MILLER/SPOOLMAN

LIVING IN THE ENVIRONMENT

17TH

Chapter 18

Air Pollution

Core Case Study: South Asia's Massive Brown Cloud

- South Asian Brown Cloud
  - Causes
  - Chemical composition
  - Areas impacted
- Air pollution connects the world
  - Affects west coast of the United States
- China and India need stricter air pollution standards

The Asian Brown Cloud

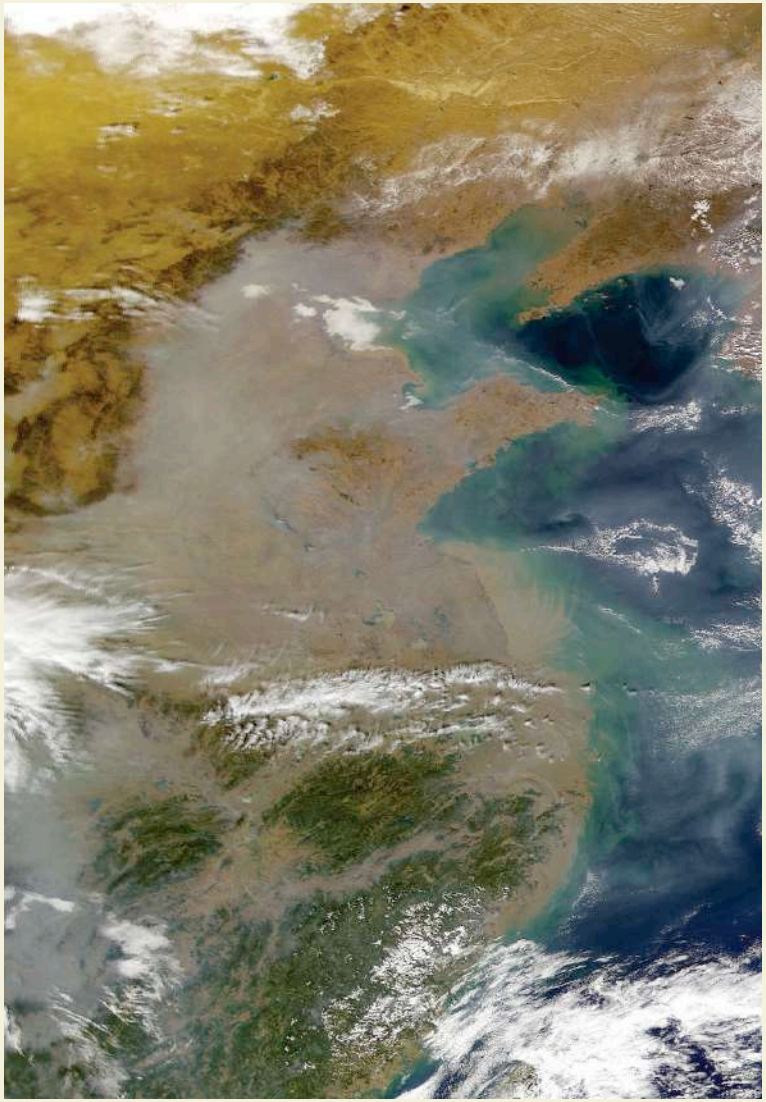

Fig. 18-1, p. 465

Air Pollution in Shanghai, China

Fig. 18-2, p. 465

18-1 What Is the Nature of the Atmosphere?

- ***Concept 18-1*** *The two innermost layers of the atmosphere are the troposphere, which supports life, and the stratosphere, which contains the protective ozone layer.*

The Atmosphere Consists of Several Layers

- Density varies
  - Decreases with altitude

- **Atmospheric pressure**
  - Decreases with altitude

Air Movements in the Troposphere Play a Key Role in Earth's Weather and Climate

- **Troposphere**
  - 75–80% of the earth's air mass
  - Closest to the earth's surface
  - Chemical composition of air
  - Rising and falling air currents: weather and climate
  - Involved in chemical cycling

Natural Capital: The Earth's Atmosphere Is a Dynamic System with Four Layers

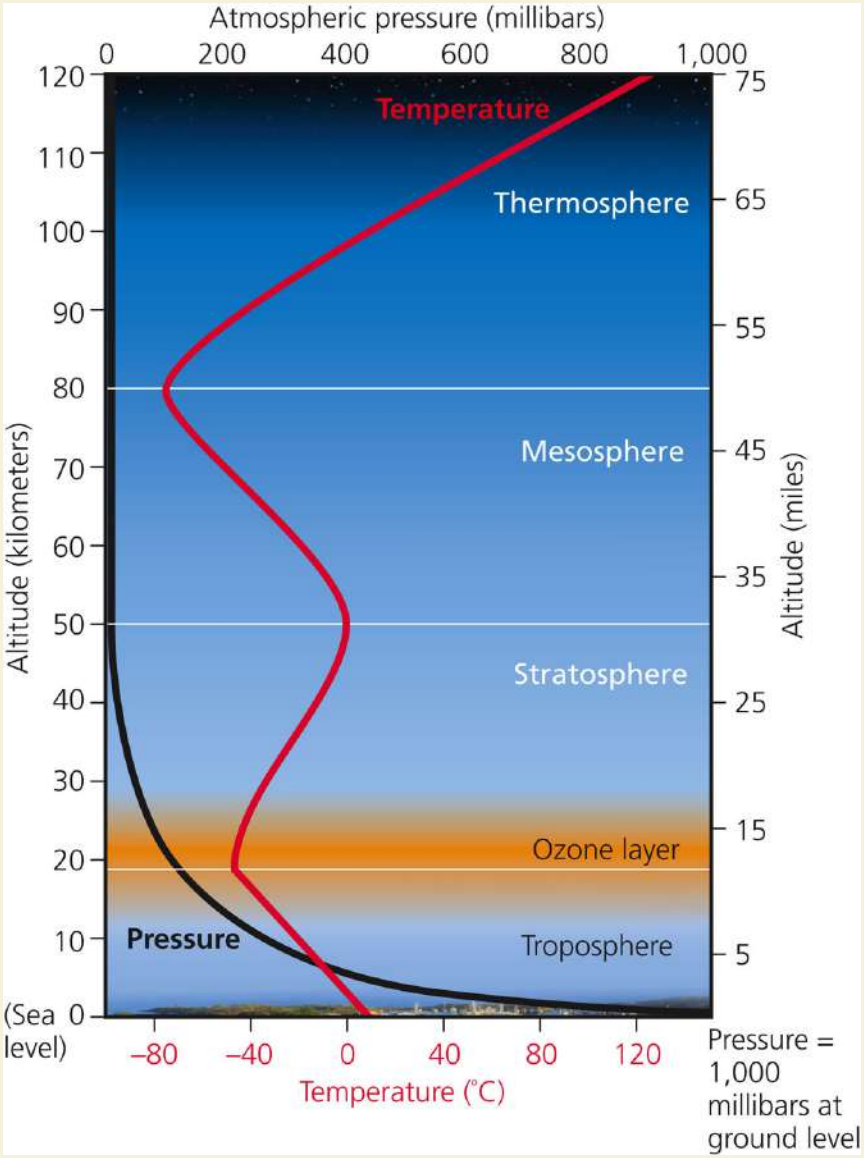

Fig. 18-3, p. 467

Case Study: The South Asian Brown Clouds, Melting Glaciers, and Atmospheric Cooling

- 2008 UNEP study on South Asian Brown Clouds
  - Causing gradual melting of Himalayan glaciers
  - Particles absorb sunlight and warm air above the glaciers
  - Reflect some sunlight back to space
  - Overall cooling affect on earth's atmosphere

The Stratosphere Is Our Global Sunscreen

- **Stratosphere**
  - Similar composition to the troposphere, with 2 exceptions
    - Much less water
    - O_3, **ozone layer**
  - **Ozone layer**
    - Filters 95% of harmful UV radiation
    - Allows us and other life to exist on land

18-2 What Are the Major Outdoor Pollution Problems?

- ***Concept 18-2*** *Pollutants mix in the air to form industrial smog, primarily as a result of burning coal, and photochemical smog, caused by emissions from motor vehicles, industrial facilities, and power plants.*

Air Pollution Comes from Natural and Human Sources (1)

- **Air pollution**
  - Concentrations high enough to harm human health or alter climate

- Natural sources
  - Dust blown by wind
  - Pollutants from wildfires and volcanoes
  - Volatile organics released by plants

Air Pollution Comes from Natural and Human Sources (2)

- Human sources: mostly in industrialized and/or urban areas
  - Stationary sources: power plants and industrial facilities
  - Mobile sources: motor vehicles

Burning Fossil Fuels Causes Air Pollution

Fig. 18-4, p. 468

Some Pollutants in the Atmosphere Combine to Form Other Pollutants

- **Primary pollutants**
  - Emitted directly into the air
- **Secondary pollutants**
  - From reactions of primary pollutants
- Air quality improving in developed countries
- Less-developed countries face big problems
  - Indoor pollution: big threat to the poor

Sources and Types of Air Pollutants

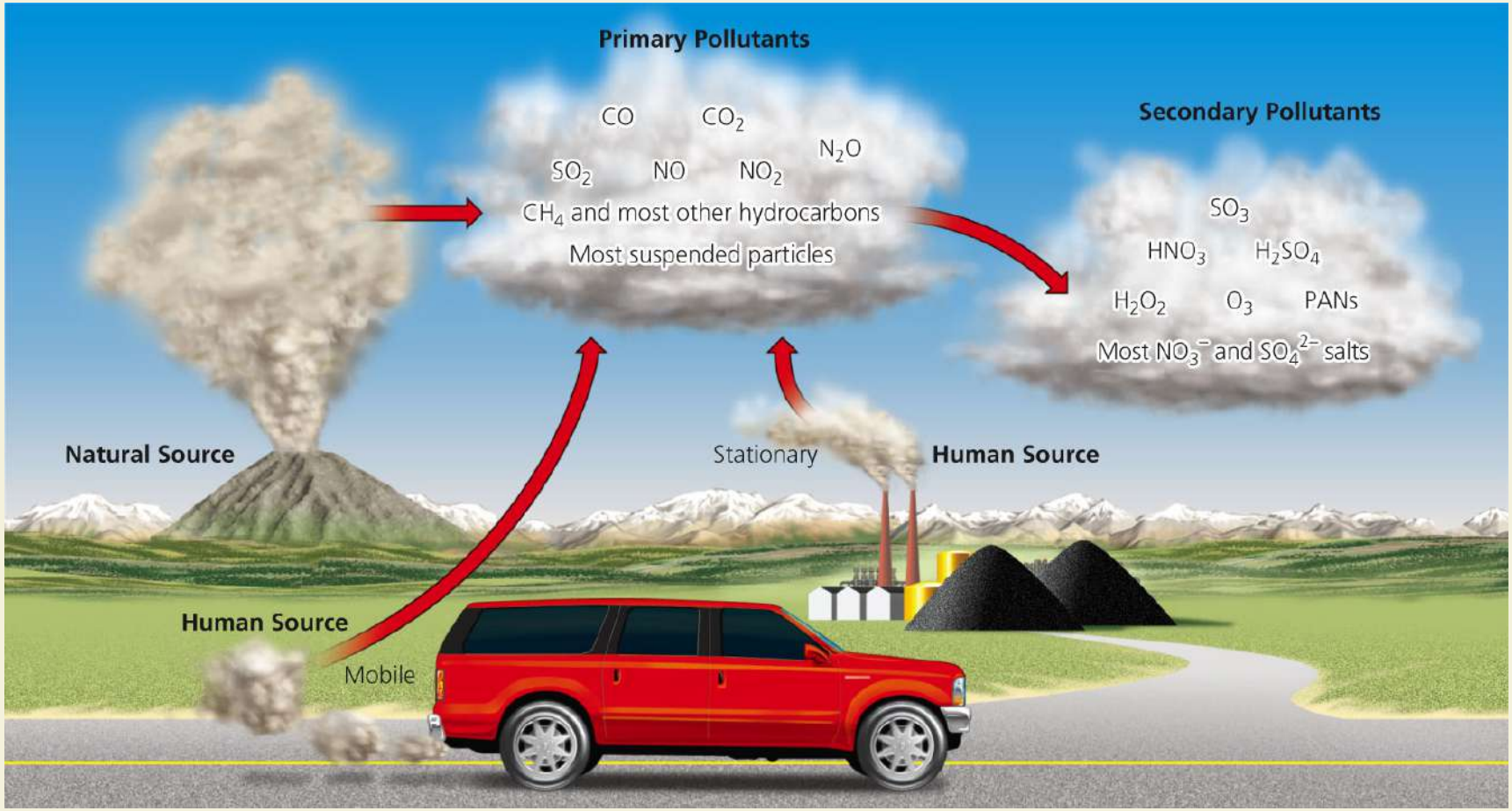

Fig. 18-5, p. 469

Indoor Air Pollution in Bangladesh

Fig. 18-6, p. 469

What Are the Major Outdoor Air Pollutants? (1)

- **Carbon oxides**
  - Carbon monoxide (CO)
  - Carbon dioxide (CO_2)
  - Sources
  - Human health and environmental impact

What Are the Major Outdoor Air Pollutants? (2)

- **Nitrogen oxides (NO)** and **nitric acid (HNO_3)**
  - Sources
  - Acid deposition
  - Photochemical smog
  - Human health and environmental impact

- **Sulfur dioxide (SO_2) and sulfuric acid (H_2SO_4)**
  - Sources
  - Human health and environmental impact

What Are the Major Outdoor Air Pollutants? (3)

- **Particulates**
  - Suspended particulate matter (SPM)
    - Fine
    - Ultrafine
  - Sources
  - Human health and environmental impact

What Are the Major Outdoor Air Pollutants? (4)

- **Ozone (O_3)**
  - Sources
  - Human and environmental impact

- **Volatile organic compounds (VOCs)**
  - Hydrocarbons and terpenes
  - Sources
  - Human and environmental impact

Chemical Reactions That Form Major Outdoor Air Pollutants

Table 18-1 Chemical Reactions That Form Major Air Pollutants

Pollutant	Chemical Reaction
Carbon monoxide (CO)	$2C + O_2 \rightarrow 2CO$
Carbon dioxide (CO_2)	$C + O_2 \rightarrow CO_2$
Nitric oxide (NO)	$N_2 + O_2 \rightarrow 2NO$
Nitrogen dioxide (NO_2)	$2NO + O_2 \rightarrow 2NO_2$
Sulfur dioxide (SO_2)	$S + O_2 \rightarrow SO_2$

Table 18-1, p. 470

Statue Corroded by Acid Deposition and Other Forms of Air Pollution, RI, U.S.

Fig. 18-7, p. 471

Case Study: Lead Is a Highly Toxic Pollutant (1)

- In air, water, soil, plants, animals
- Does not break down in the environment
- Human health and environmental impact
  - Children most vulnerable
  - Can cause death, mental retardation, paralysis

Case Study: Lead Is a Highly Toxic Pollutant (2)

- Reduction of lead (Pb)
  - Unleaded gasoline
  - Unleaded paint

- Still problems
  - 15-18 million children have brain damage
  - Need global ban on lead in gasoline and paint

Solutions: Lead Poisoning, Prevention and Control

Solutions

Lead Poisoning

Prevention

- Phase out leaded gasoline worldwide
- Phase out waste incineration
- Ban use of lead solder
- Ban use of lead in computer and TV monitors
- Ban lead glazing for ceramicware used to serve food
- Ban candles with lead cores
- Test blood for lead by age 1

Control

- Replace lead pipes and plumbing fixtures containing lead solder
- Remove leaded paint and lead dust from older houses and apartments
- Sharply reduce lead emissions from incinerators
- Remove lead from TV sets and computer monitors before incineration or land disposal
- Test for lead in existing ceramicware used to serve food
- Test existing candles for lead
- Wash fresh fruits and vegetables

Fig. 18-8, p. 472

Science Focus: Detecting Air Pollutants

- Chemical instruments
- Satellites
- Lasers and remote sensors
- Biological indicators
  - Lichens

Natural Capital: Lichen Species, Vulnerability to Air Pollutants

Fig. 18-A, p. 473

Burning Coal Produces Industrial Smog

- Chemical composition of **industrial smog**
- Reduction of this smog in urban cities of the United States
- China and smog
  - Human deaths
  - Need strong standards, especially for coal burning

How Pollutants Are Formed from Burning Coal and Oil, Leading to Industrial Smog

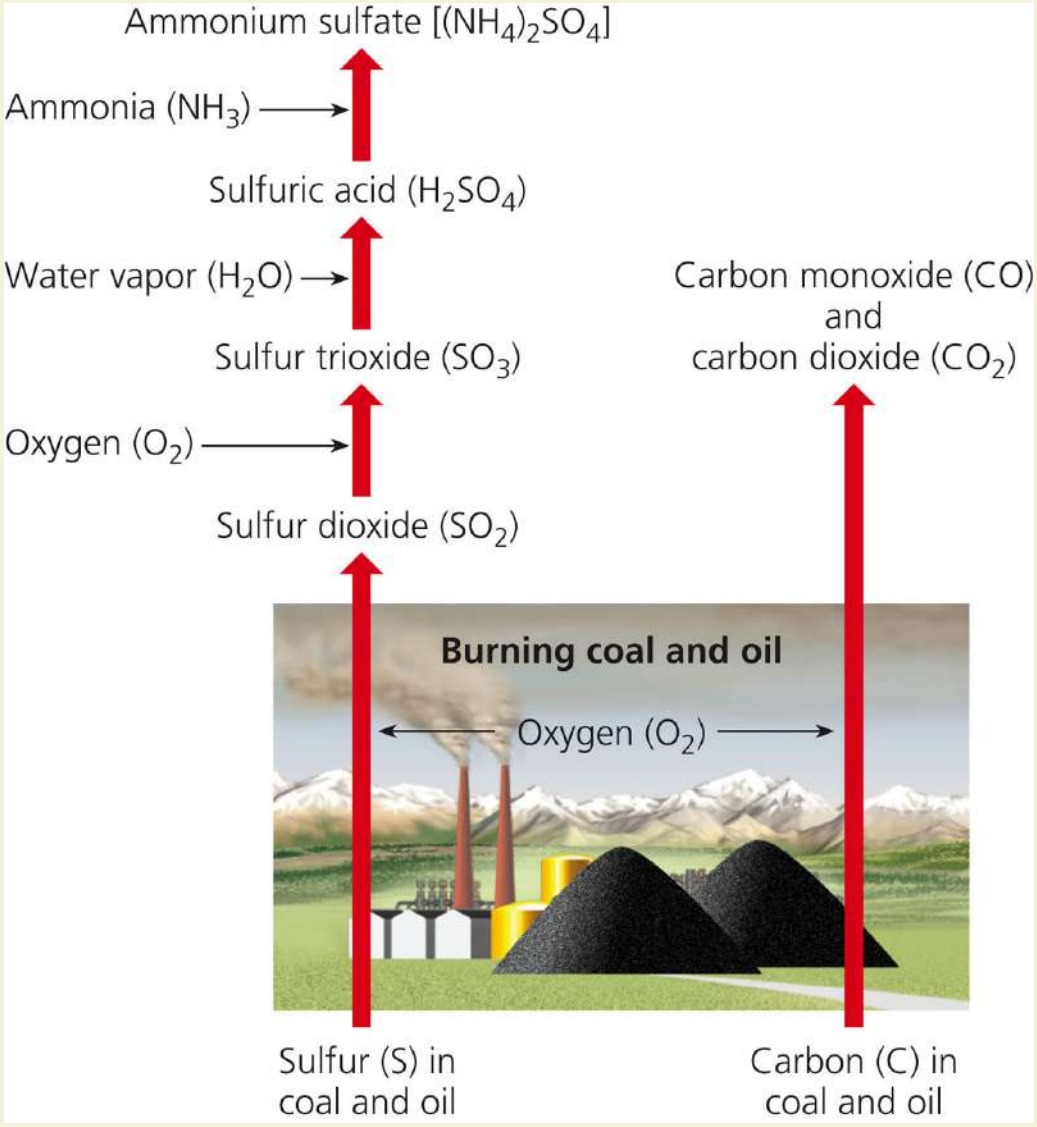

Fig. 18-9, p. 474

Industrial Smog in India

Fig. 18-10, p. 474

Sunlight Plus Cars Equals Photochemical Smog

- **Photochemical Smog**
  - Chemical composition
  - Sources

- VOCs + NO_x + Heat + Sunlight yields
  - Ground level O_3 and other photochemical oxidants
  - Aldehydes
  - Other secondary pollutants

- Human health and environmental impact

A Model of How Pollutants That Make Up Photochemicals Are Formed

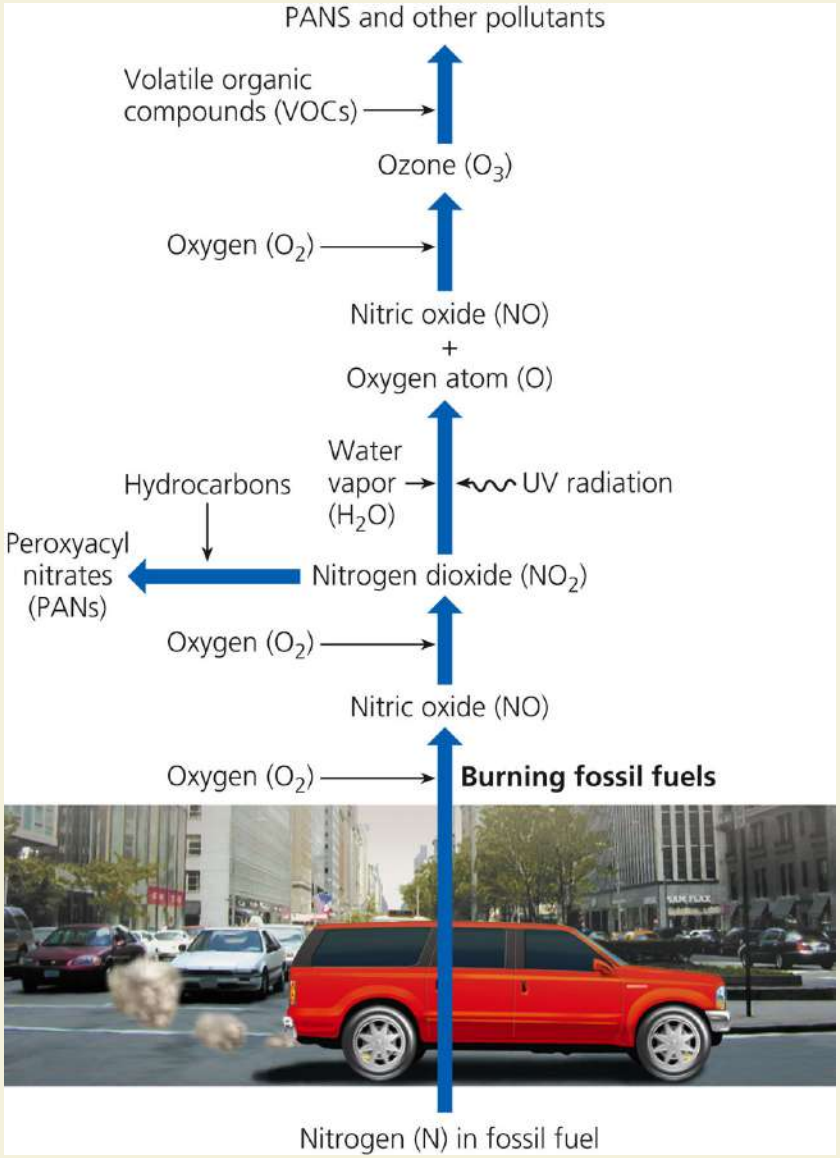

Fig. 18-11, p. 475

Global Outlook: Photochemical Smog in Santiago, Chile

Fig. 18-12, p. 475

Several Factors Can Decrease or Increase Outdoor Air Pollution (1)

- Outdoor air pollution may be decreased by
  1. Settling of particles due to gravity
  2. Rain and snow
  3. Salty sea spray from the ocean
  4. Winds
  5. Chemical reactions

Several Factors Can Decrease or Increase Outdoor Air Pollution (2)

- Outdoor air pollution may be increased by
  1. Urban buildings
  2. Hills and mountains
  3. High temperatures
  4. Emissions of VOCs from certain trees and plants
  5. Grasshopper effect
  6. **Temperature inversions**
     - Warm air above cool air prevents mixing

A Temperature Inversion

Fig. 18-13, p. 476

18-3 What Is Acid Deposition and Why Is It a Problem?

- ***Concept 18-3*** *Acid deposition is caused mainly by coal-burning power plants and motor vehicle emissions, and in some regions it threatens human health, aquatic life and ecosystems, forests, and human-built structures.*

Acid Disposition Is a Serious Regional Air Pollution Problem

- **Acid deposition**, acid rain
  - Chemical sources
  - Formation
  - Local versus regional problems
  - Effects of prevailing winds
  - Buffers
  - Where is the worst acid deposition?

Natural Capital Degradation: Acid Deposition

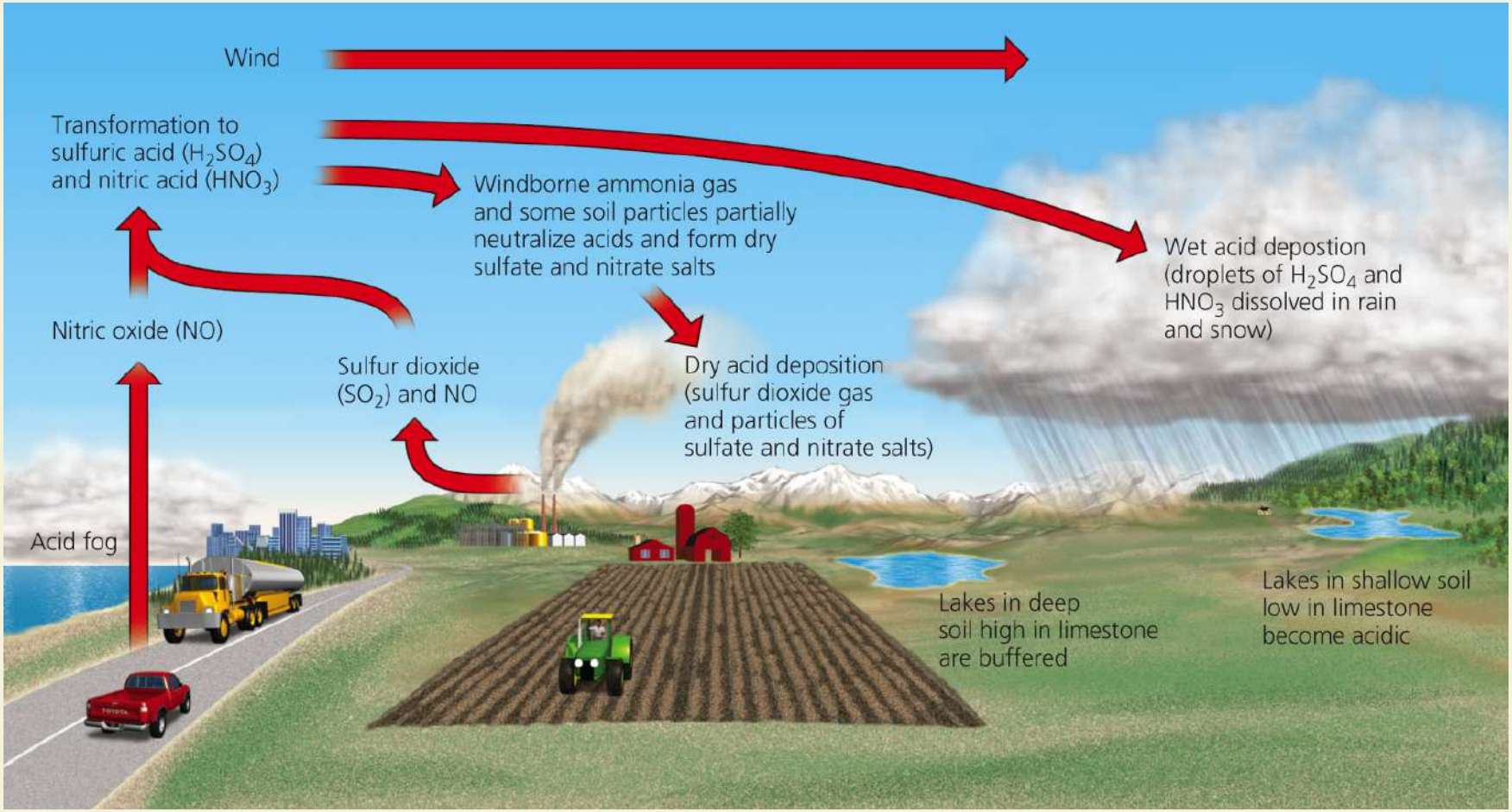

Fig. 18-14, p. 477

Current and Possible Future Acid Rain Problem Areas

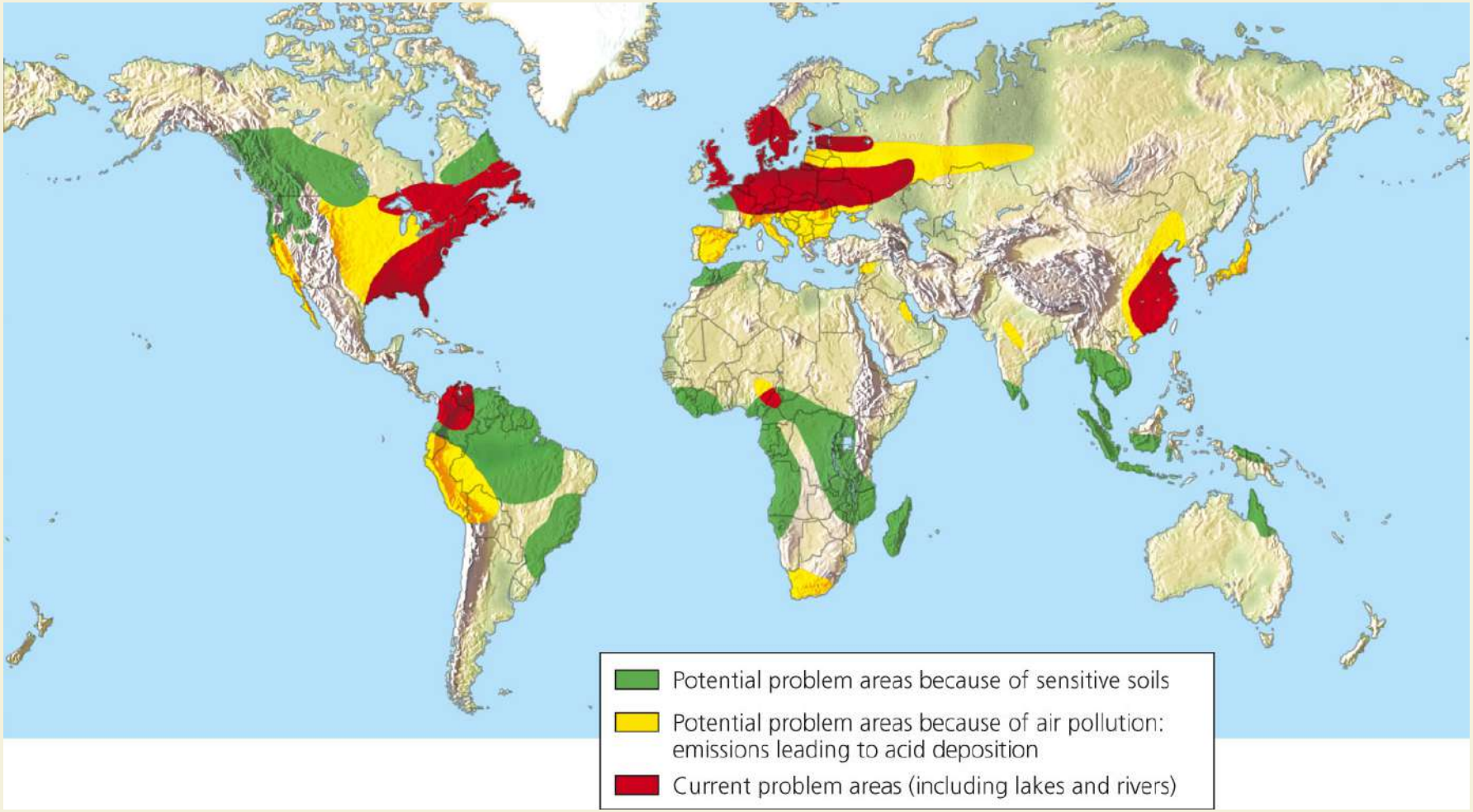

Fig. 18-15, p. 478

Acid Deposition Has a Number of Harmful Effects (1)

- Human health
  - Respiratory disorders
  - Toxins in fish
- Release of toxic metals
- Aquatic ecosystems affected
  - Lowers pH and kills organisms

Acid Deposition Has a Number of Harmful Effects (2)

- Leaching of soil nutrients
- Lower crop yields
- Forest damage
- Damage to buildings, statues, and monuments

Natural Capital Degradation: Air Pollution Damage to Trees in North Carolina, U.S.

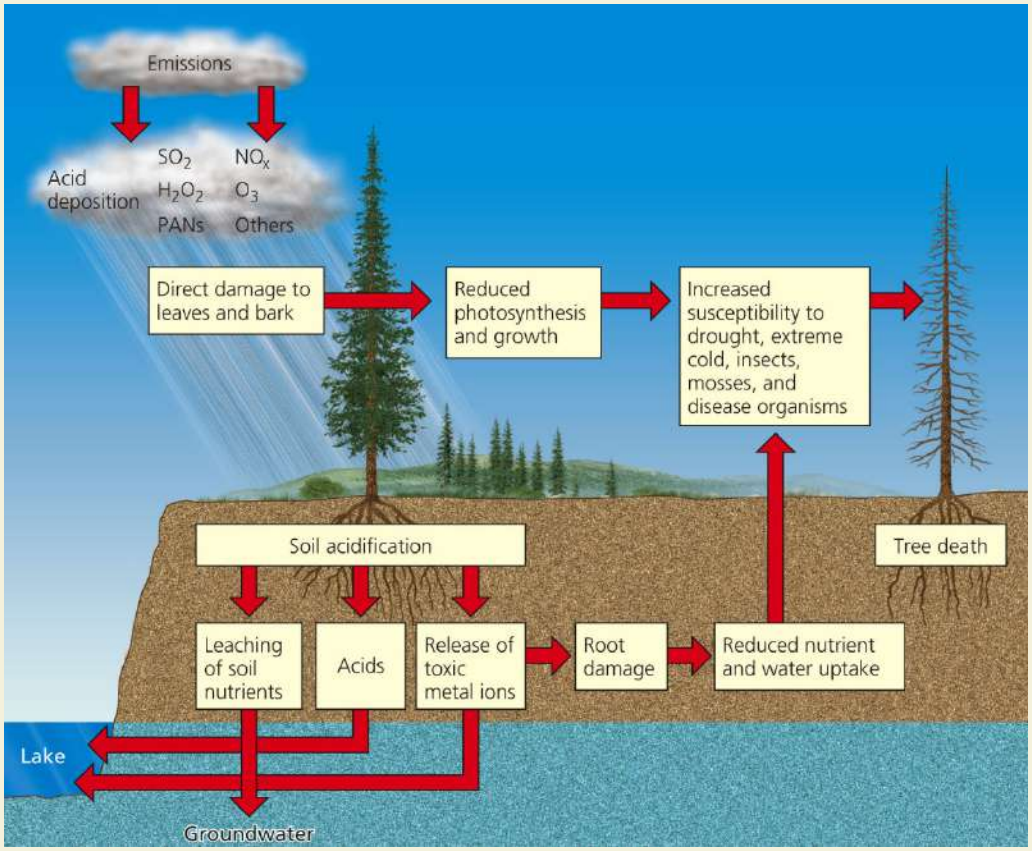

Fig. 18-16, p. 479

We Know How to Reduce Acid Deposition

- Prevention approaches

- Cleanup approaches

Solutions: Acid Deposition

Solutions

Acid Deposition

Prevention

Reduce coal use

Burn low-sulfur coal

Increase use of natural gas and renewable energy resources

Remove SO_2 particulates and NO_X from smokestack gases and remove NO_X from motor vehicular exhaust

Tax emissions of SO_2

Cleanup

Add lime to neutralize acidified lakes

Add phosphate fertilizer to neutralize acidified lakes

Fig. 18-17, p. 480

18-4 What Are the Major Indoor Air Pollution Problems?

- ***Concept 18-4*** *The most threatening indoor air pollutants are smoke and soot from the burning of wood and coal in cooking fires (mostly in less-developed countries), cigarette smoke, and chemicals used in building materials and cleaning products.*

Indoor Air Pollution Is a Serious Problem (1)

- Developing countries
  - Indoor burning of wood, charcoal, dung, crop residues, coal
  - Poor suffer the greatest risk

Burning Wood Indoors in India

Fig. 18-18, p. 481

Indoor Air Pollution Is a Serious Problem (2)

- Developed countries
  - Indoor air pollution is greater than outdoor air pollution
- Why?
  - 11 of the common air pollutants higher inside than outside
  - Greater in vehicles than outside
  - Health risks magnified: people spend 70–98% of their time is indoors or in cars

Indoor Air Pollution Is a Serious Problem (3)

- Who is at greatest risk from indoor air pollution?
  - Children under 5 and the elderly
  - Sick
  - Pregnant women
  - People with respiratory disorders or heart problems
  - Smokers
  - Factory workers

Indoor Air Pollution Is a Serious Problem (4)

- Four most dangerous indoor air pollutants
  - Tobacco smoke
  - Formaldehyde
  - Radioactive radon-222 gas
  - Very small particles
- Sources of these pollutants
- Human health risks

Indoor Air Pollution Is a Serious Problem (5)

- Other possible indoor air pollutants
  - Pesticide residue
  - Pb particles
  - Living organisms and their excrements
    - E.g., Dust mites and cockroach droppings
  - Airborne spores of molds and mildews

- Sick-building syndrome

Some Important Indoor Air Pollutants

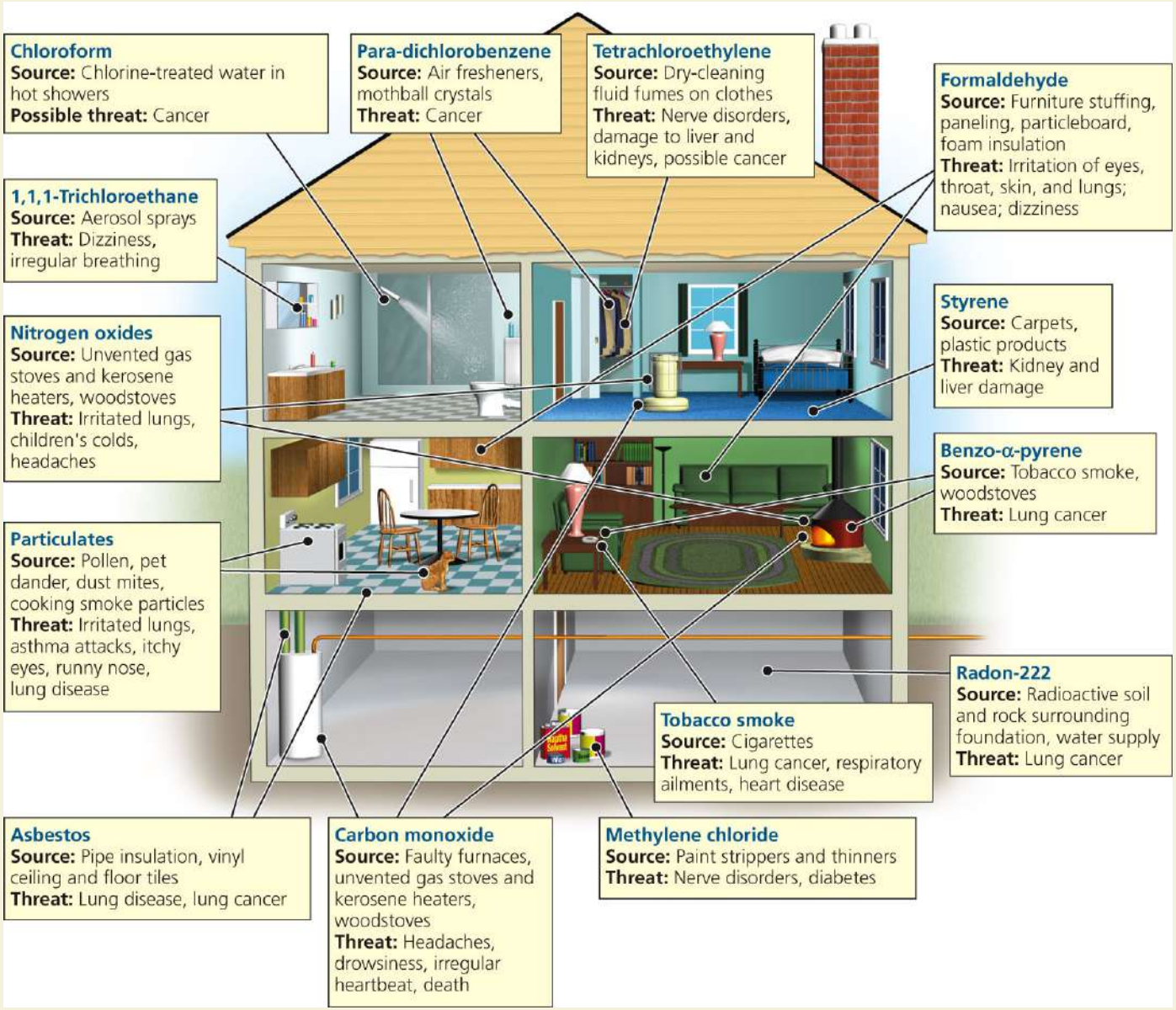

Fig. 18-19, p. 482

Case Study: Radioactive Radon Gas

- Sources
- Human health risks
- Testing for radon
- Correcting a radon problem

Science: Sources and Paths of Entry for Indoor Radon-222 Gas

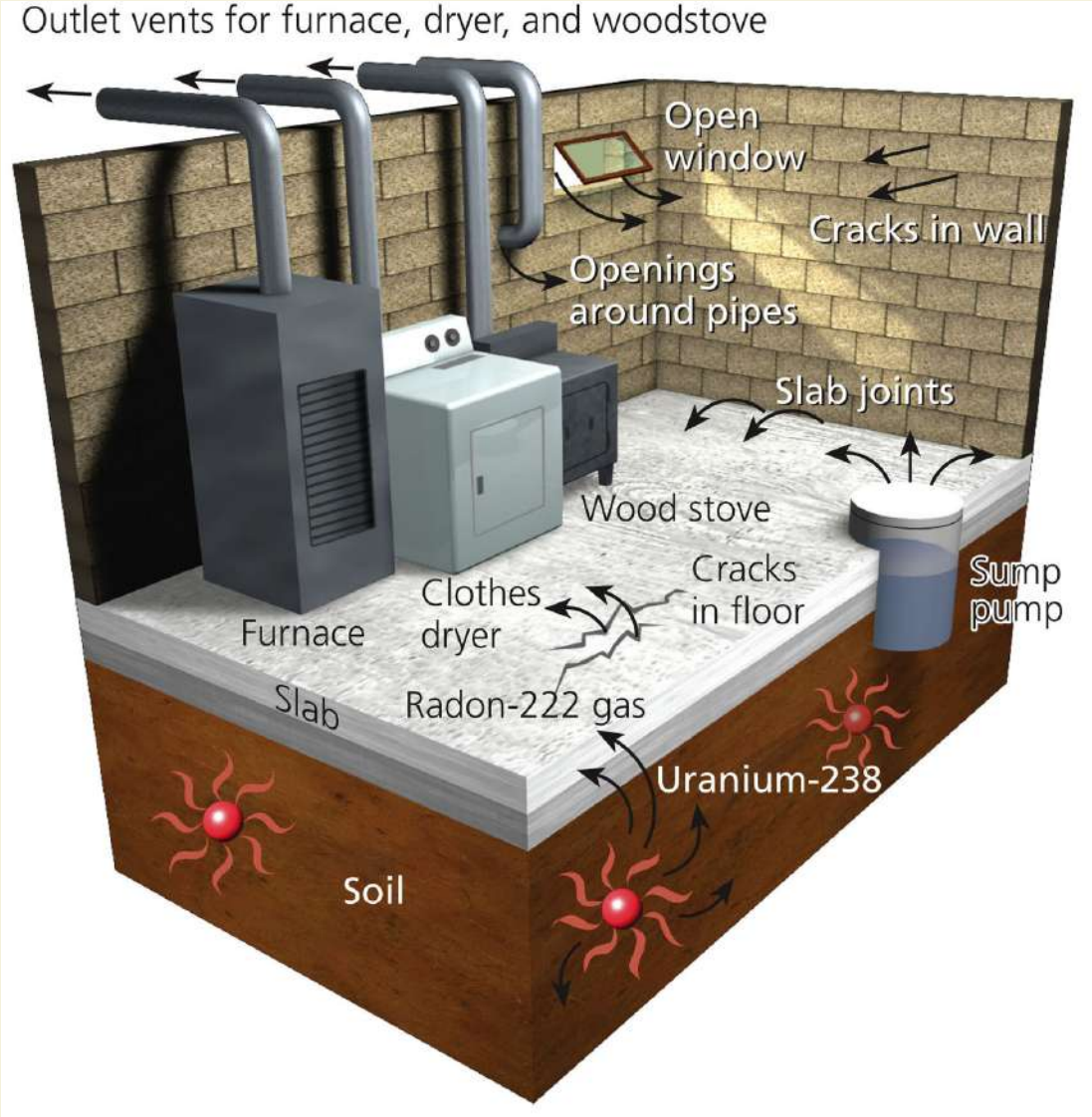

Fig. 18-20, p. 483

18-5 What Are the Health Effects of Air Pollution?

- ***Concept 18-5*** *Air pollution can contribute to asthma, chronic bronchitis, emphysema, lung cancer, heart attack, and stroke.*

Your Body's Natural Defenses against Air Pollution Can Be Overwhelmed

- Respiratory system protection from air pollutants
  - Role of cilia, mucus, sneezing, and coughing

- Effect of smoking and prolonged air pollution exposure
  - Chronic bronchitis
  - Emphysema

Major Components of the Human Respiratory System

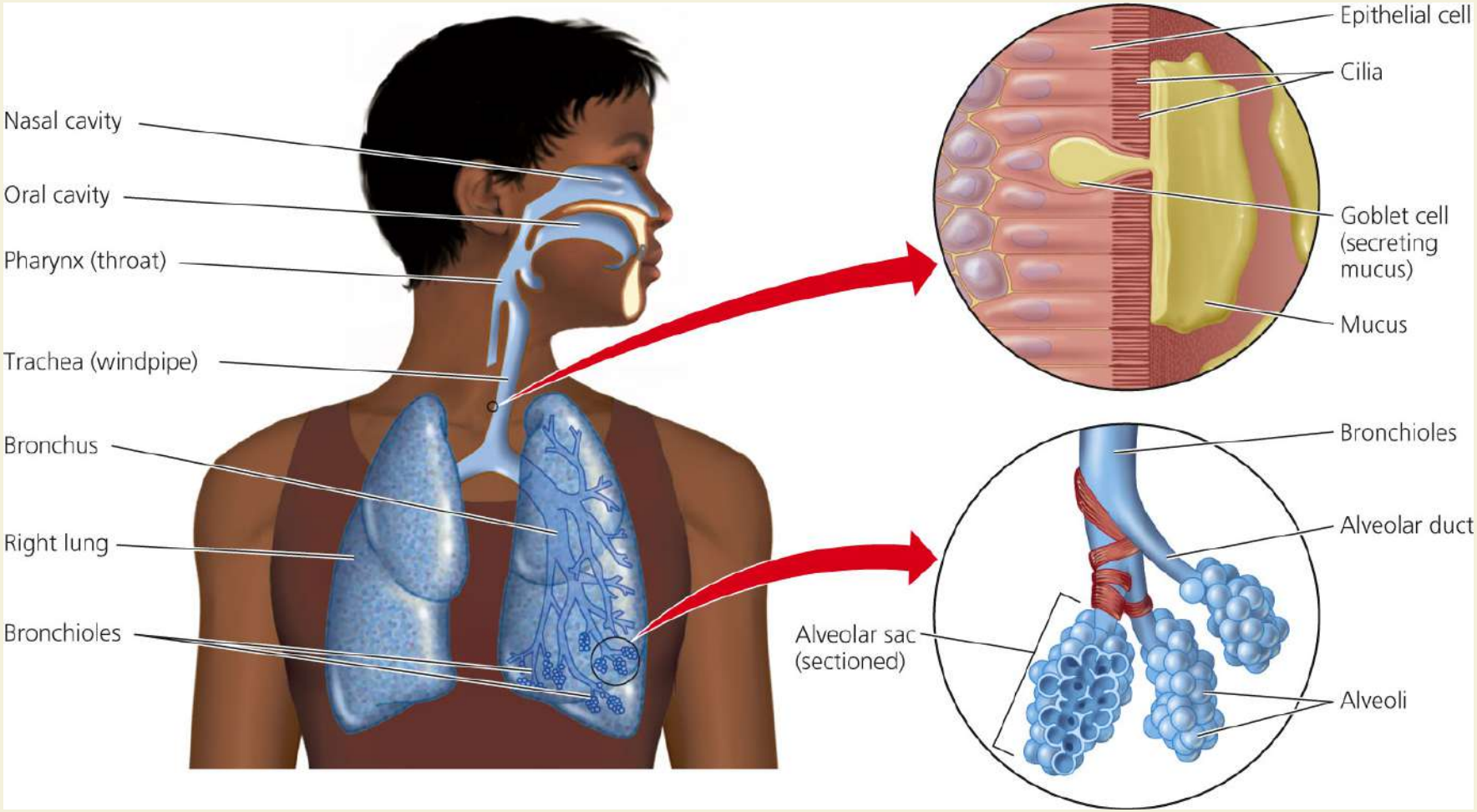

Fig. 18-21, p. 484

Air Pollution Is a Big Killer

- 2.4 million deaths per year world-wide
  - Mostly in Asia; 750,000 in China
  - 150,000 to 350,000 in the United States
  - Role of coal-burning power plants

- EPA: proposed stricter emission standards for diesel-powered vehicles
  - 125,000 die in U.S. each year from diesel fumes
  - Emissions from one truck = 150 cars

Premature Deaths from Air Pollution in the U.S.

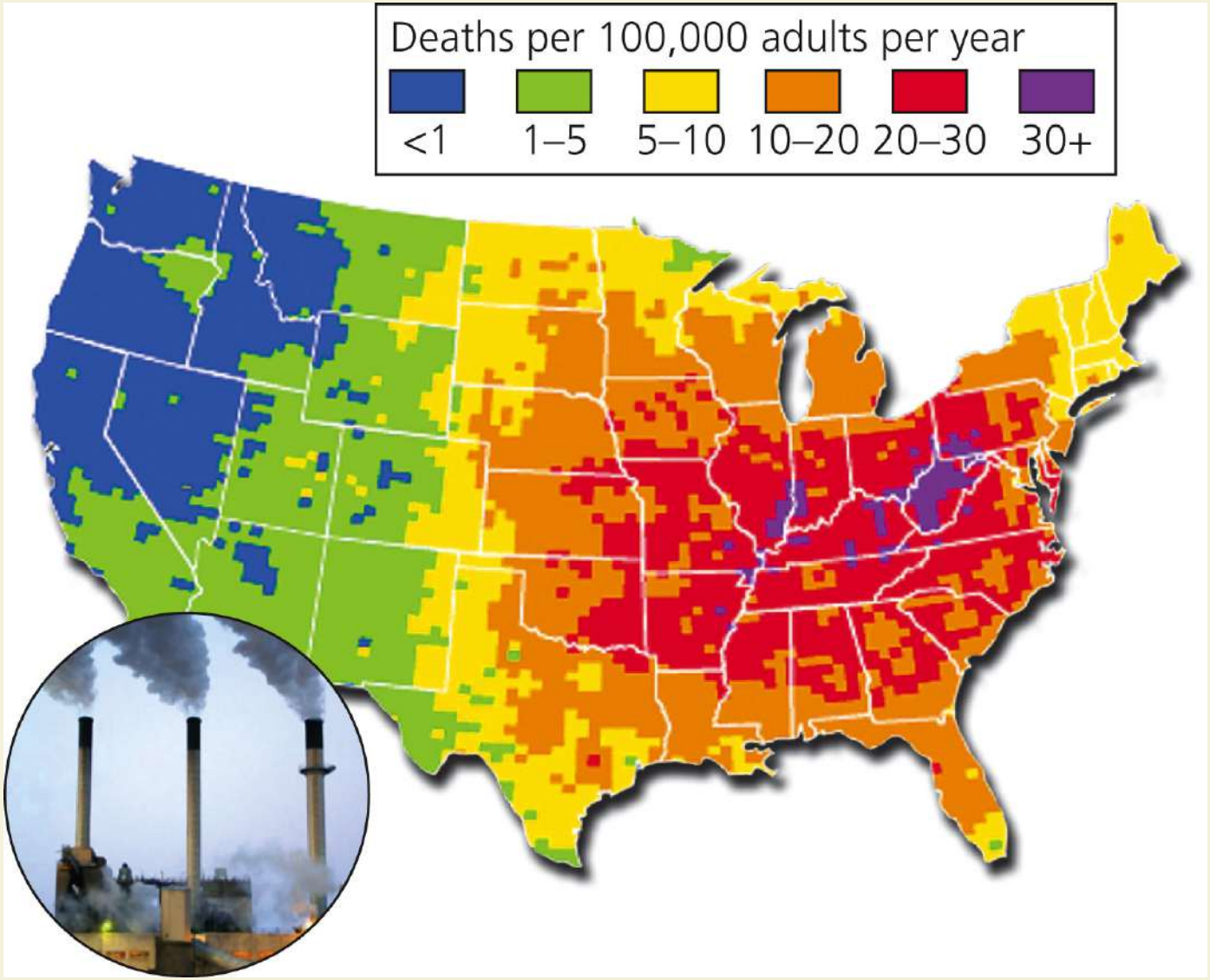

Fig. 18-22, p. 485

18-6 How Should We Deal with Air Pollution?

- ***Concept 18-6*** *Legal, economic, and technological tools can help us to clean up air pollution, but the best solution is to prevent it.*

Laws and Regulations Can Reduce Outdoor Air Pollution (1)

- United States
  - Clean Air Acts: 1970, 1977, and 1990 created regulations enforced by states and cities

- EPA
  - National ambient air quality standards for 6 outdoor pollutants
  - National emission standards for 188 hazardous air pollutants (HAPs)
    - Toxic Release Inventory (TRI)

Laws and Regulations Can Reduce Outdoor Air Pollution (2)

- Good news in U.S.
  - Decrease in emissions
  - Use of low-sulfur diesel fuel
    - Cuts pollution
- Less-developed countries
  - More air pollution

Case Study: U.S. Air Pollution Can Be Improved (1)

- Rely on prevention of pollution, not cleanup
- Sharply reduce emissions from power plants, industrial plants, and other industry
- Raise fuel-efficiency for cars, SUVs, and light trucks
- Better regulation of emissions of motorcycles and two-cycle gasoline engines

Case Study: U.S. Air Pollution Can Be Improved (2)

- Regulate air pollution for oceangoing ships in American ports
- Regulate emissions at U.S. airports
- Sharply reduce indoor pollution
- Increased and more accurate monitoring of air pollutants

We Can Use the Marketplace to Reduce Outdoor Air Pollution

- Emission trading or cap-and-trade program
  - Mixed reactions to program
  - SO_2 emissions down significantly
  - NO_x now in effect
  - Mercury plan strongly opposed for creating toxic hotspots

- Many problems with making cap-and-trade effective

There Are Many Ways to Reduce Outdoor Air Pollution

- There are ways to deal with
  - Stationary source air pollution
  - Motor vehicle air pollution
    - New cars have lower emissions

- Less-developed countries far behind developed countries in implementing solutions

Solutions: Stationary Source Air Pollution

Solutions

Stationary Source Air Pollution

Prevention

Burn low-sulfur coal or remove sulfur from coal

Convert coal to a liquid or gaseous fuel

Phase out coal use

Reduction or Disposal

Disperse emissions (which can increase downwind pollution) with tall smokestacks

Remove pollutants from smokestack gases

Tax each unit of pollution produced

Fig. 18-23, p. 487

Solutions: Motor Vehicle Air Pollution

Solutions

Motor Vehicle Air Pollution

Prevention

Walk, bike, or use mass transit

Improve fuel efficiency

Get older, polluting cars off the road

Cleanup

Require emission control devices

Inspect car exhaust systems twice a year

Set strict emission standards

Fig. 18-24, p. 487

Reducing Indoor Air Pollution Should Be a Priority

- Greater threat to human health than outdoor pollution

- What can be done?
  - Prevention
  - Cleanup

Solutions: Indoor Pollution

Solutions

Indoor Air Pollution

Prevention

Ban indoor smoking

Set stricter formaldehyde emissions standards for carpet, furniture, and building materials

Prevent radon infiltration

Use less polluting cleaning agents, paints, and other products

Cleanup or Dilution

Use adjustable fresh air vents for work spaces

Circulate air more frequently

Circulate a building's air through rooftop greenhouses

Use efficient venting systems for wood-burning stoves

Fig. 18-25, p. 488

Turbo Stove in India

Fig. 18-26, p. 488

What Can You Do? Indoor Air Pollution

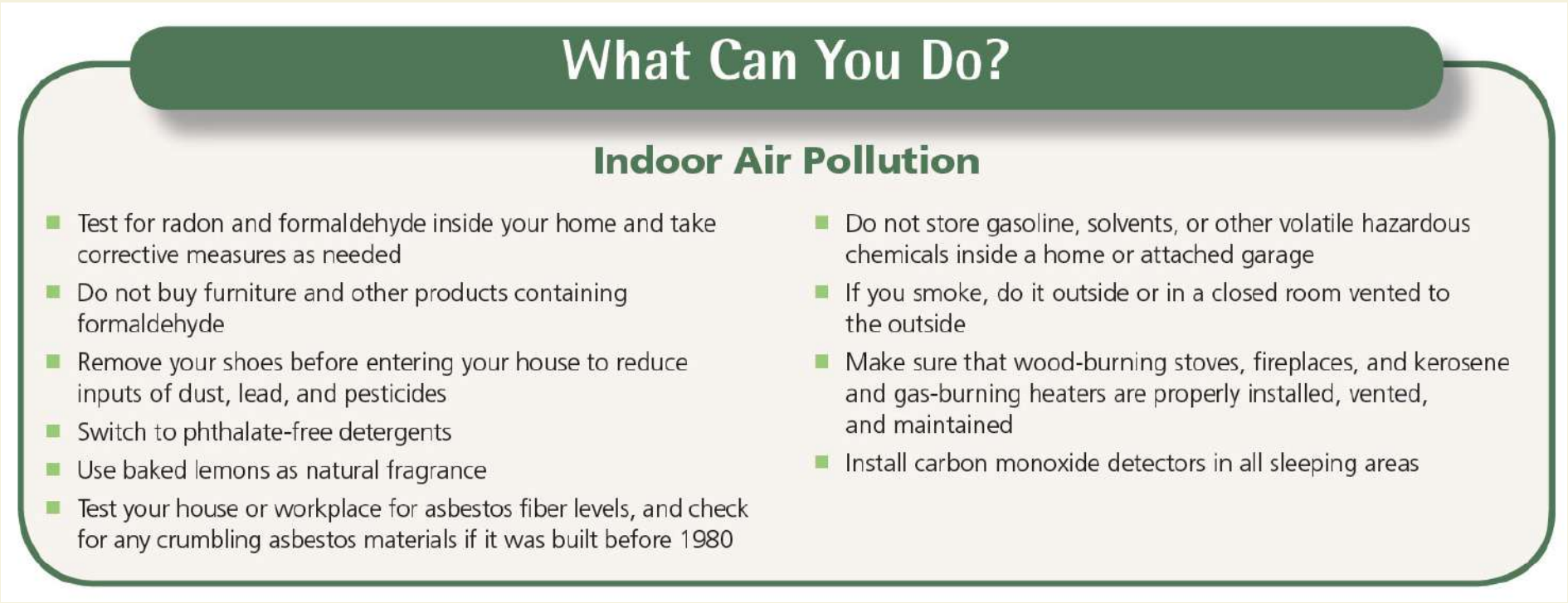

Fig. 18-27, p. 489

We Need to Put More Emphasis on Pollution Prevention

- Output approaches

- New shift to preventing outdoor and indoor pollution
  - Pressure from citizens

Three Big Ideas

1. Outdoor air pollution, in the forms of industrial smog, photochemical smog, and acid deposition, and indoor air pollution are serious global problems.

2. Each year, at least 2.4 million people die prematurely from the effects of air pollution; indoor air pollution, primarily in less-developed countries, causes about two-thirds of those deaths.

Three Big Ideas

3. We need to put our primary emphasis on preventing outdoor and indoor air pollution throughout the world.