toxic pollutants

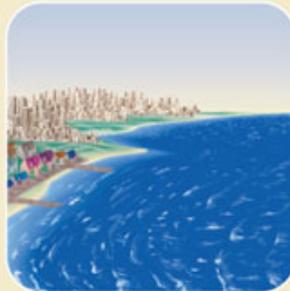
Separate sewage and storm lines

Ban dumping of wastes and sewage by ships in coastal waters

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### 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

# ABC Video: Beach pollution



▶ **PLAY**

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

- ***Concept 20-5*** *Reducing water pollution requires preventing it, working with nature to treat sewage, cutting resource use and waste, reducing poverty, and slowing population growth.*
-

# We Need to Reduce Surface Water Pollution from Nonpoint Sources (1)

- Reduce erosion
    - Keep cropland covered with vegetation
  - Reduce the amount of fertilizers
  - Plant buffer zones of vegetation
  - Use organic farming techniques
-

# We Need to Reduce Surface Water Pollution from Nonpoint Sources (2)

- 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
  - EPA: experimenting with a discharge trading policy
  - 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
  - Weaken or strengthen the Clean Water Act
-

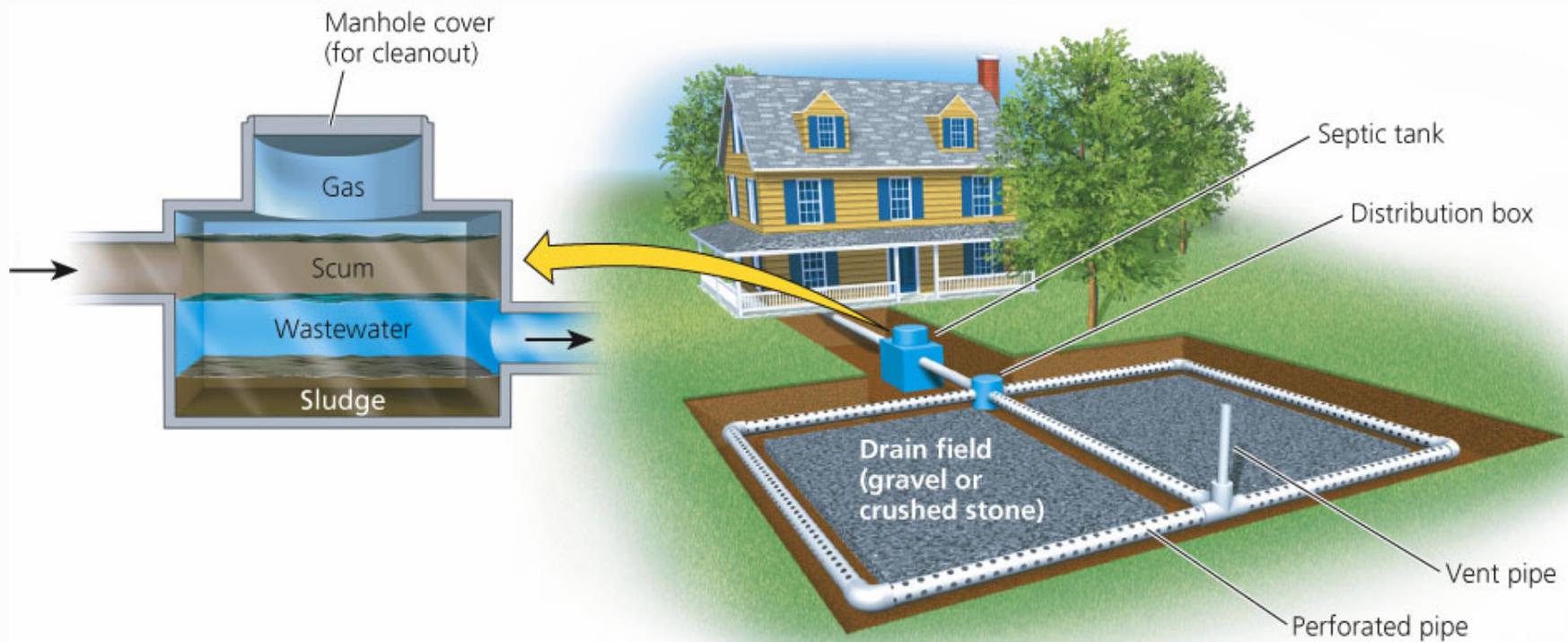
# Sewage Treatment Reduces Water Pollution (1)

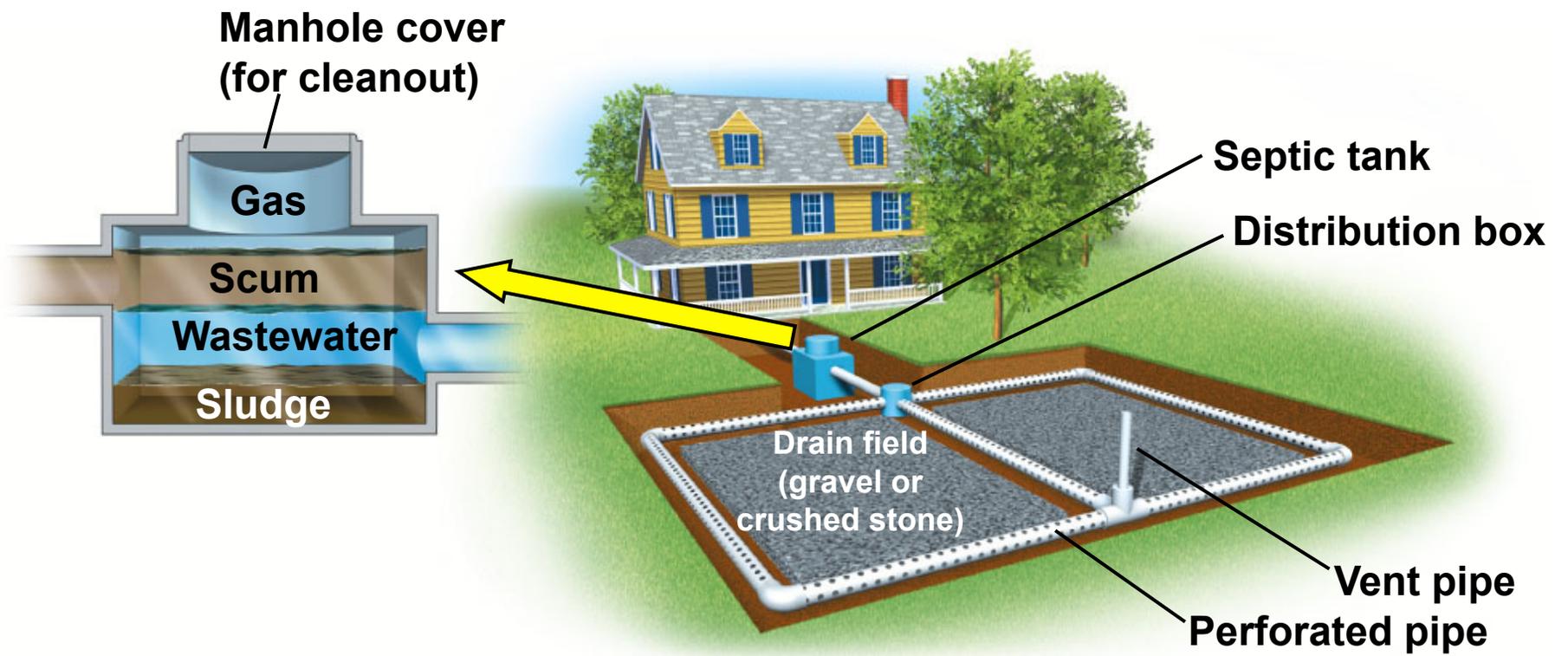
- **Septic tank system**
  
  - **Wastewater or sewage treatment plants**
    - **Primary sewage treatment**
      - Physical process
    - **Secondary sewage treatment**
      - Biological process
    - **Tertiary or advance sewage treatment**
      - **Bleaching, chlorination**
-

# Sewage Treatment Reduces Water Pollution (2)

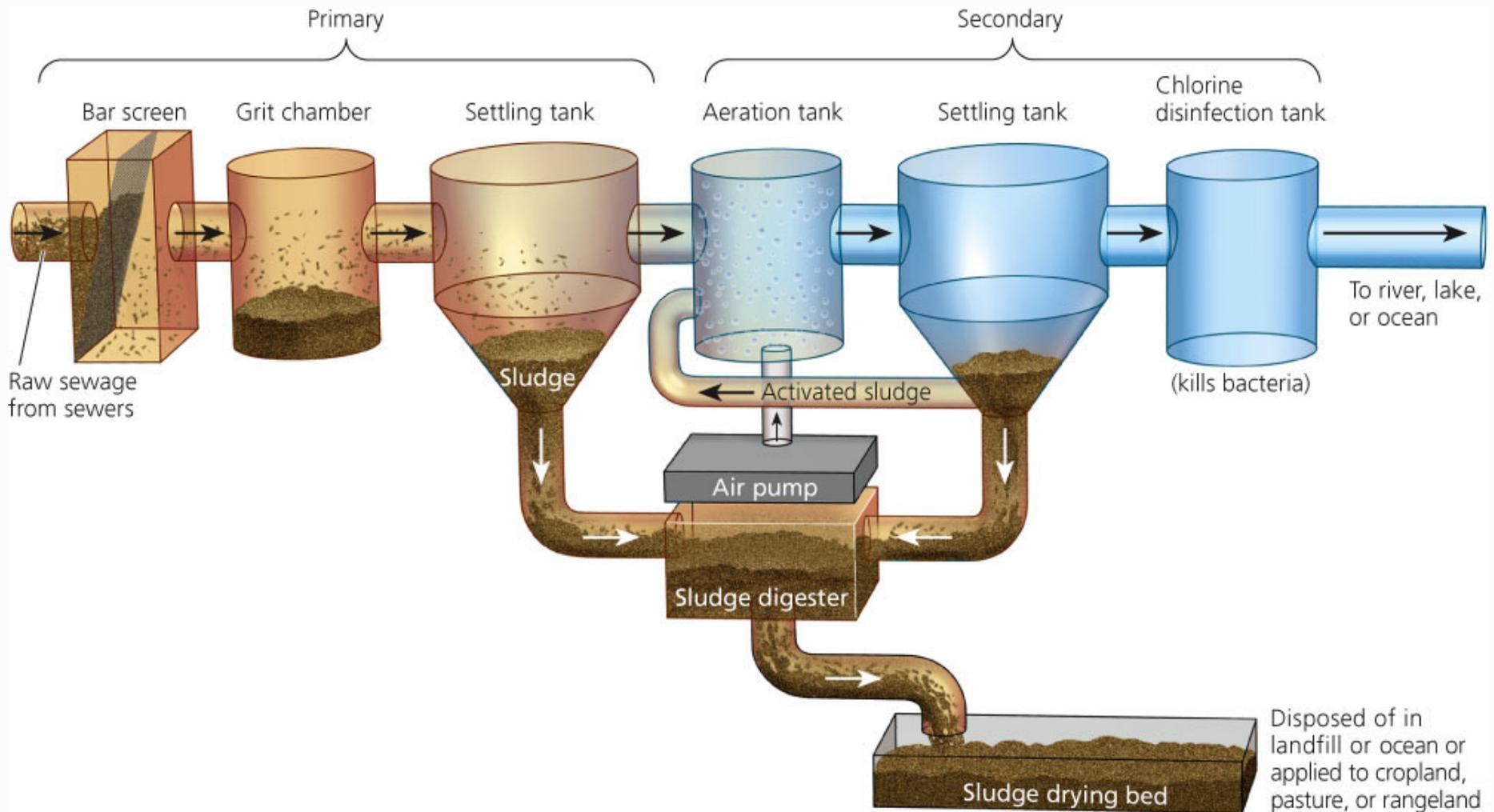
- Should there be separate pipes for sewage and storm runoff?
  - Health risks of swimming in water with blended sewage wastes
-

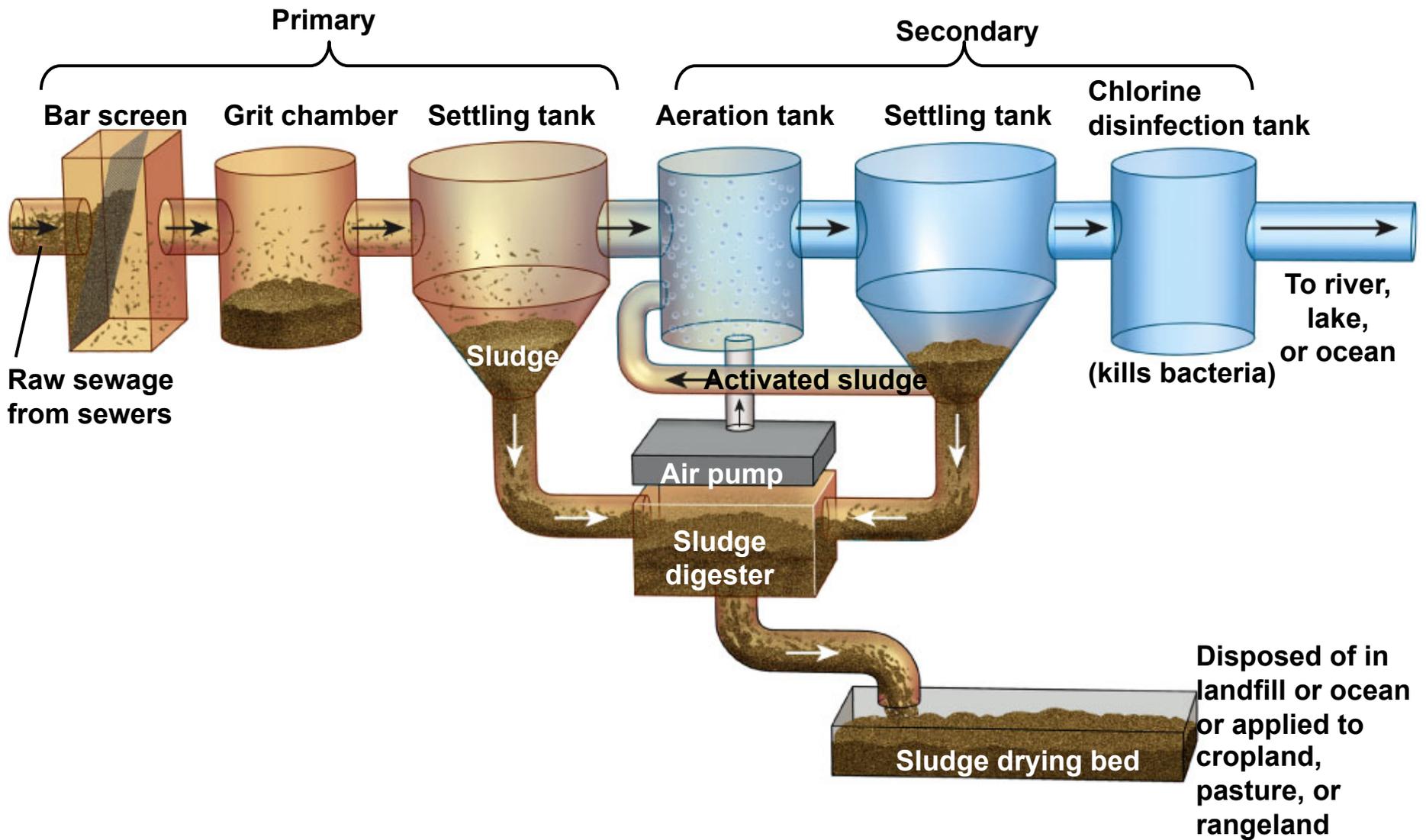
# Solutions: Septic Tank System





# Solutions: Primary and Secondary Sewage Treatment





Stepped Art

Fig. 20-19, p. 554

# 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.



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# There Are Sustainable Ways to Reduce and Prevent Water Pollution

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

# Solutions: Water Pollution, Methods for Preventing and Reducing Water Pollution

## SOLUTIONS

### Water Pollution

- Prevent groundwater contamination
- Reduce nonpoint runoff
- Reuse treated wastewater for irrigation
- Find substitutes for toxic pollutants
- Work with nature to treat sewage
- Practice the three R's of resource use (reduce, reuse, recycle)
- Reduce air pollution
- Reduce poverty
- Slow population growth

# What Can You Do? Water Pollution, Ways to Help Reduce Water Pollution

## WHAT CAN YOU DO?

### Reducing Water Pollution

- Fertilize garden and yard plants with manure or compost instead of commercial inorganic fertilizer
- Minimize your use of pesticides, especially near bodies of water
- Prevent yard wastes from entering storm drains
- Do not use water fresheners in toilets
- Do not flush unwanted medicines down the toilet
- Do not pour pesticides, paints, solvents, oil, antifreeze, or other products containing harmful chemicals down the drain or onto the ground

# ABC Video: MTBE pollution



▶ **PLAY**

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