MILLER/SPOOLMAN

LIVING IN THE ENVIRONMENT

17TH

Chapter 19

Climate Control and Ozone Depletion

Science Focus: Melting Ice in Greenland

- Largest island: 80% composed of glaciers
- 10% of the world's fresh water
- Glacial melting and movement accelerating
- Effect on sea level if melting continues
  - 1 meter rise by 2100

19-1 How Might the Earth's Temperature and Climate Change in the Future?

- ***Concept 19-1*** *Considerable scientific evidence indicates that the earth's atmosphere is warming, because of a combination of natural effects and human activities, and that this warming is likely to lead to significant climate disruption during this century.*

Weather and Climate Are Not the Same

- Weather is short-term changes
  - Temperature
  - Air pressure
  - Precipitation
  - Wind

- Climate is average conditions in a particular area over a long period of time
  - Temperature
  - Precipitation
  - Fluctuations are normal

Climate Change is Not New (1)

- Over the past 4.7 billion years the climate has been altered by
  - Volcanic emissions
  - Changes in solar input
  - Movement of the continents
  - Impacts by meteors
  - Changing global air and ocean circulation

- Over the past 900,000 years
  - Glacial and interglacial periods

Climate Change is Not New (2)

- Over the past 10,000 years
  - Interglacial period
- Over the past 1,000 years
  - Temperature stable
- Over the past 100 years
  - Temperature changes; methods of determination

Estimated Changes in the Average Global Temperature of the Atmosphere

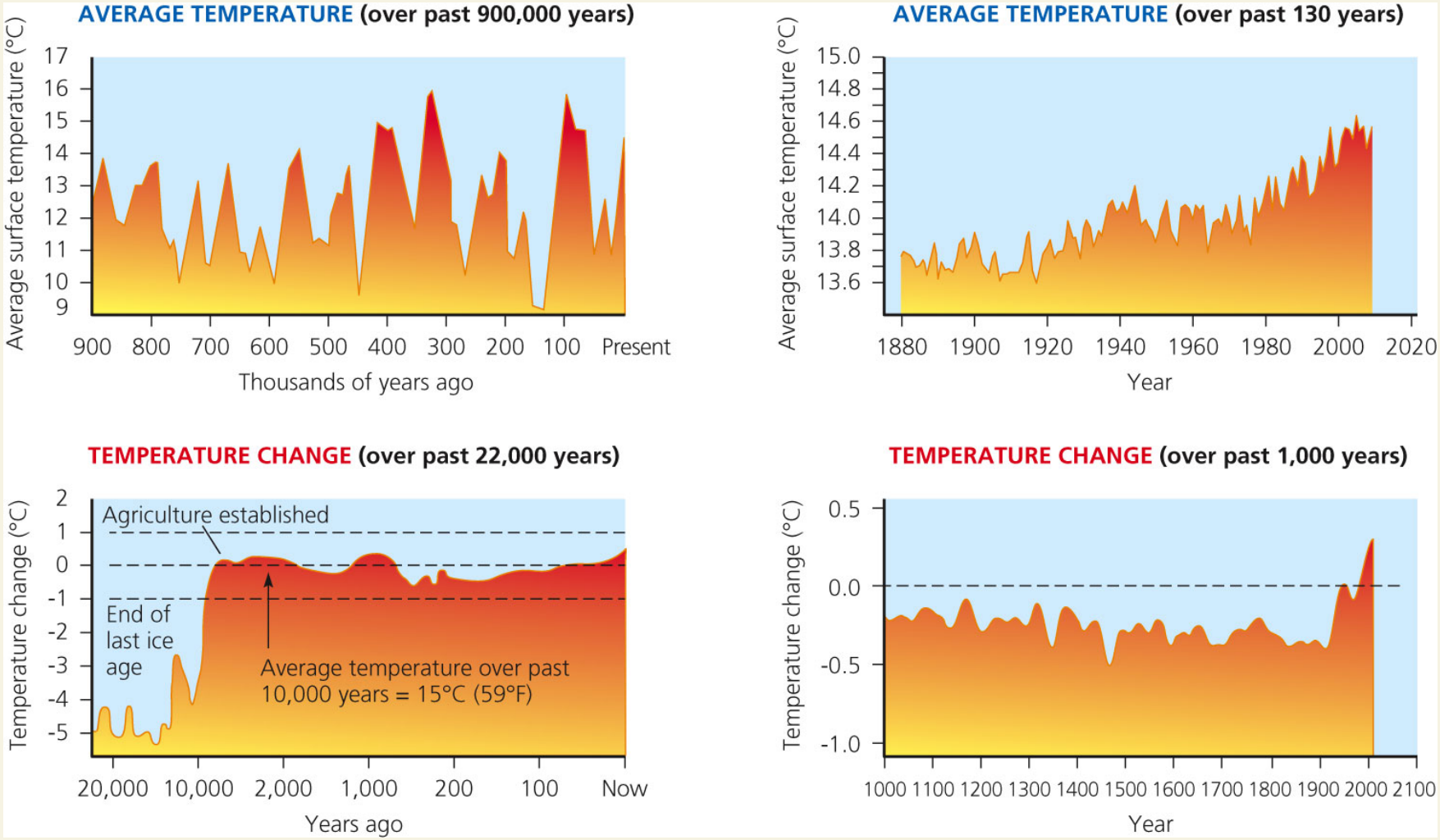


Fig. 19-2, p. 494

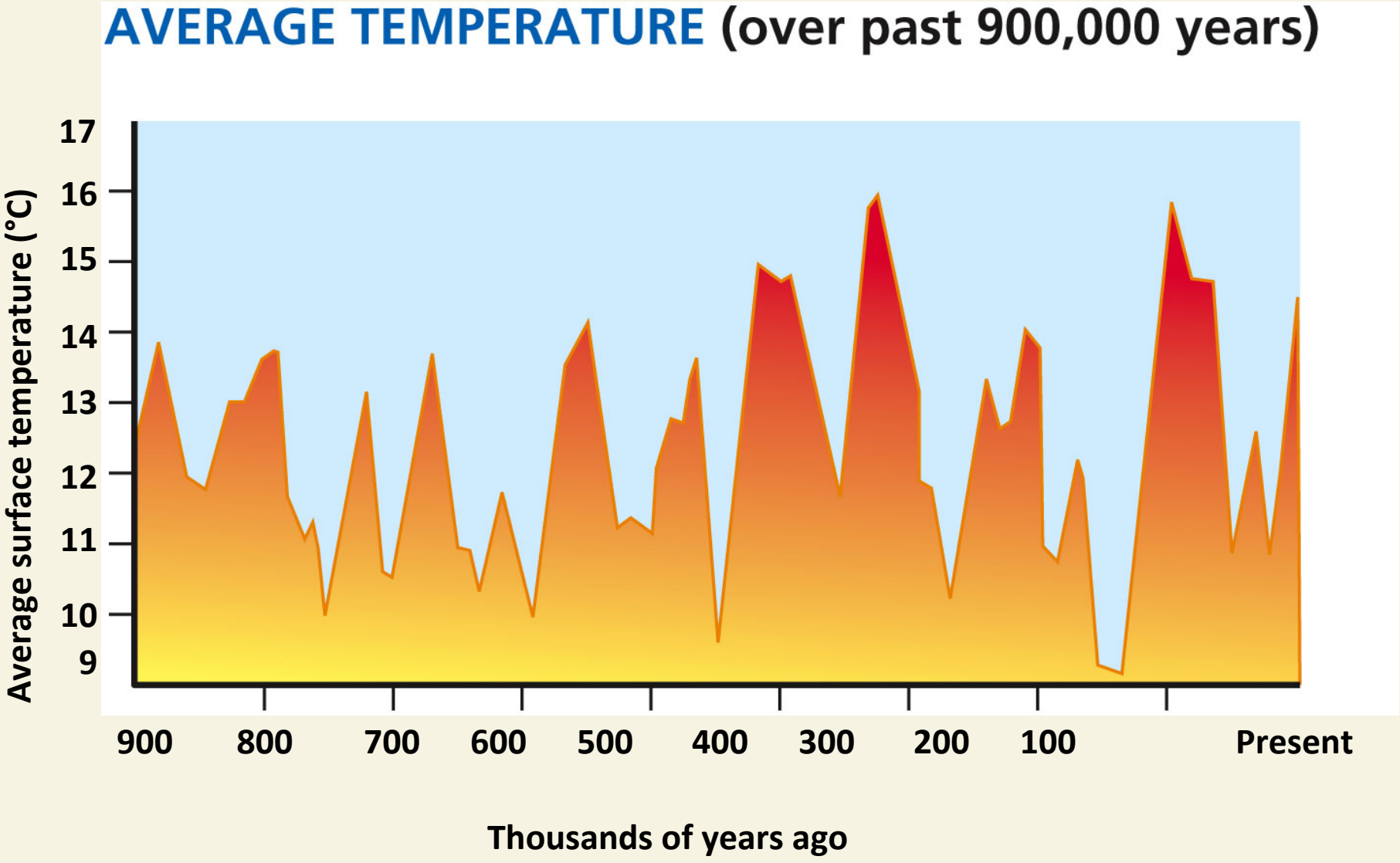


Fig. 19-2a, p. 494

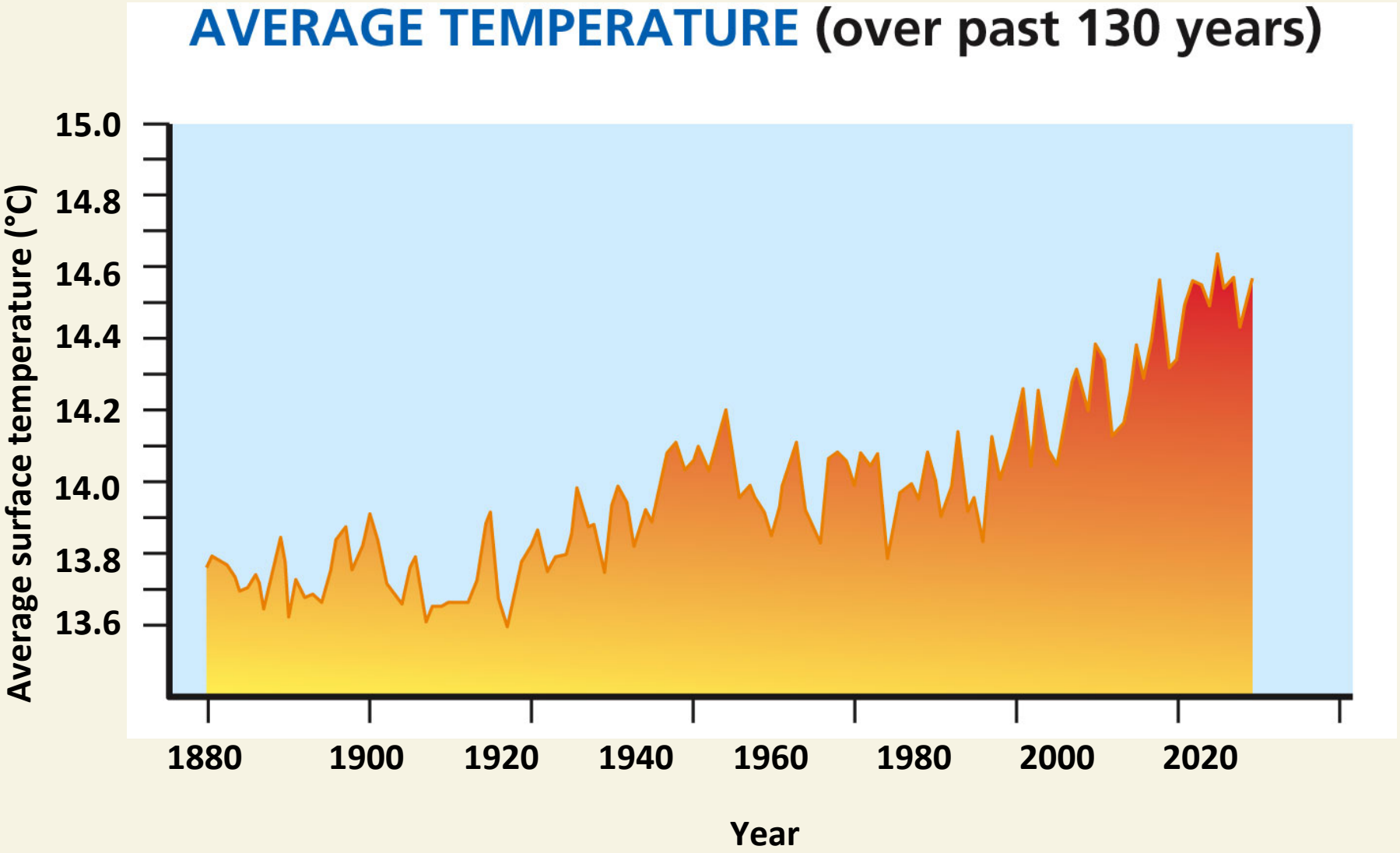


Fig. 19-2b, p. 494

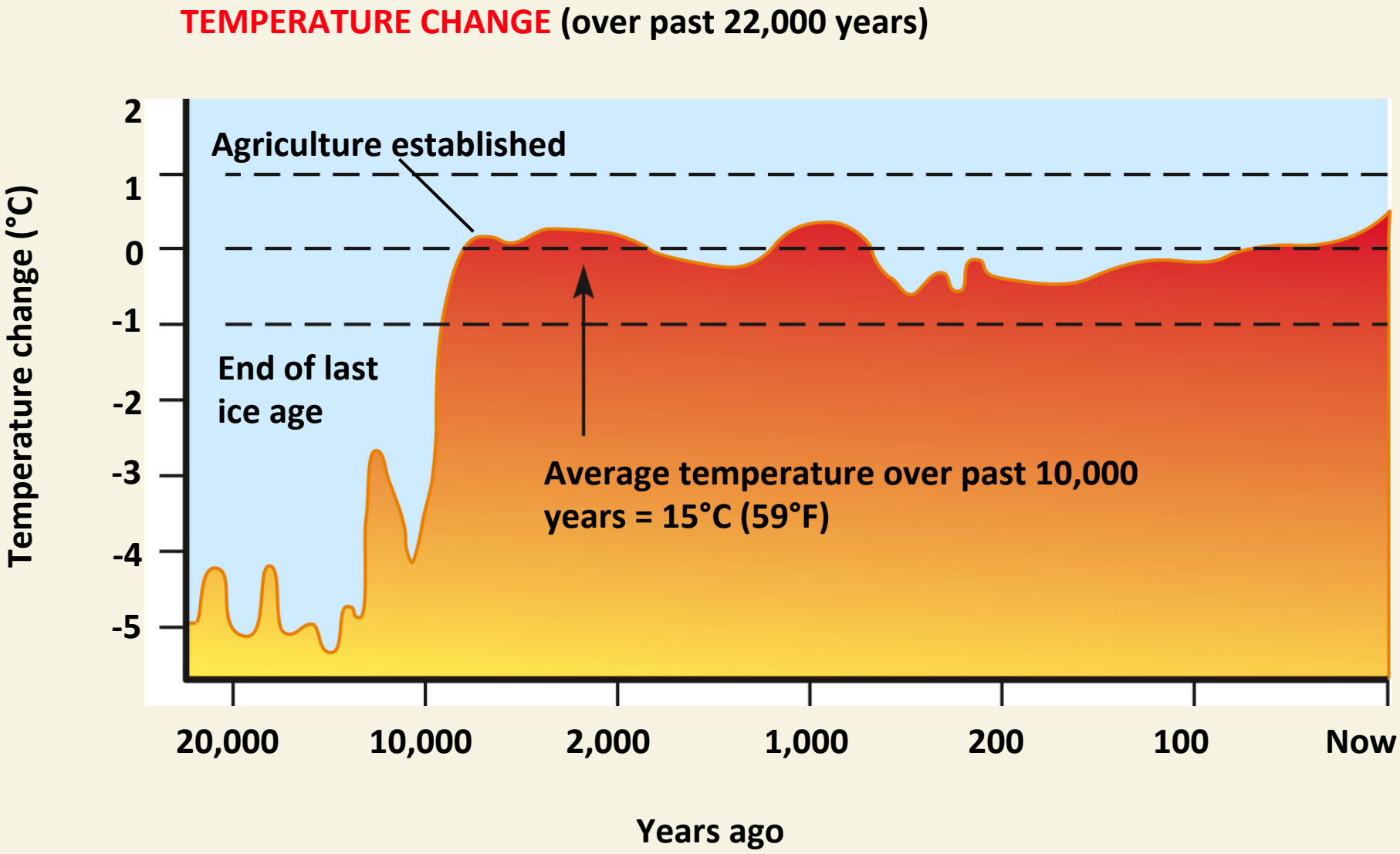


Fig. 19-2c, p. 494

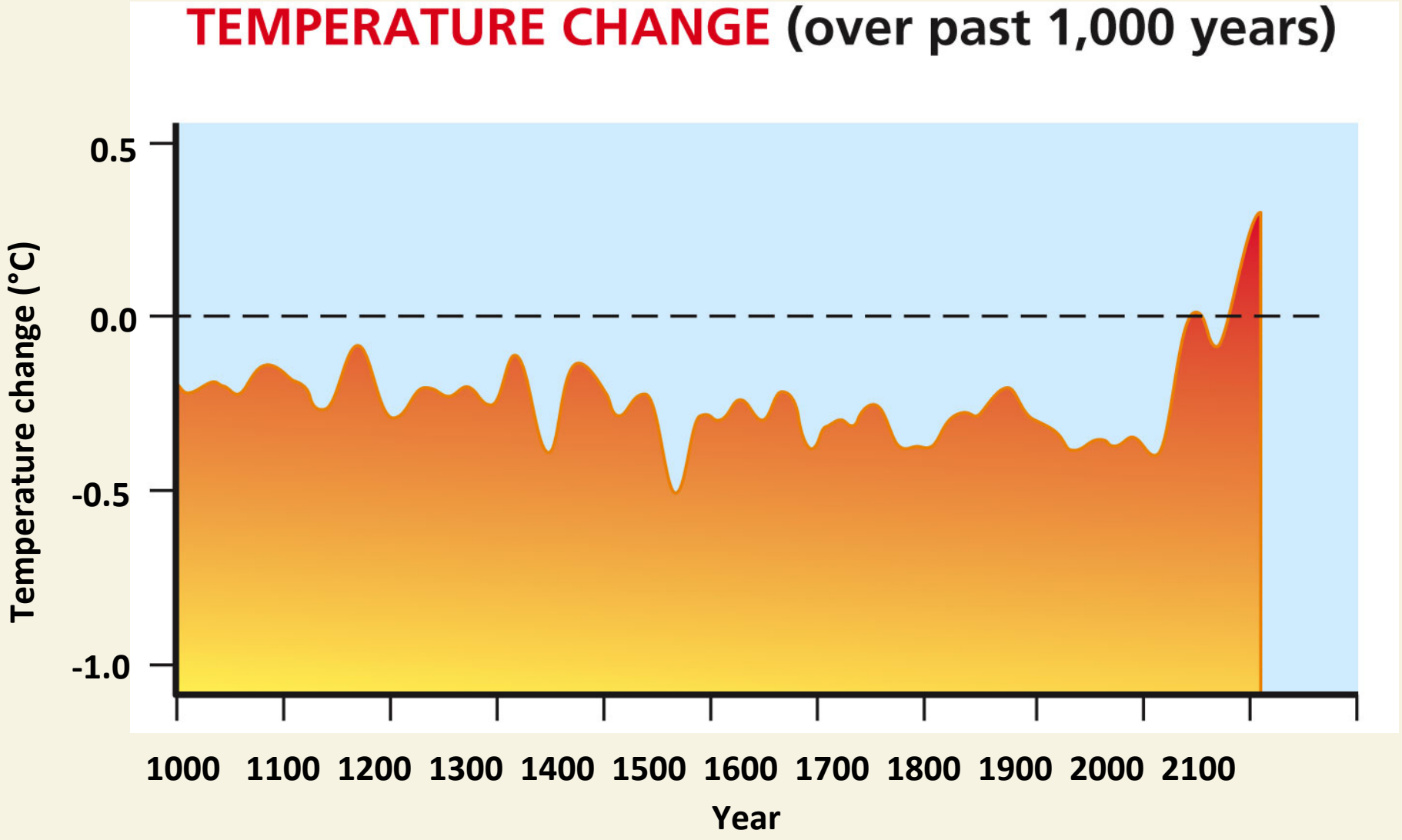
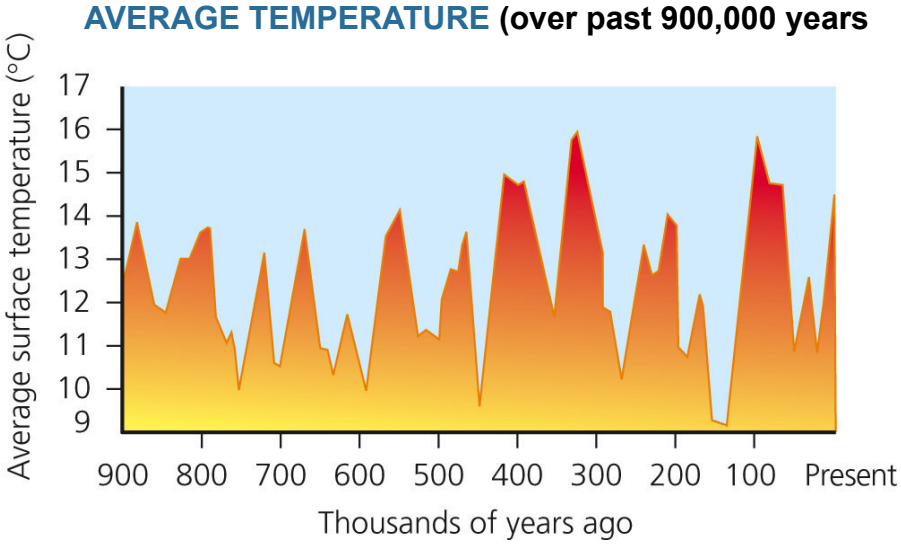
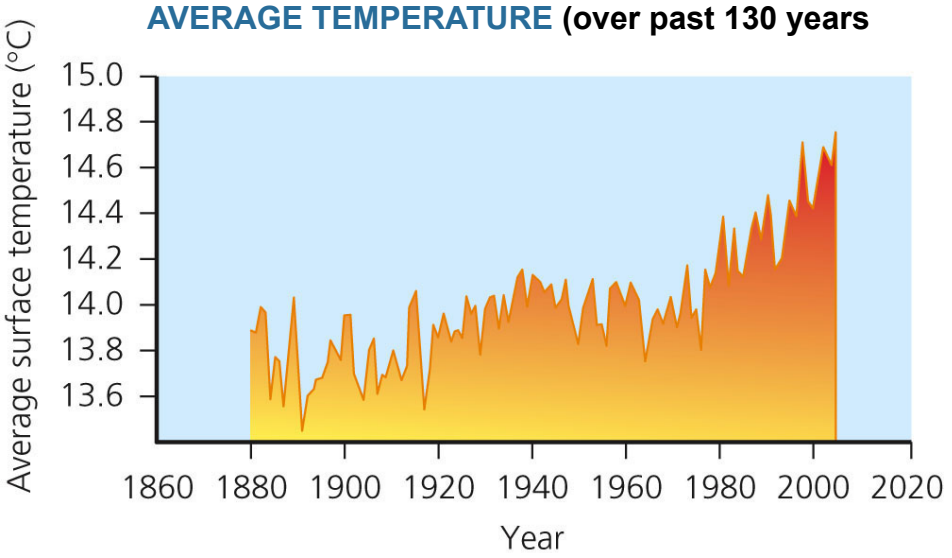
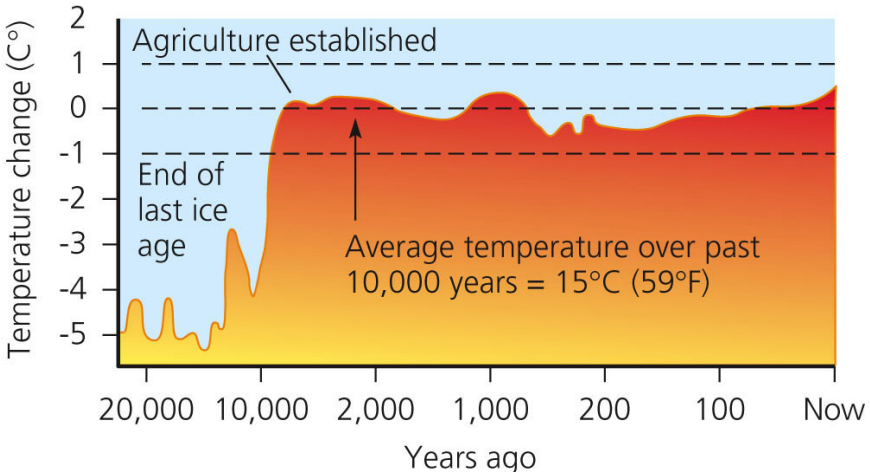


Fig. 19-2d, p. 494







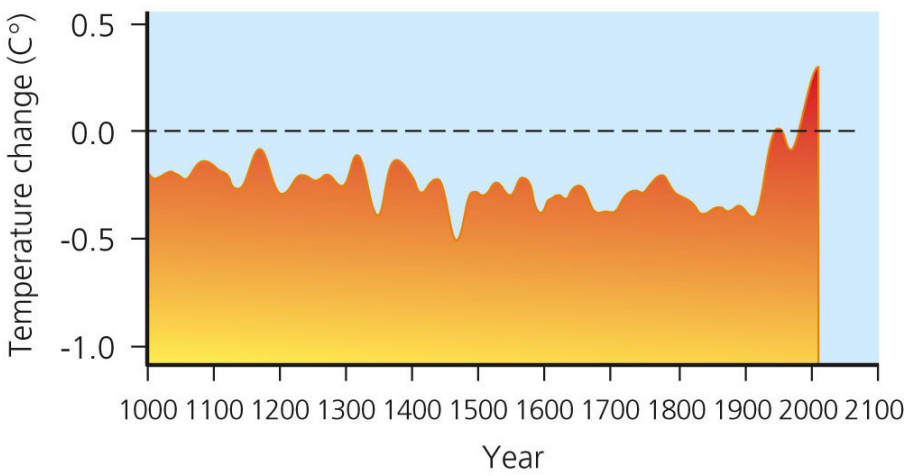


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Fig. 19-2, p. 494

Science: Ice Cores Are Extracted by Drilling Deep Holes in Ancient Glaciers

Fig. 19-3, p. 495

Our Climate, Lives, and Economies Depend on the Natural Greenhouse Effect

- Greenhouse gases absorb heat radiated by the earth
  - The gases then emit infrared radiation that warms the atmosphere

- Without the natural greenhouse effect
  - Cold, uninhabitable earth

Human Activities Emit Large Quantities of Greenhouses Gases

- Since the Industrial Revolution
  - CO_2, CH_4, and N_2O emissions higher
  - Main sources: agriculture, deforestation, and burning of fossil fuels

- Correlation of rising CO_2 and CH_4 with rising global temperatures

Atmospheric Levels of CO_2 and CH_4, Global Temperatures, and Sea Levels

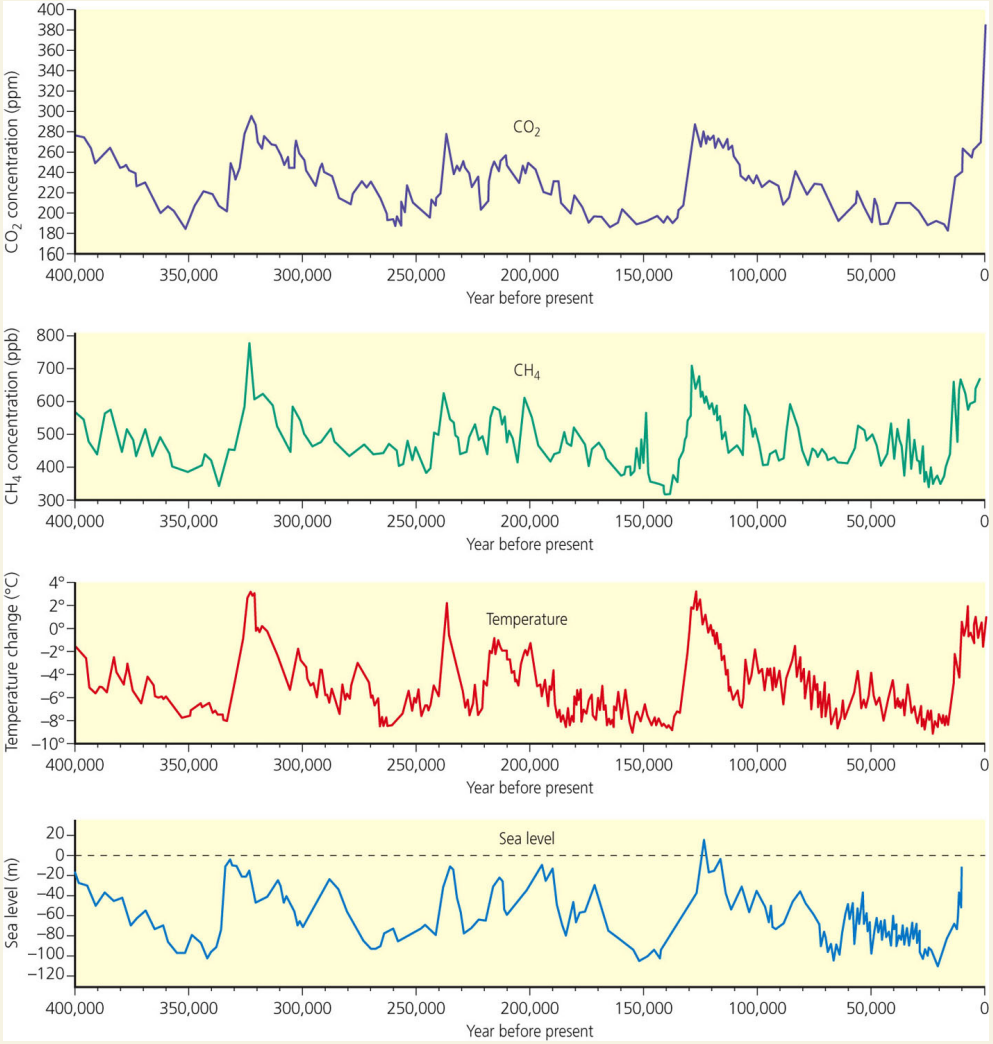

Fig. 19-4, p. 496

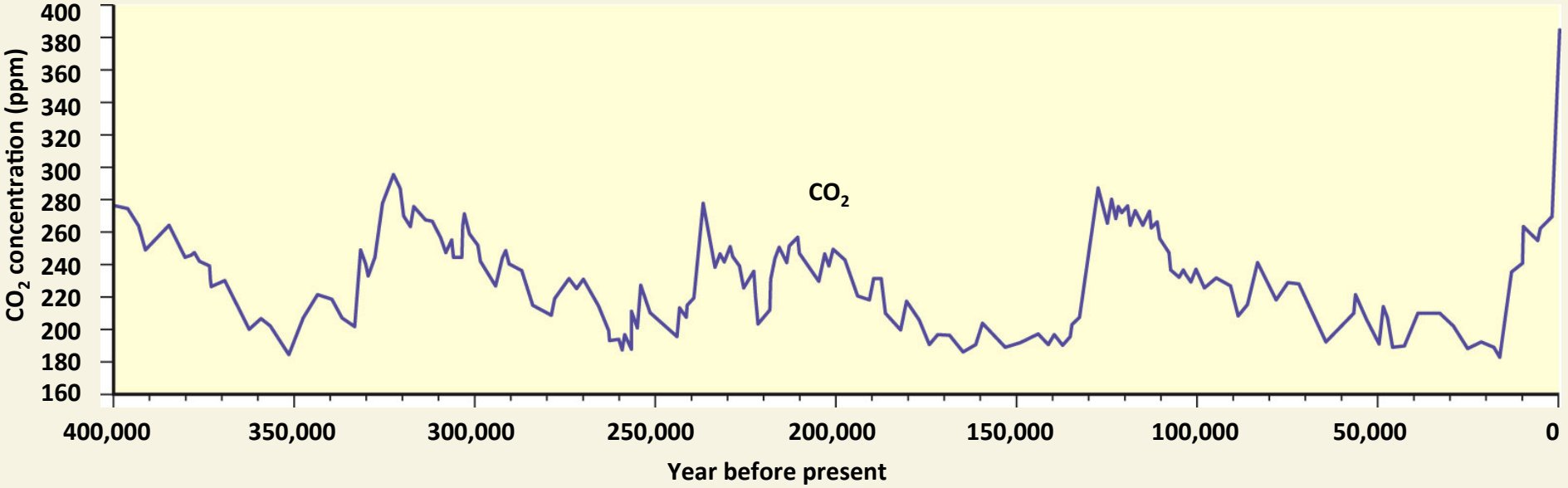

Fig. 19-4a, p. 496

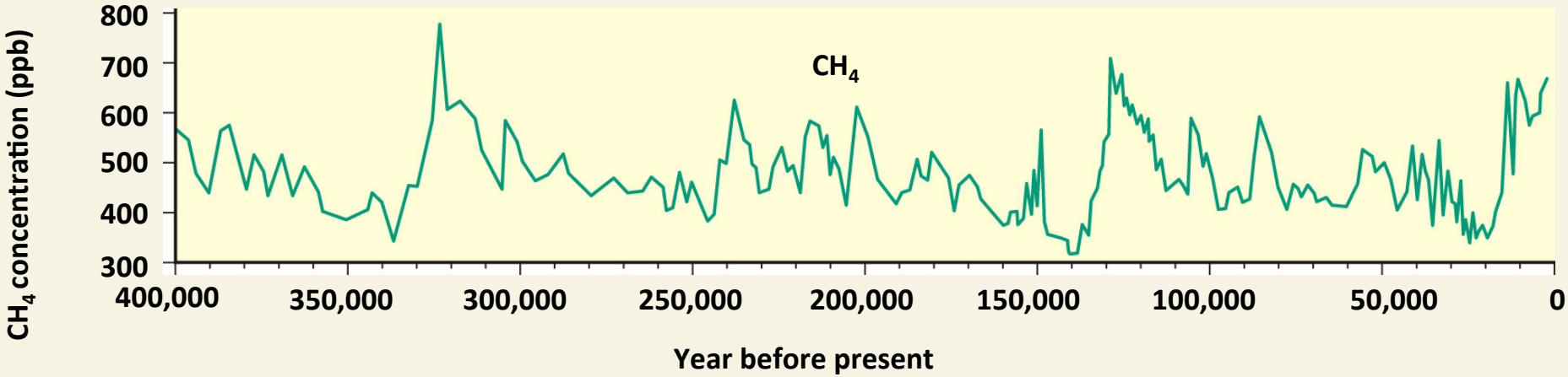

Fig. 19-4b, p. 496

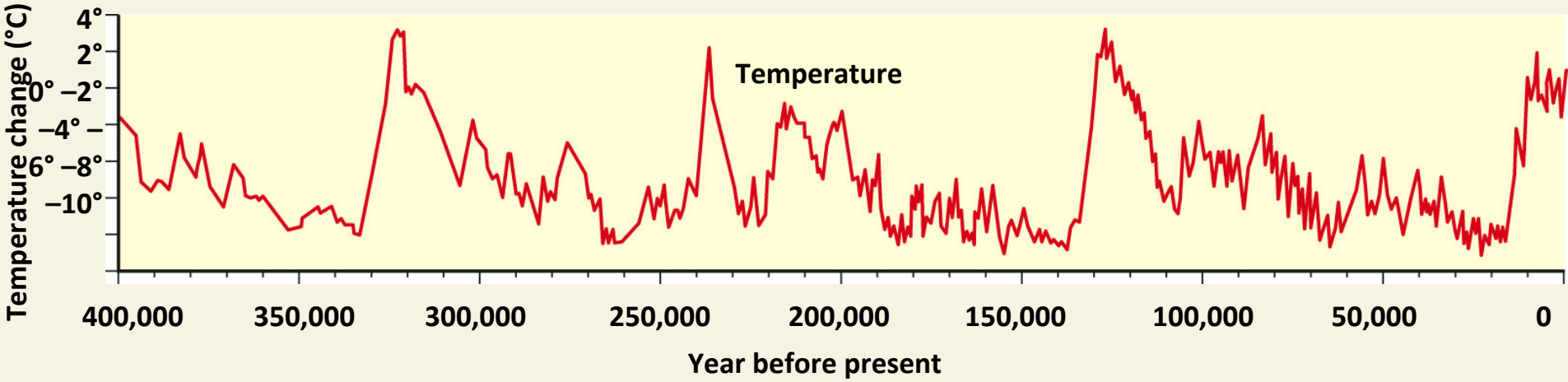

Fig. 19-4c, p. 496

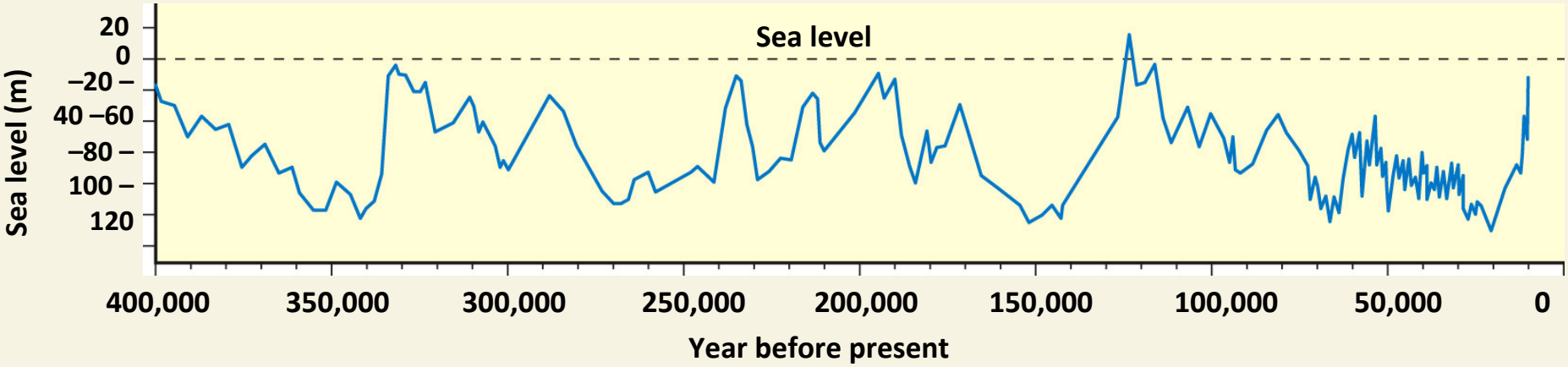

Fig. 19-4d, p. 496

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Fig. 19-4, p. 496

Correlation of CO_2 and Temperature

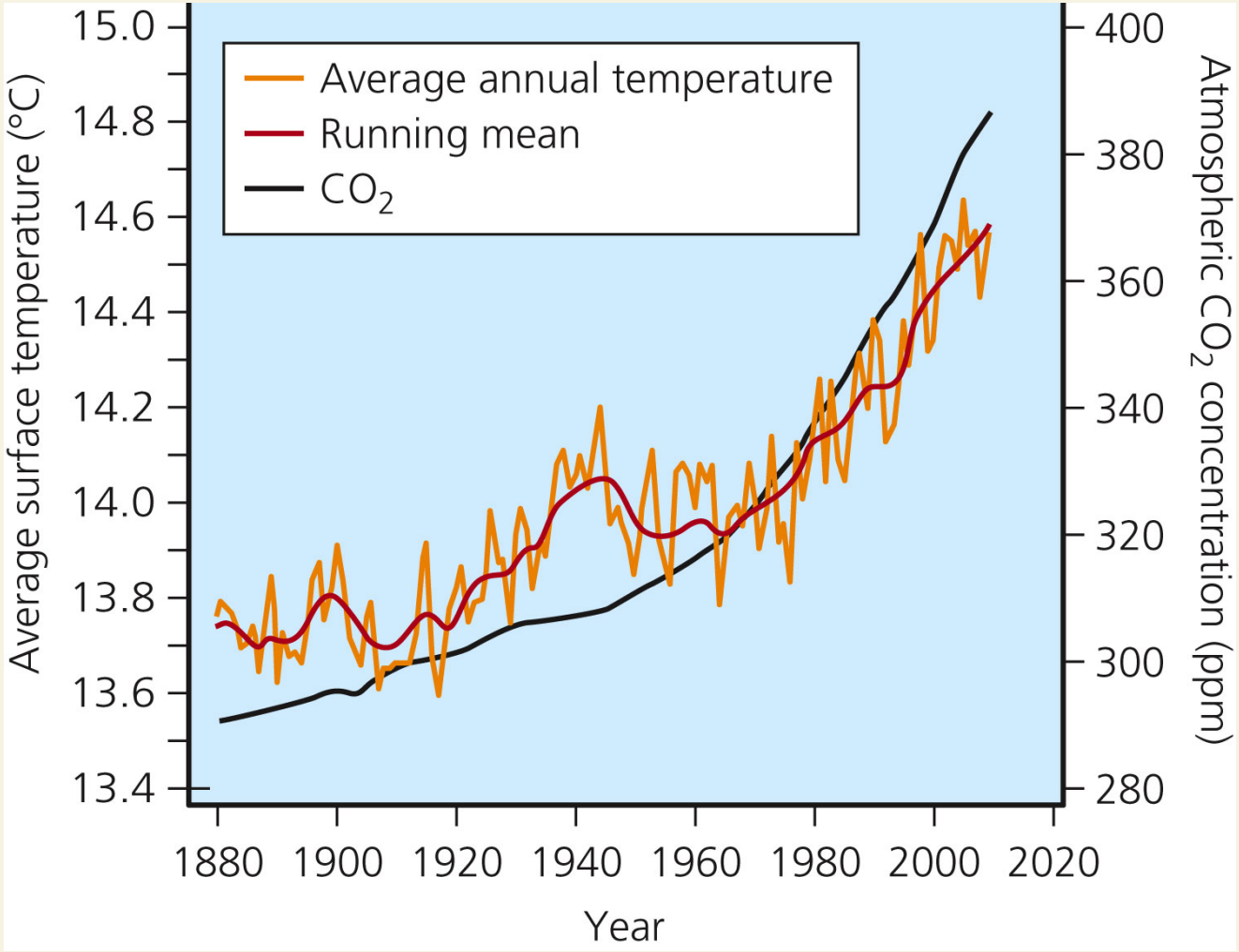

Fig. 19-5, p. 497

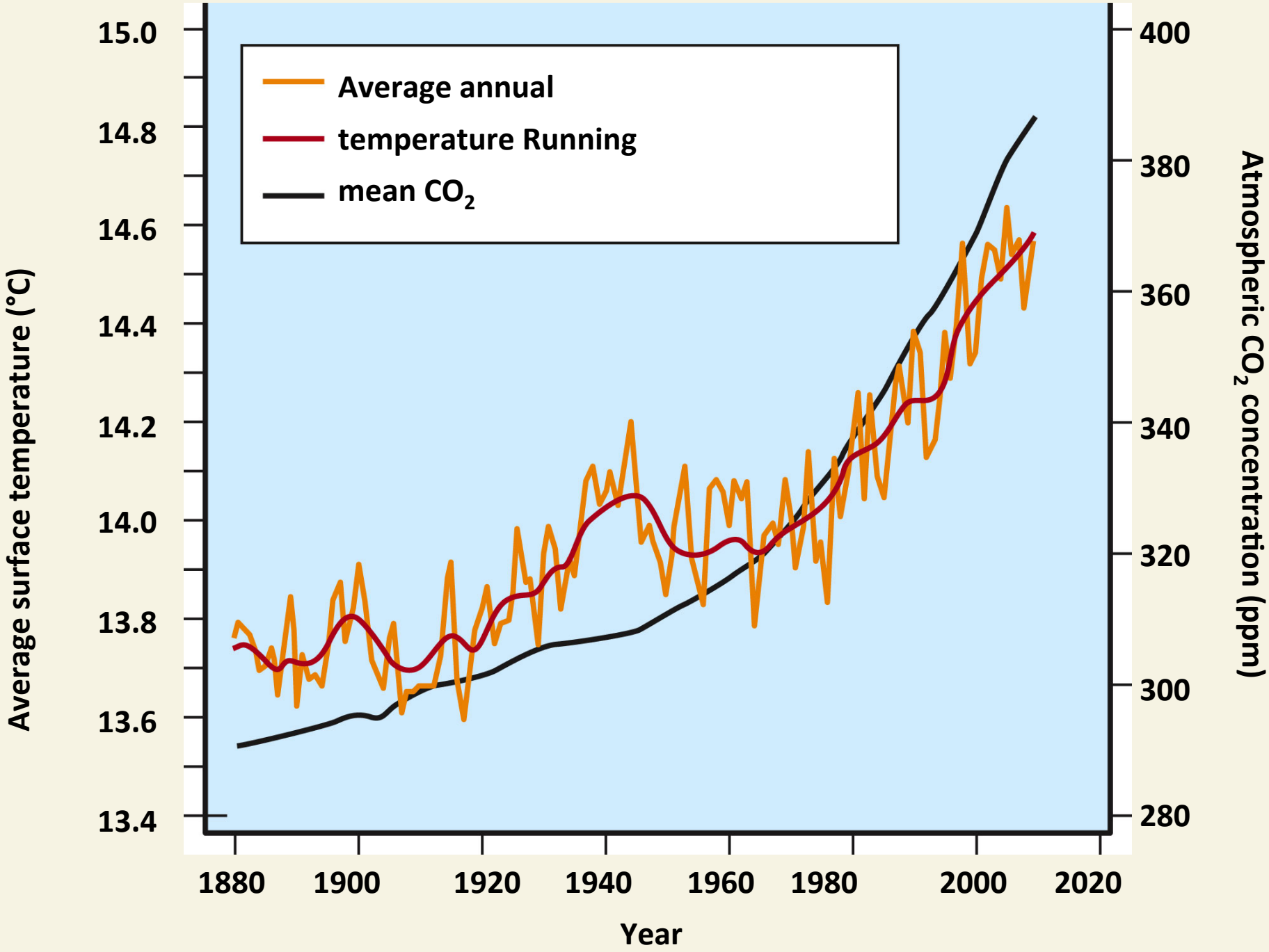
Average annual
temperature Running
mean CO_2
Average surface temperature (°C)
15.0
14.8
14.6
14.4
14.2
14.0
13.8
13.6
13.4
Atmospheric CO_2 concentration (ppm)
400
380
360
340
320
300
280
1880
1900
1920
1940
1960
1980
2000
2020
Year

Fig. 19-5, p. 497

CO_2 Concentrations, 1960-2009

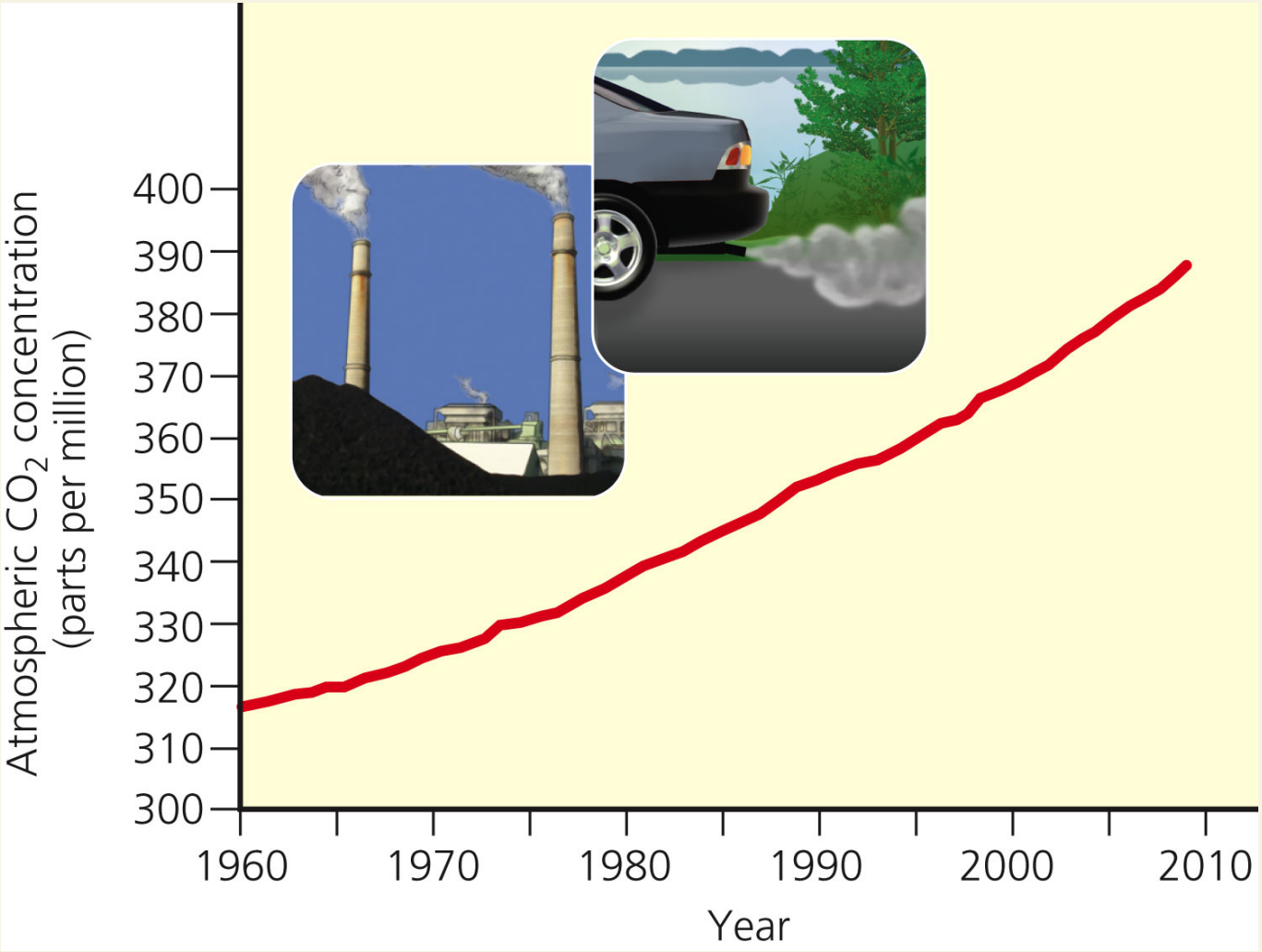

Figure 14, Supplement 9

Human Activities Play a Key Role in Recent Atmospheric Warming (1)

- Intergovernmental Panel on Climate Change (IPCC), with 2010 updates
  - 90–99% likely that lower atmosphere is warming
    - Especially since 1960
    - Mostly from human-caused increases in greenhouse gases
    - Earth's climate is now changing from increased greenhouse gases
  - Increased greenhouse gas concentrations will likely trigger significant climate disruption this century
  - Ecological, economic, and social disruptions

Human Activities Play a Key Role in Recent Atmospheric Warming (2)

- Intergovernmental Panel on Climate Change (IPCC), with 2010 updates, cont.
  - 1906–2005: Ave. temp increased about 0.74˚C
  - 1970–2009: Annual greenhouse emissions from human activities up 70%
  - 2000-2009 warmest decade since 1881
  - Past 50 years: Arctic temp rising almost twice as fast as the rest of the earth
  - Melting of glaciers and increased floating sea ice
  - Last 100 years: sea levels rose 19 cm

Human Activities Play a Key Role in Recent Atmospheric Warming (3)

- What natural and human-influenced factors could have an effect on temperature changes?
  - Amplify
  - Dampen

Melting of Alaska's Muir Glacier between 1948 and 2004

Fig. 19-6, p. 499

The Big Melt: Some of the Floating Sea Ice in the Arctic Sea

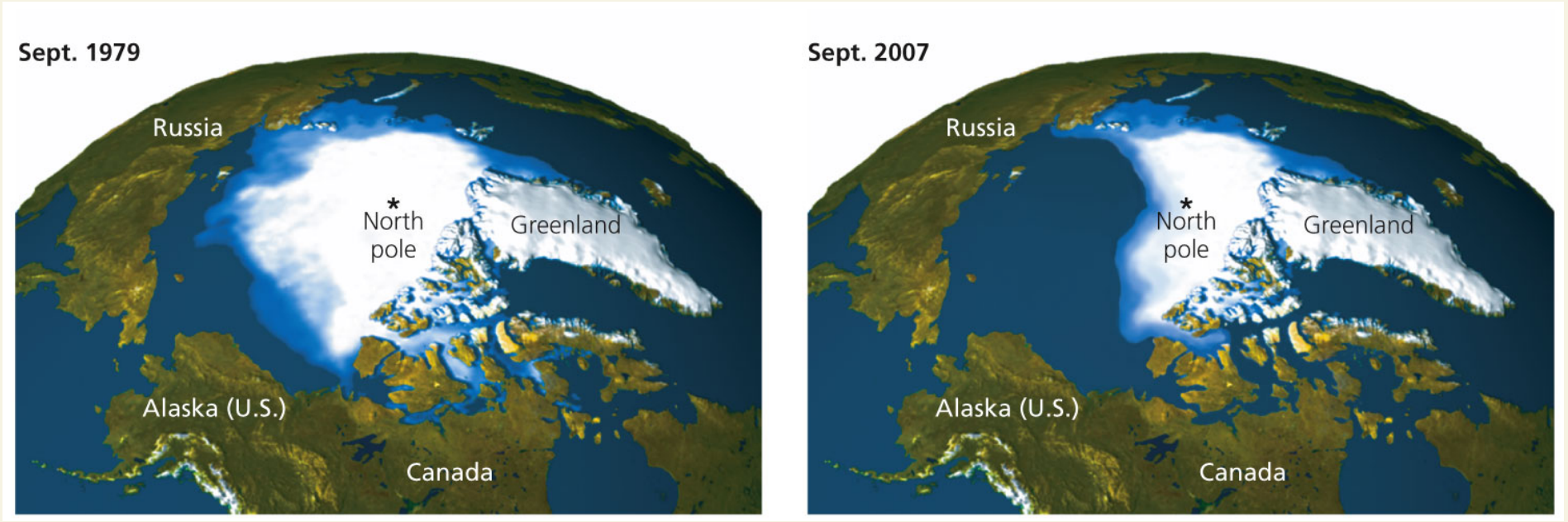

Fig. 19-7, p. 499

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Fig. 19-7, p. 499

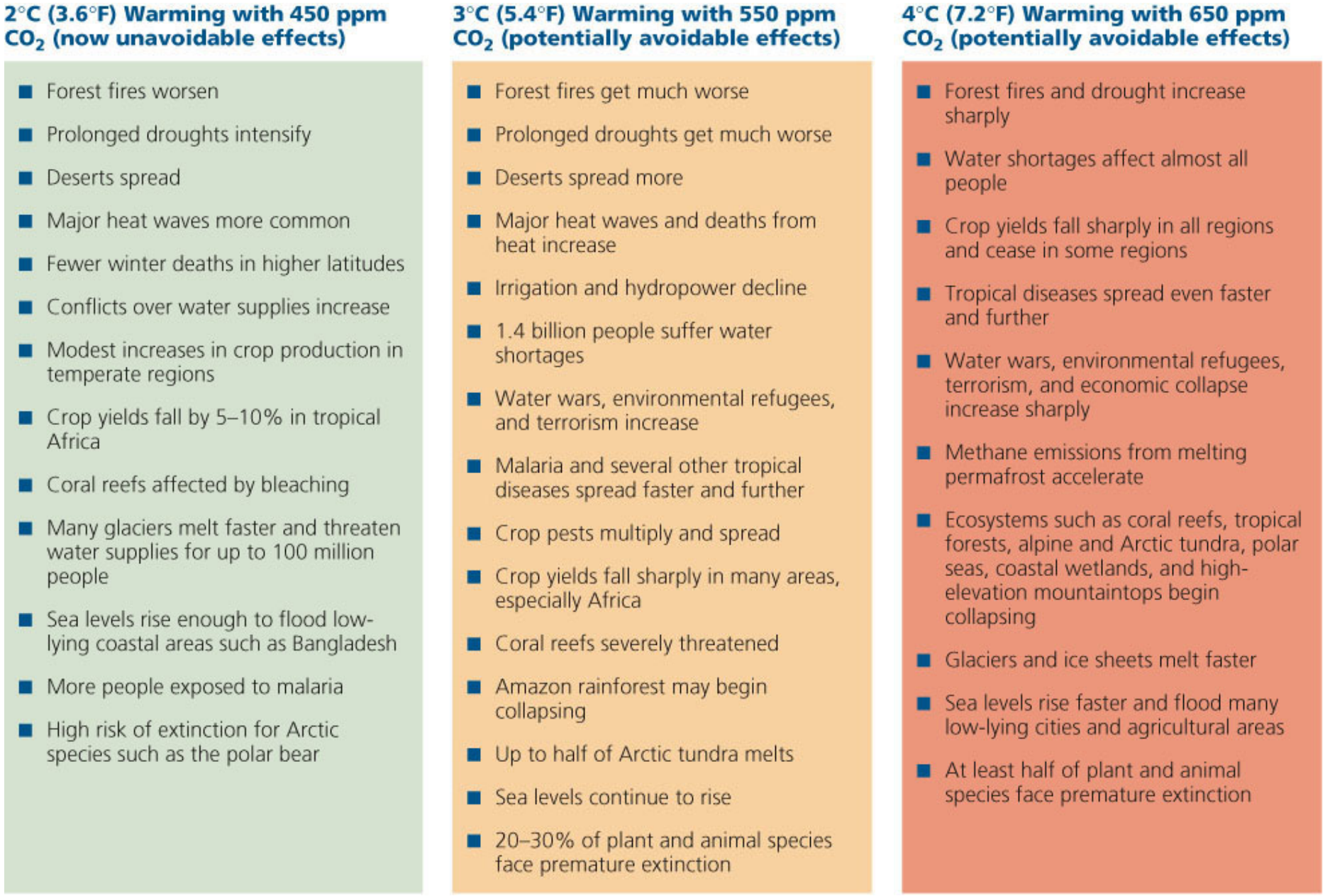

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Fig. 19-7, p. 507

Science Focus: How Valid Are IPCC Conclusions?

- 2500 scientists working for over two decades to reach consensus on climate change data and likely impact
  - Unanimity impossible to achieve
  - Gaps in data
  - Debate about interpreting data
  - Need for better models
  - 2007 IPCC report and Nobel Prize

Science Focus: Using Models to Project Future Changes in Atmospheric Temperatures

- Mathematical models used for projections
- Global warming: rapid rate
- Human factors are the major cause of temperature rise over the last 30 years
- Always uncertainty with any scientific model

Simplified Model of Some Major Processes That Interact to Determine Climate

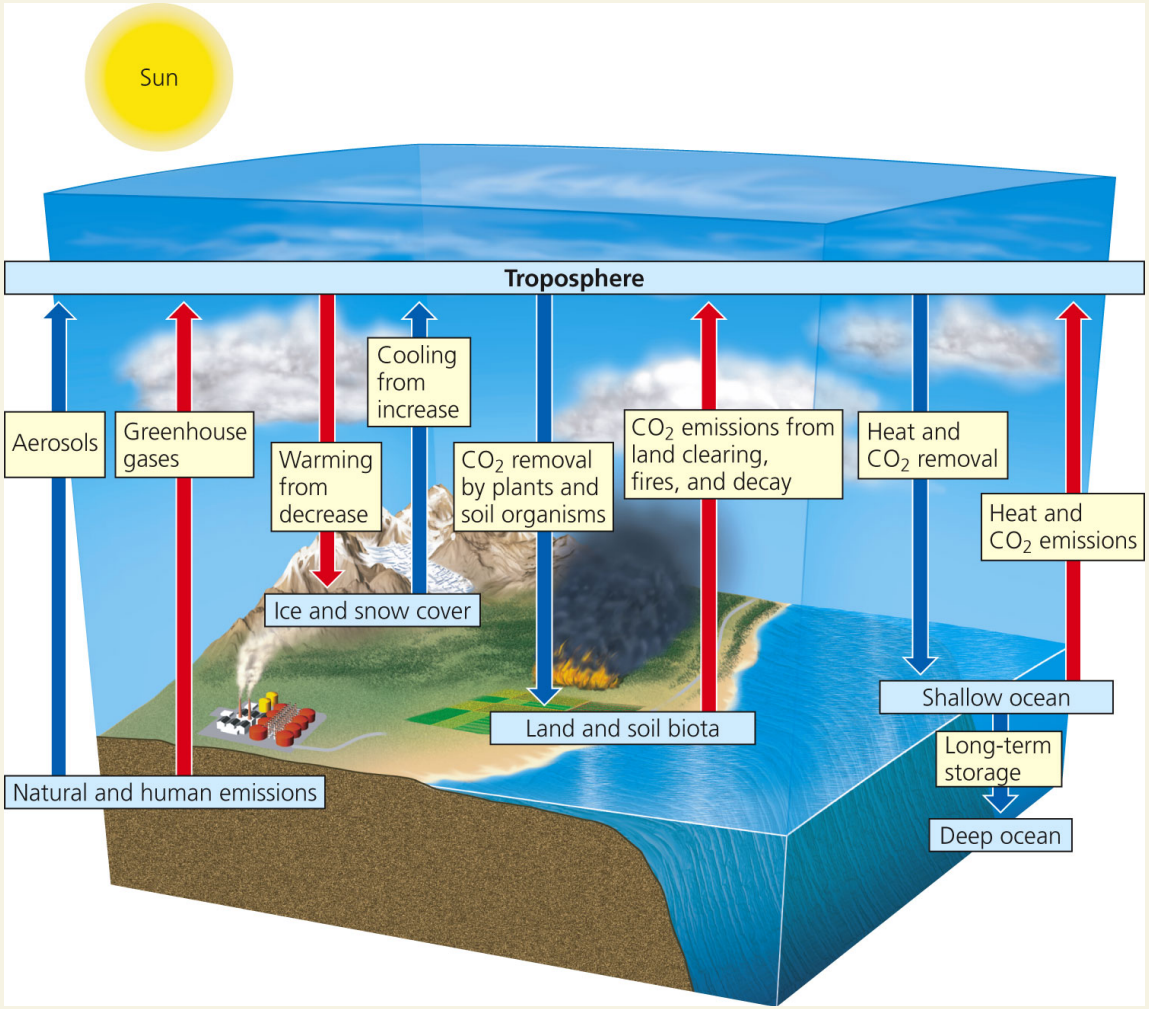

Fig. 19-A, p. 500

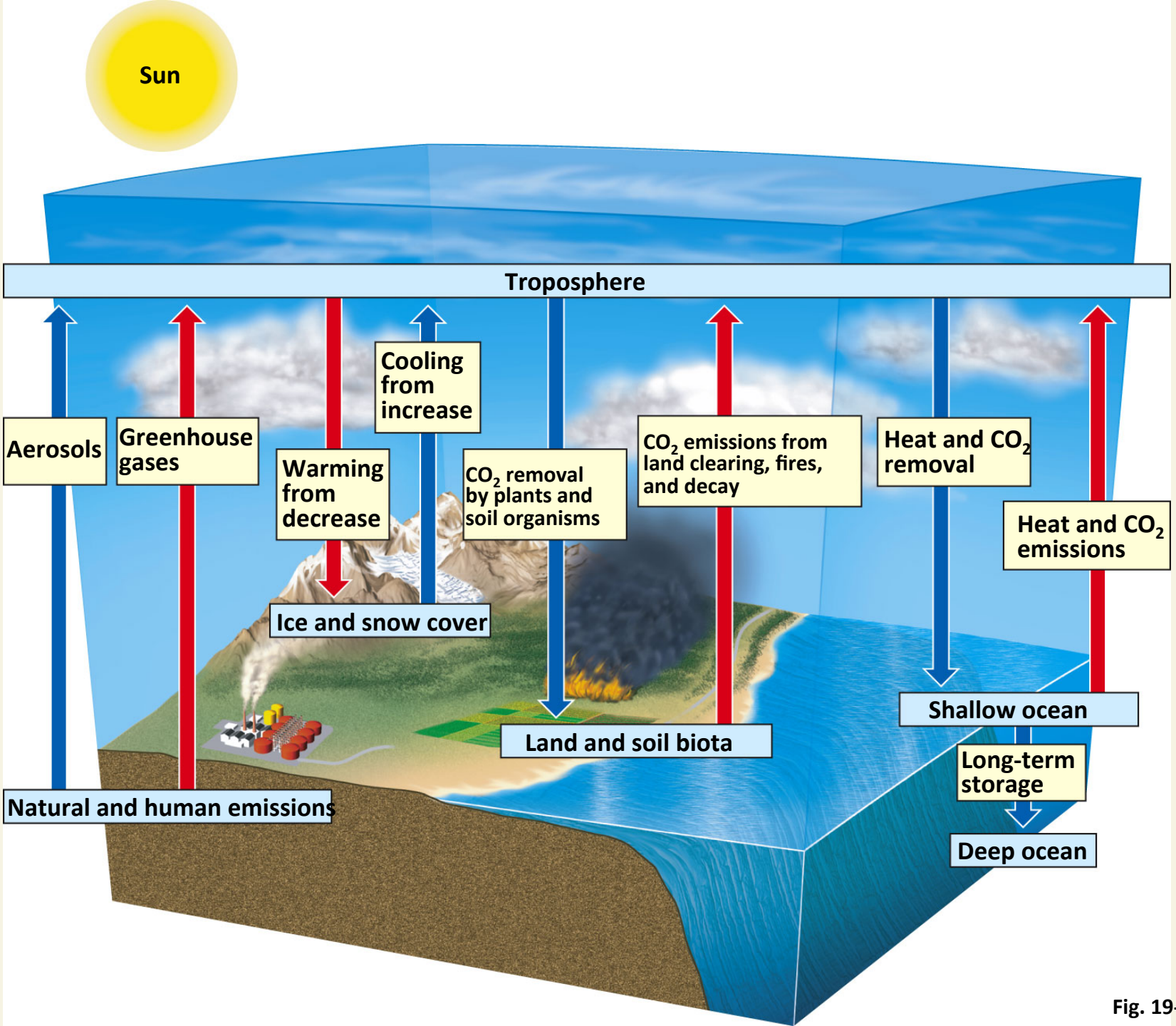
Sun
Troposphere
Aerosols
Greenhouse gases
Cooling from increase
Warming from decrease
CO_2 removal by plants and soil organisms
CO_2 emissions from land clearing, fires, and decay
Heat and CO_2 removal
Heat and CO_2 emissions
Ice and snow cover
Land and soil biota
Shallow ocean
Long-term storage
Deep ocean
Natural and human emissions

Fig. 19-A, p. 500

Comparison of Measured Temperature from 1860–2008 and Projected Changes

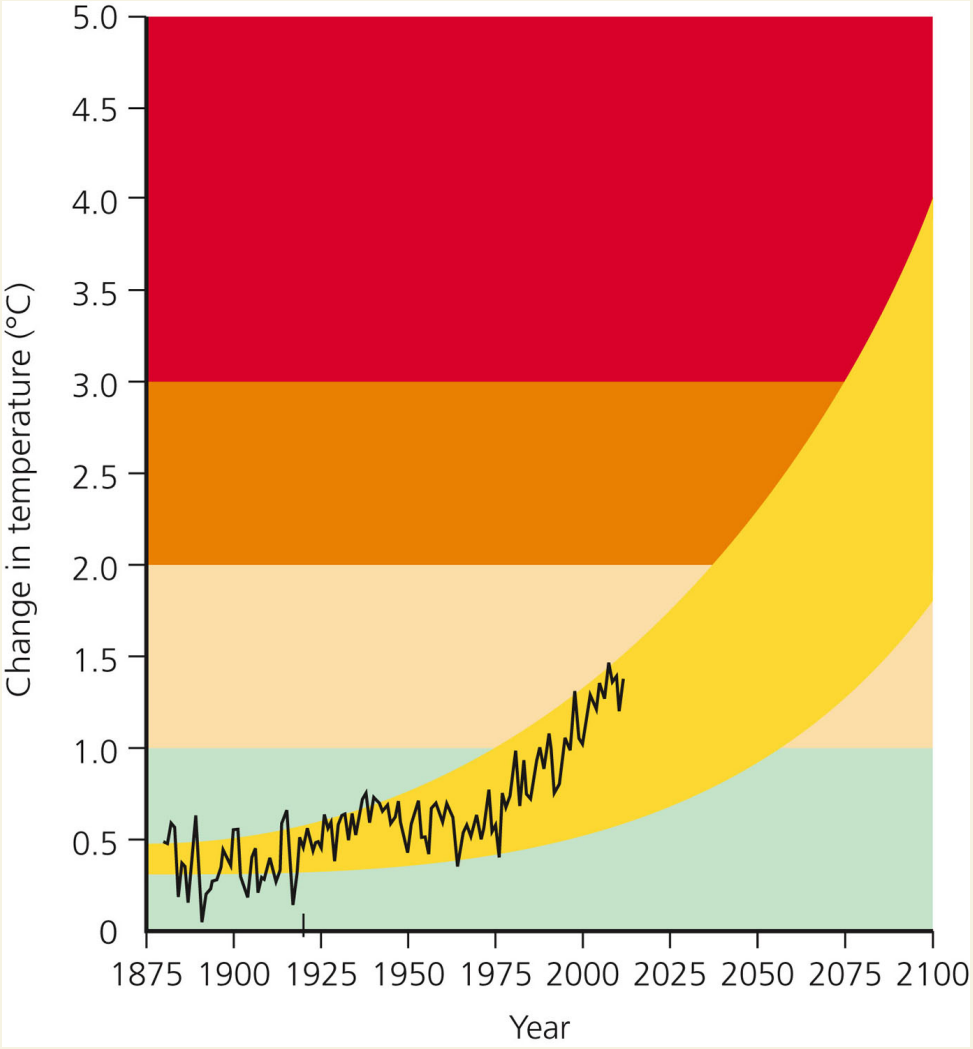

Fig. 19-B, p. 501

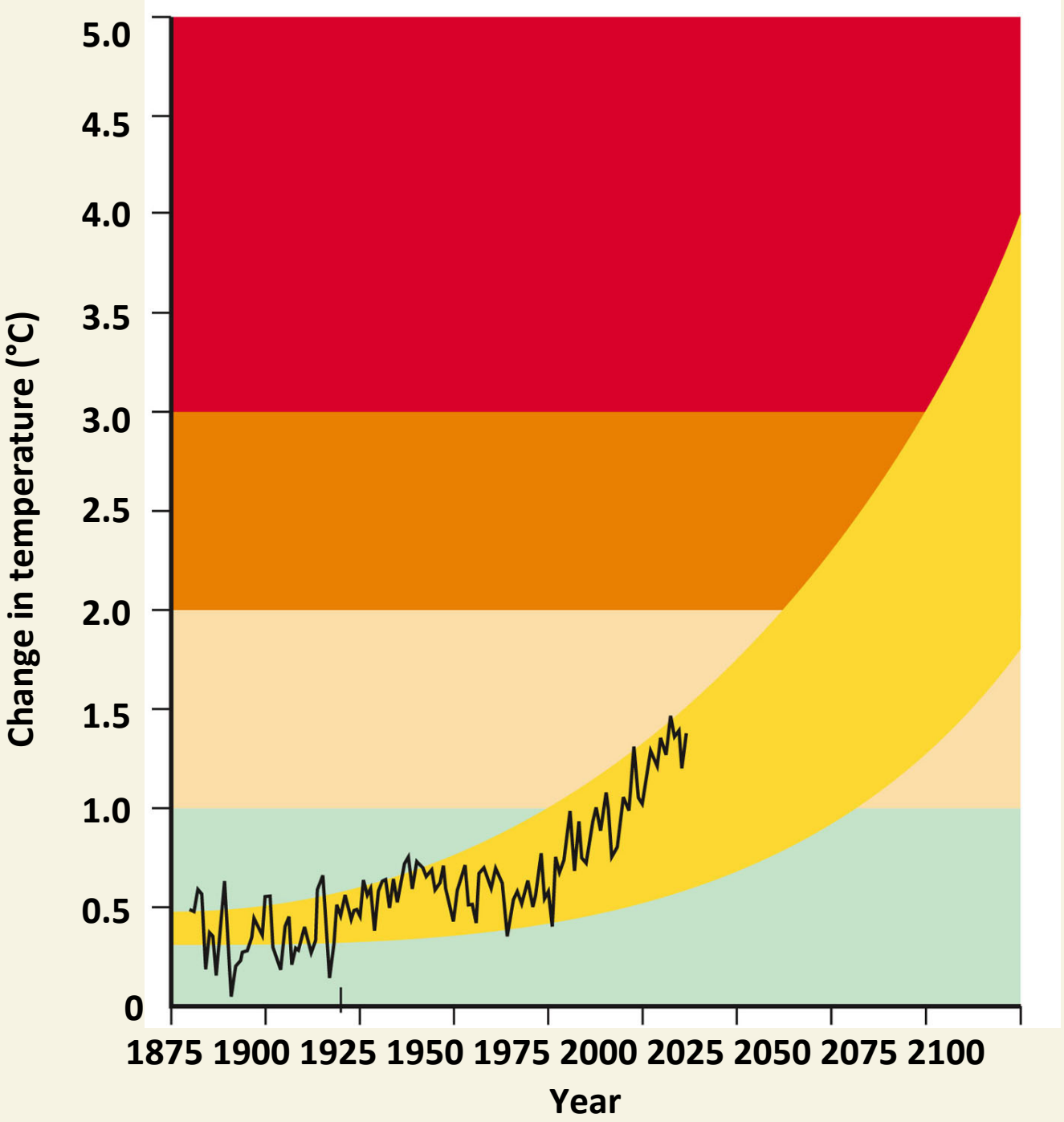
Change in temperature (°C)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
1875 1900 1925 1950 1975 2000 2025 2050 2075 2100
Year

Fig. 19-B, p. 501

Individuals Matter: Sounding the Alarm – James Hansen

- 1988 appearance before Congress began debate over atmospheric warming
- Promoted creation of IPCC
- Climate scientist at NASA
- Rising levels of greenhouse gases will lead to drastic climate disruption

James Hansen

Fig. 19-C, p. 502

CO_2 Emissions Play an Important Role (1)

- From burning fossil fuels and forests
- Abetted by deforestation; forests remove CO_2 from the atmosphere
- 2010: 389 ppm
- 2050: 560 ppm
- 2100: 1,390 ppm
- 450 ppm as tipping point

CO_2 Emissions Play an Important Role (2)

- Largest emitters, 2009
  1. China
  2. United States
  3. European Union (27 countries)
  4. Indonesia
  5. Russia
  6. Japan
  7. India

Cumulative CO2 emissions, 1900-2005

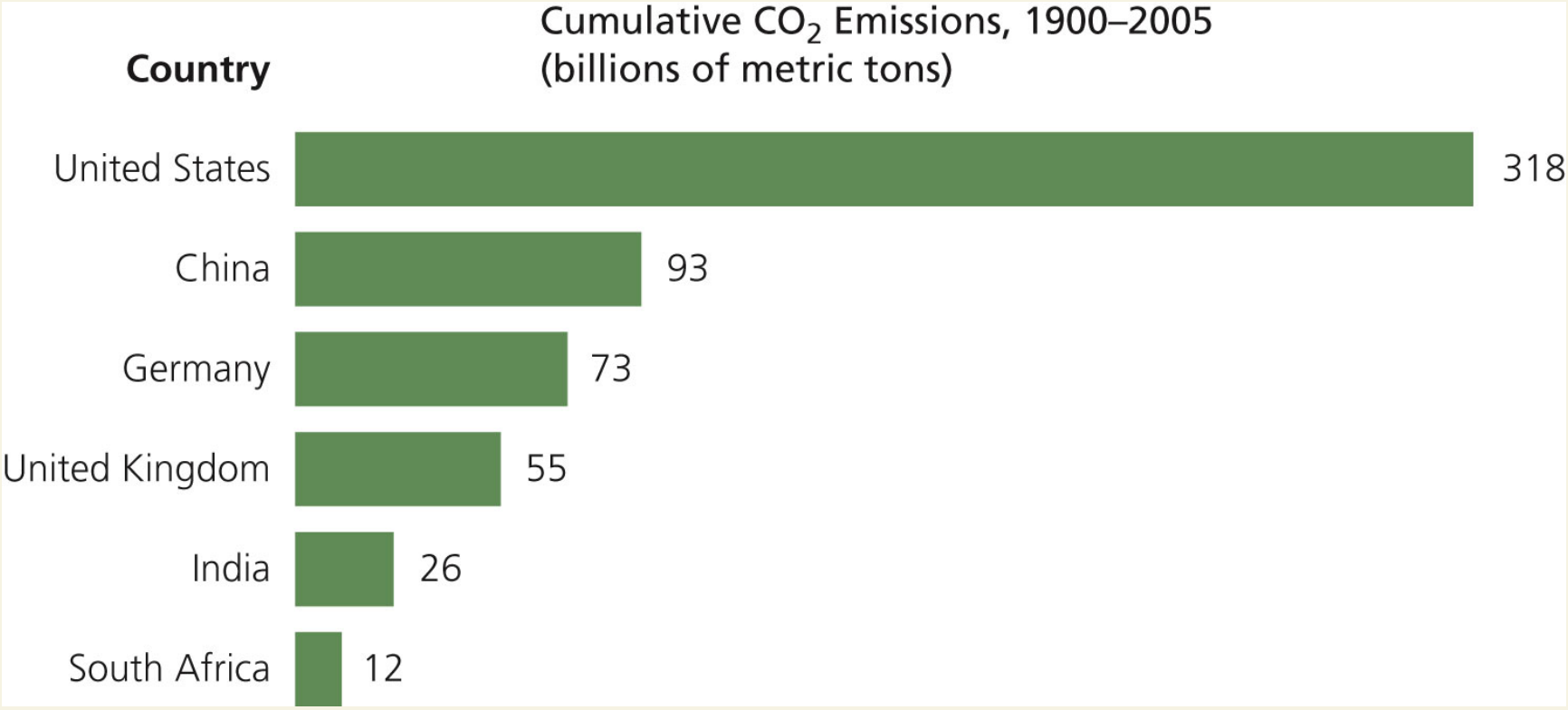

Figure 15, Supplement 9

Waste Heat Also Plays a Role in Climate Disruption

- Burning any fuel creates heat

- Many sources of heat
  - Power plants
  - Internal combustion engines
  - lights

What Role Does the Sun Play?

- Researchers think atmospheric warming not due to an increase in energy output from the sun

- Since 1975
  - Troposphere has warmed
  - Stratosphere has cooled

- This is not what a hotter sun would do

What Role Do the Oceans Play in Projected Climate Disruption?

- Solubility of CO_2 in ocean water

- Warmer oceans
  - Last century: 0.32-0.67C°increase
  - Absorb less CO_2 and hasten atmospheric warming
  - CO_2 levels increasing acidity
  - Affect phytoplankton and other organisms

There Is Uncertainty about the Effects of Cloud Cover on Global Warming

- Warmer temperatures create more clouds
  - Thick, low altitude cumulus clouds: decrease surface temperature
  - Thin, cirrus clouds at high altitudes: increase surface temperature

- Effect of jet contrails on climate temperature

Cumulus Clouds and Cirrus Clouds

Fig. 19-8, p. 503

Outdoor Air Pollution Can Temporarily Slow Global Warming

- Aerosol and soot pollutants
  - Will not enhance or counteract projected global warming
  - Fall back to the earth or are washed out of the lower atmosphere
  - Reduction: especially in developed countries

19-2 What Are Some Possible Effects of a Warmer Atmosphere?

- ***Concept 19-2*** *The projected rapid change in the atmosphere's temperature could have severe and long-lasting consequences, including increased drought and flooding, rising sea levels, and shifts in the locations of croplands and wildlife habitats.*

Enhanced Atmospheric Warming Could Have Serious Consequences

- Worst-case scenarios
  - Ecosystems collapsing
  - Low-lying cities flooded
  - Wildfires in forests
  - Prolonged droughts
  - More destructive storms
  - Glaciers shrinking; rivers drying up
  - Extinction of up to half the world's species
  - Spread of tropical infectious diseases

Severe Drought Is Likely to Increase

- Accelerate global warming, lead to more drought
- Increased wildfires
- Declining streamflows, dry lakes, lower water tables
- Dry climate ecosystems will increase
- Other effects of prolonged lack of water

More Ice and Snow Are Likely to Melt (1)

- Why will global warming be worse in the polar regions?

- Mountain glaciers affected by
  - Average snowfall
  - Average warm temperatures
  - 99% of Alaska's glaciers are shrinking

- When mountain glaciers disappear, there will be far less water in many major rivers

More Ice and Snow Are Likely to Melt (2)

- Glaciers disappearing from
  - Himalayas in Asia
  - Alps in Europe
  - Andes in South America
- Greenland
  - Warmer temperatures

Shrinking Athabasca Glacier in Canada

Fig. 19-9, p. 506

Permafrost Is Likely to Melt: Another Dangerous Scenario

- If permafrost in Arctic region melts
  - Methane, a greenhouse gas, will be released into the atmosphere
- Arctic permafrost contains 50-60x the amount of carbon dioxide emitted annually from burning fossil fuels
- Methane in permafrost on Arctic Sea floor

Projected Decreases in Arctic Tundra in Russia, 2004-2100

Fig. 19-10, p. 507

Fig. 19-10a, p. 507

Fig. 19-10b, p. 507

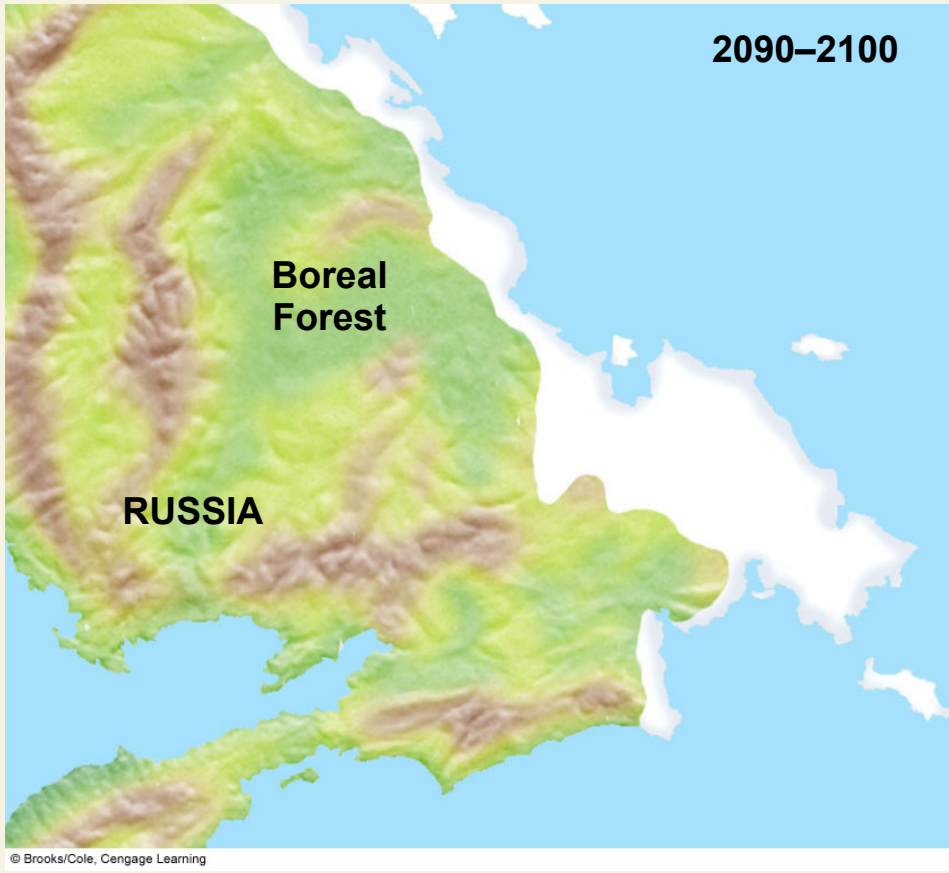

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Fig. 19-10, p. 507

Sea Levels Are Rising (1)

- 0.8-2 meters by 2100
- Expansion of warm water
- Melting of land-based ice
- What about Greenland?

Sea Levels Are Rising (2)

- Projected irreversible effect
  - Degradation and loss of 1/3 of coastal estuaries, wetlands, and coral reefs
  - Disruption of coastal fisheries
  - Flooding of
    - Low-lying barrier islands and coastal areas
    - Agricultural lowlands and deltas
  - Contamination of freshwater aquifers
  - Submergence of low-lying islands in the Pacific and Indian Oceans and the Caribbean
  - Flooding of coastal cities

Areas of Florida to Flood If Average Sea Level Rises by One Meter

Fig. 19-11, p. 507

Fig. 19-11, p. 507

Low-Lying Island Nation: Maldives in the Indian Ocean

Fig. 19-12, p. 508

Extreme Weather Is Likely to Increase in Some Areas

- Heat waves and droughts in some areas
  - Could kill large numbers of people
- Prolonged rains and flooding in other areas
- Will storms get worse?
  - More studies needed

Climate Disruption Is a Threat to Biodiversity (1)

- Most susceptible ecosystems
  - Coral reefs
  - Polar seas
  - Coastal wetlands
  - High-elevation mountaintops
  - Alpine and arctic tundra

Climate Disruption Is a Threat to Biodiversity (2)

- What about
  - Migratory animals
  - Forests

- Which organisms could increase with global warming? Significance?
  - Insects
  - Fungi
  - Microbes

Exploding Populations of Mountain Pine Beetles in British Columbia, Canada

Fig. 19-13, p. 509

Agriculture Could Face an Overall Decline

- Regions of farming may shift
  - Decrease in tropical and subtropical areas
  - Increase in northern latitudes
    - Less productivity; soil not as fertile

- Hundreds of millions of people could face starvation and malnutrition

A Warmer World Is Likely to Threaten the Health of Many People

- Deaths from heat waves will increase
- Deaths from cold weather will decrease
- Higher temperatures can cause
  - Increased flooding
  - Increase in some forms of air pollution, more O_3
  - More insects, microbes, toxic molds, and fungi

Detection of Dengue Fever in Mosquitoes, as of 2005

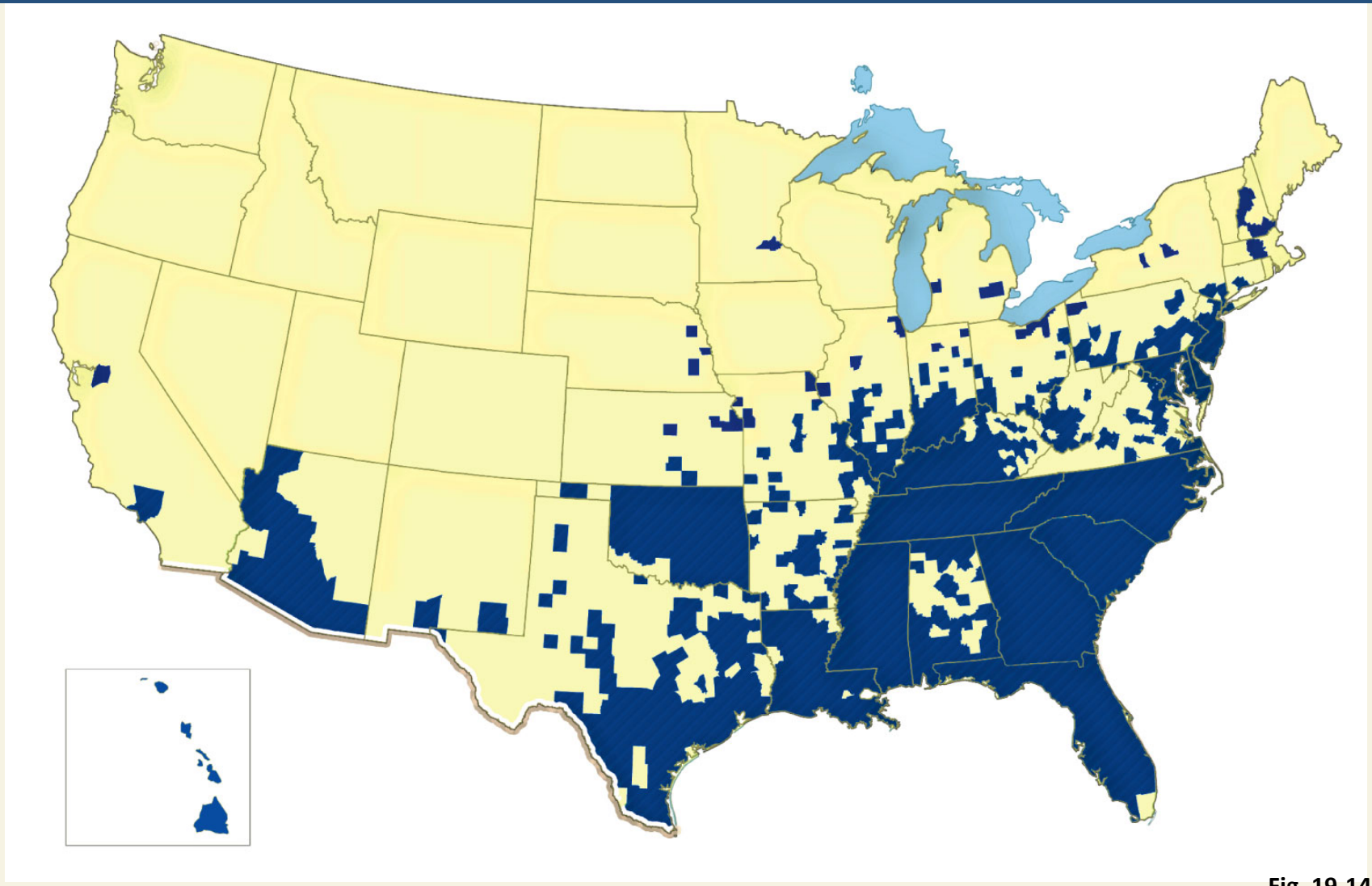

Fig. 19-14, p. 510

19-3 What Can We Do to Slow Projected Climate Disruption?

- ***Concept 19-3*** *To slow the projected rate of atmospheric warming and climate change, we can increase energy efficiency, sharply reduce greenhouse gas emissions, rely more on renewable energy resources, and slow population growth.*

Dealing with Climate Disruption Is Difficult

- Global problem with long-lasting effects
- Long-term political problem
- Harmful and beneficial impacts of climate change unevenly spread
- Many proposed actions disrupt economies and lifestyles
- Humans don't deal well with long-term threats

Possible Climate-Change Tipping Points

- Atmospheric carbon level of 450 ppm
- Melting of all Arctic summer sea ice
- Collapse and melting of the Greenland ice sheet
- Severe ocean acidification, collapse of phytoplankton populations, and a sharp drop in the ability of the oceans to absorb CO_2
- Massive release of methane from thawing Arctic permafrost
- Collapse and melting of most of the western Antarctic ice sheet
- Severe shrinkage or collapse of Amazon rainforest

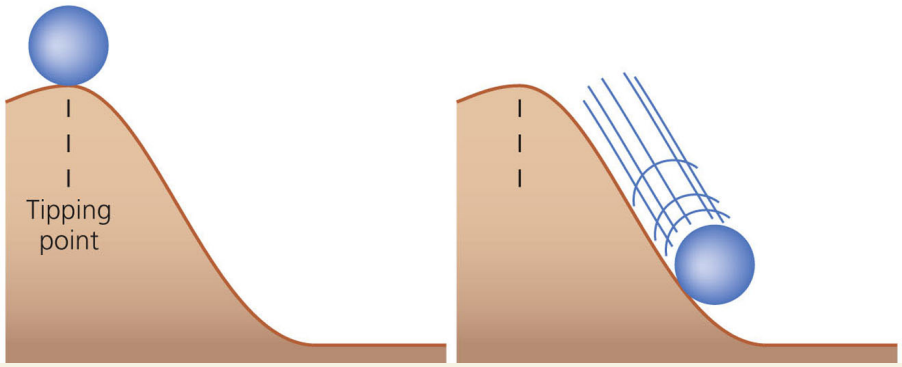

Fig. 19-15, p. 511

- Atmospheric carbon level of 450 ppm
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- Collapse and melting of the Greenland ice sheet
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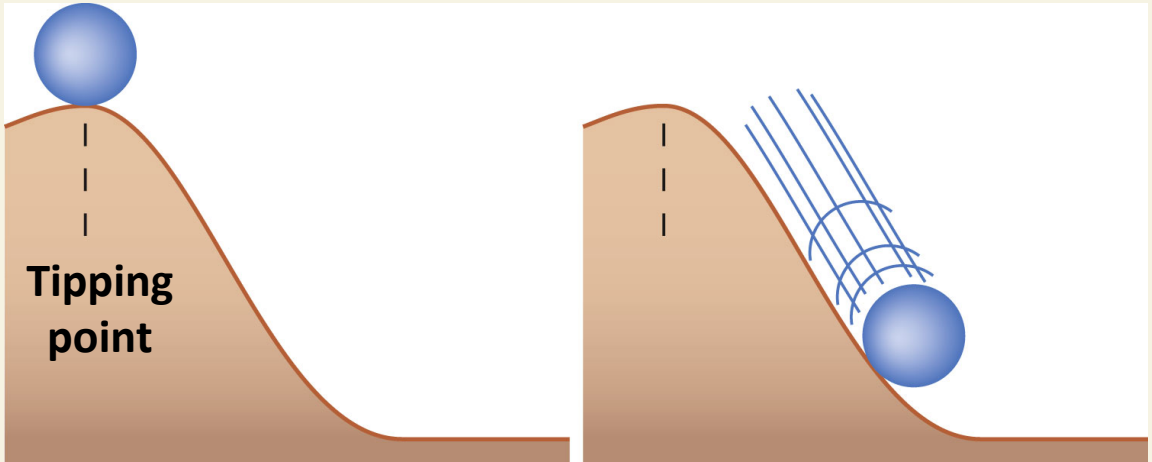

Fig. 19-15, p. 511

Science Focus: Science, Politics, and Climate

- 2006-2010: increase from 30% to 48% of Americans who think global warming is exaggerated

- Fossil fuel industries

- Play on public's lack of knowledge of
  - How science works
  - Difference between weather and climate

What Are Our Options?

- Three approaches
  1. Drastically reduce the amount of greenhouse gas emissions
  2. Devise strategies to reduce the harmful effects of global warming
  3. Suffer consequences of inaction

Solutions: Slowing Climate Disruption

Solutions

Slowing Climate Disruption

Prevention

Cut fossil fuel use (especially coal)

Shift from coal to natural gas

Improve energy efficiency

Shift to renewable energy resources

Transfer energy efficiency and renewable energy technologies to developing countries

Reduce deforestation

Use more sustainable agriculture and forestry

Put a price on greenhouse gas emissions

Reduce poverty

Slow population growth

Cleanup

Remove CO_2 from smokestack and vehicle emissions

Store (sequester) CO_2 by planting trees

Sequester CO_2 in soil by using no-till cultivation and taking cropland out of production

Sequester CO_2 deep underground (with no leaks allowed)

Sequester CO_2 in the deep ocean (with no leaks allowed)

Repair leaky natural gas pipelines and facilities

Use animal feeds that reduce CH_4 emissions from cows (belching)

Fig. 19-16, p. 513

Solutions

Slowing Climate Disruption

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Fig. 19-16, p. 513

Individuals Matter: John Sterman's Bathtub Model

- Atmosphere as a bathtub
- Inputs of CO2
- Ways CO2 is removed from atmosphere

Bathtub Model of CO_2 in Atmosphere

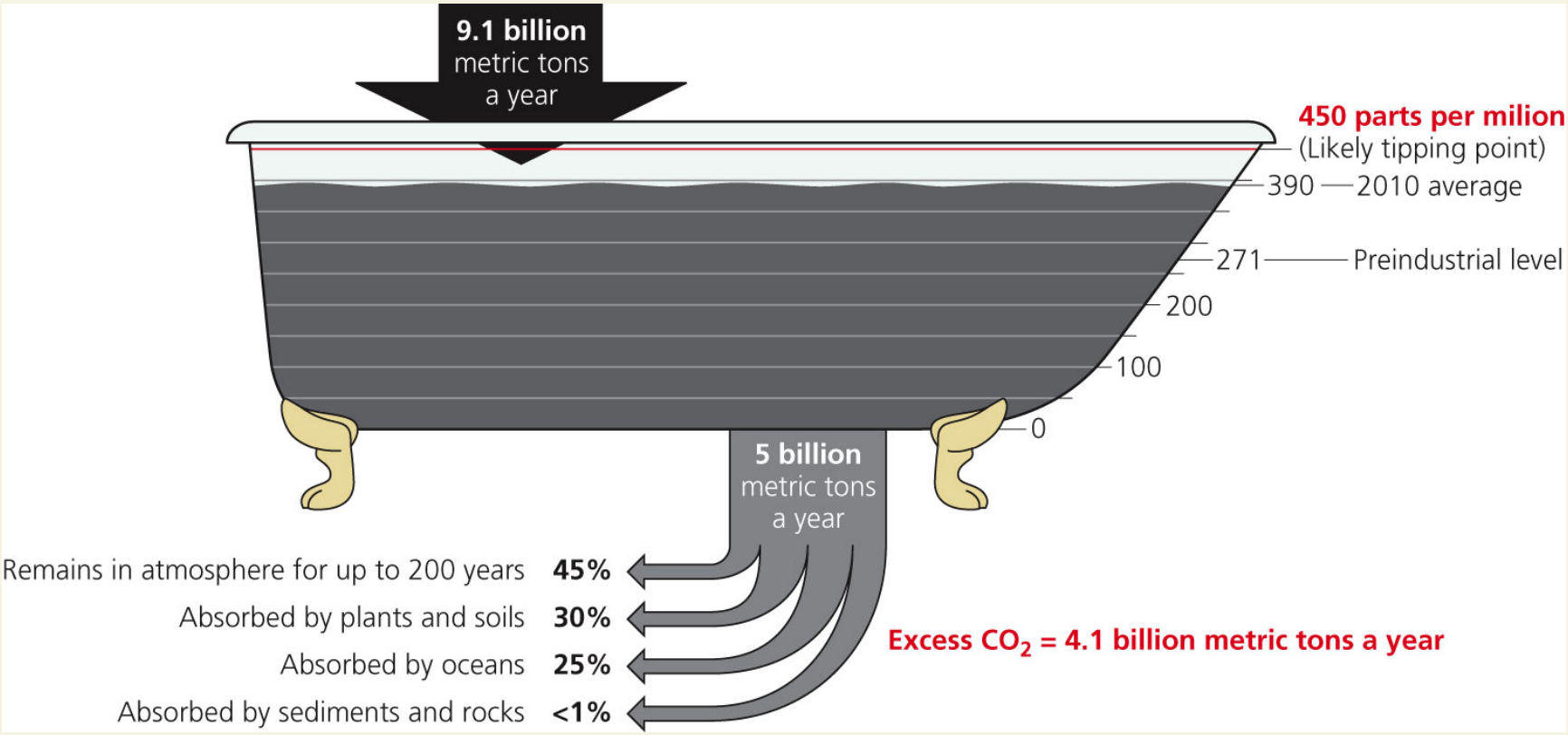


Fig. 19-D, p. 512

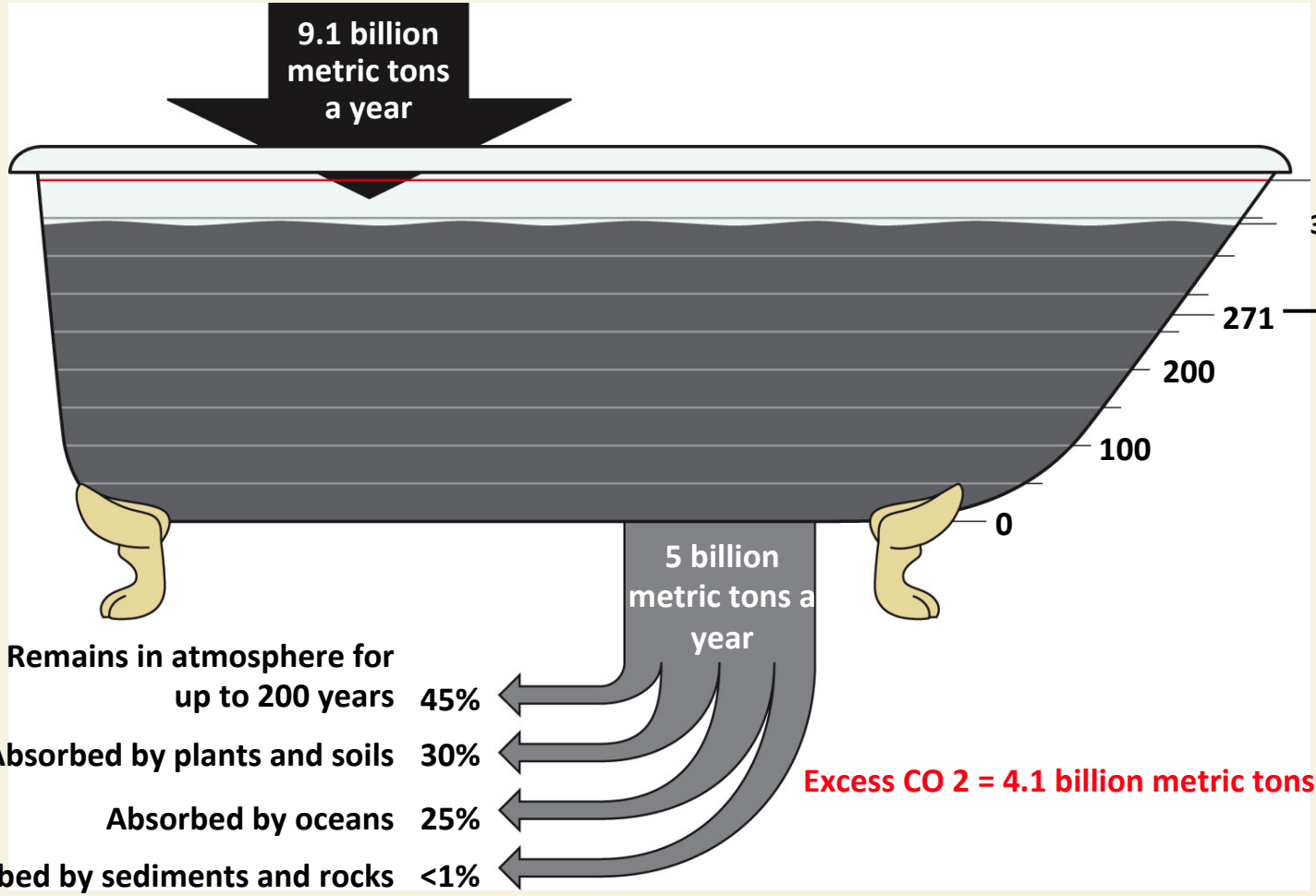

9.1 billion metric tons a year
450 parts per milion
tipping point)
390 —2010 average
271
Preindustrial level
200
100
0
5 billion metric tons a year
Remains in atmosphere for up to 200 years 45%
Absorbed by plants and soils 30%
Absorbed by oceans 25%
Absorbed by sediments and rocks <1%
Excess CO 2 = 4.1 billion metric tons a year

Fig. 19-D, p. 512

Prevent and Reduce Greenhouse Gas Emissions

- Improve energy efficiency to reduce fossil fuel use
- Increased use of low-carbon renewable energy resources
- Stop cutting down tropical forests
- Shift to more sustainable and climate-friendly agriculture

Collect Greenhouse Gas Emissions and Stash Them Somewhere

- Solutions
  1. Massive global tree planting; how many?
  2. Restore wetlands that have been drained for farming
  3. Plant fast-growing perennials on degraded land
  4. Preserve and restore natural forests
  5. Promote biochar
  6. Seed oceans with iron to stimulate growth of phytoplankton
  7. **Carbon capture and storage** – from coal-burning plants

Science Focus: Is Capturing and Storing CO_2 the Answer?

- **Carbon capture and storage (CCS)**

- Several problems with this approach
  - Large inputs of energy to work
    - Increasing CO_2 emissions
  - Promotes the continued use of coal (world's dirtiest fuel)
  - Effect of government subsidies and tax breaks
  - Stored CO_2 would have to remain sealed forever: no leaking

Capturing and Storing CO_2

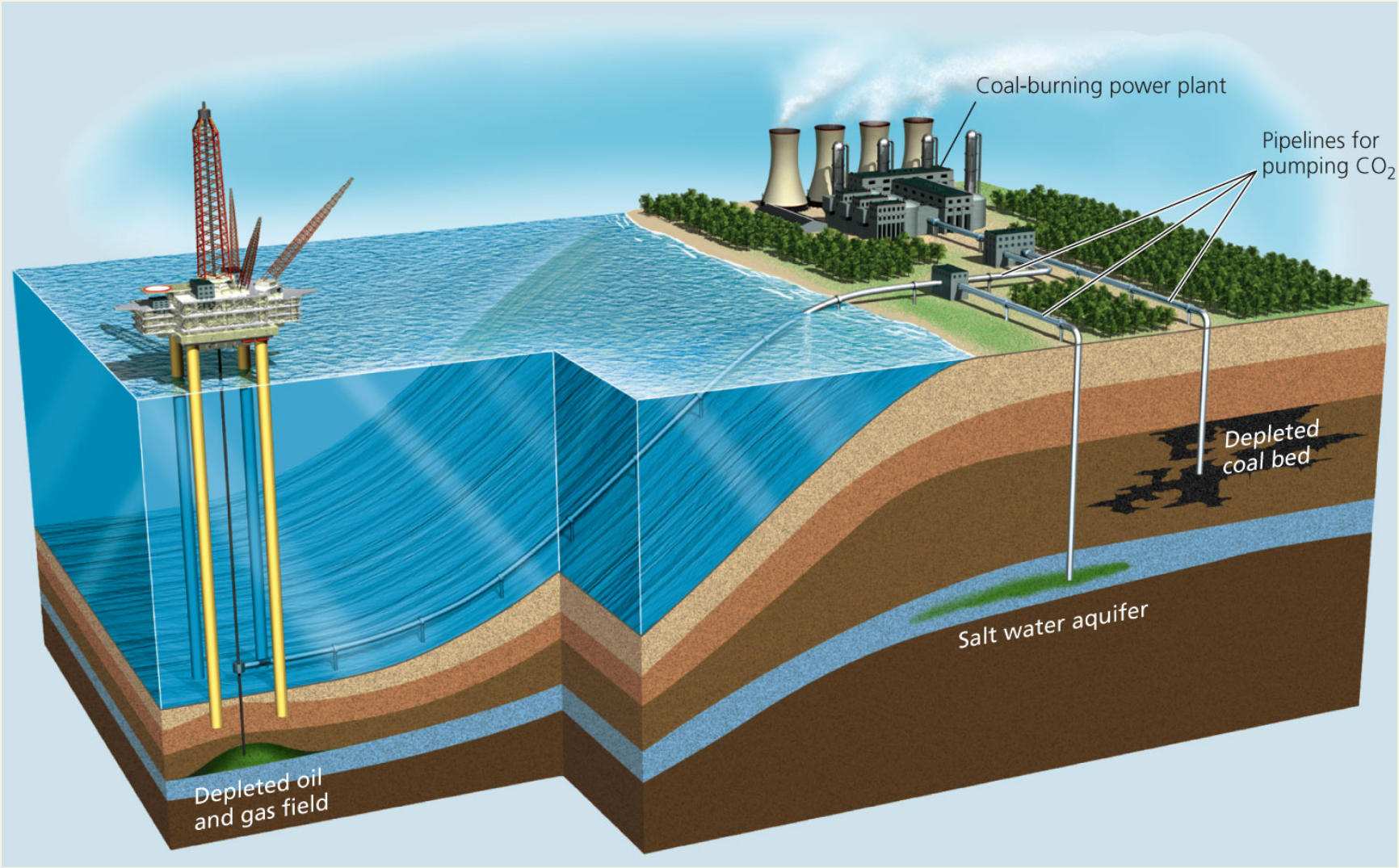


Fig. 19-E, p. 515

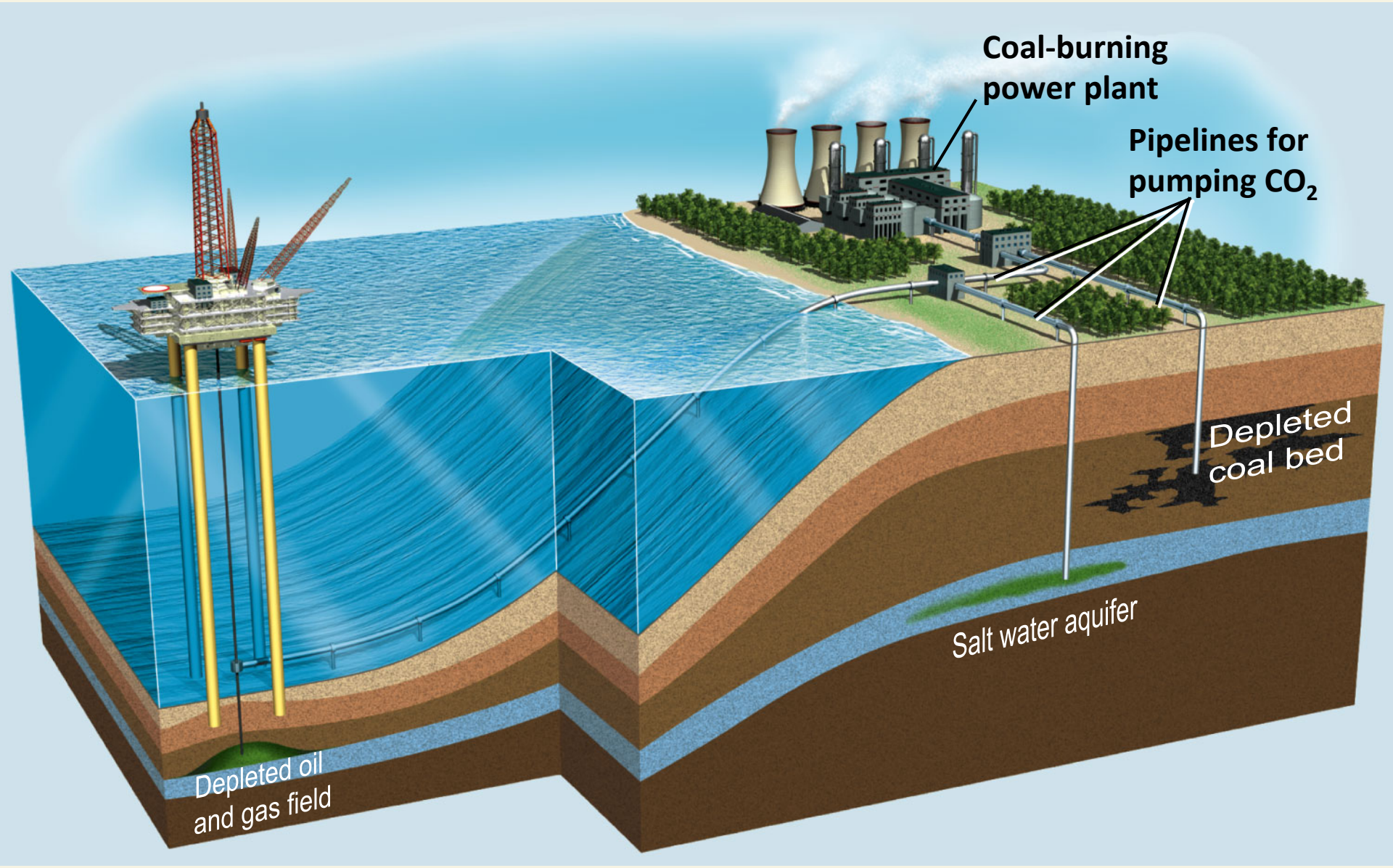

Coal-burning power plant
Pipelines for pumping CO_2
Depleted coal bed
Salt water aquifer
Depleted oil and gas field

Fig. 19-E, p. 515

Some Propose Geo-Engineering Schemes to Help Slow Climate Change (1)

- Last resort, if other methods and policies fail
- Injection of sulfate particles into the stratosphere
  - Would it have a cooling effect?
  - Would it accelerate O_3 depletion?
- Giant mirrors in orbit around earth
- Large pipes to bring nutrients from bottom of ocean to top to promote algae growth

Some Propose Geo-Engineering Schemes to Help Slow Climate Change? (2)

- Doesn't address the continued build-up of CO_2 in the atmosphere
- All depend on costly and complex plans
- If any of these fixes fail, what about a rebound effect?

Governments Can Help Reduce the Threat of Climate Disruption

1. Strictly regulate CO_2 and CH_4 as pollutants
2. Carbon tax on fossil fuels
3. Cap-and-trade approach
4. Increase subsidies to encourage use of energy-efficient technology
5. Technology transfer

Trade-Offs: Carbon and Energy Taxes

Trade-Offs

Carbon and Energy Taxes

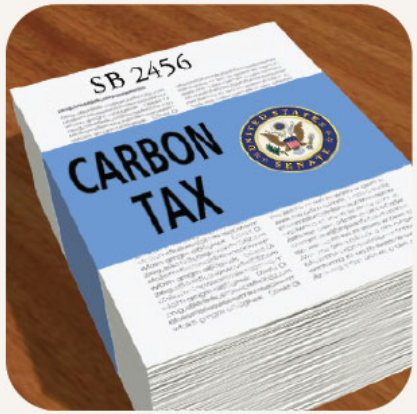
Advantages

Simple to administer

Clear price on carbon

Covers all emitters

Predictable revenues



Disadvantages

Tax laws can get complex

Vulnerable to loopholes

Doesn't guarantee lower emissions

Politically unpopular

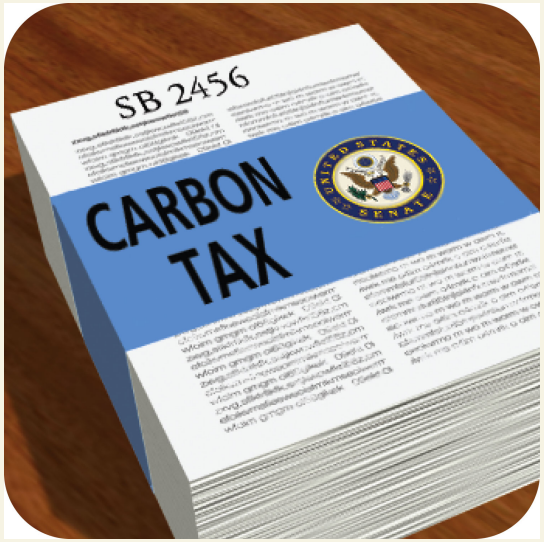
Fig. 19-17, p. 516

Trade-Offs

Carbon and Energy Taxes

Advantages

- Simple to administer
- Clear price on carbon
- Covers all emitters
- Predictable revenues



Disadvantages

- Tax laws can get complex
- Vulnerable to loopholes
- Doesn't guarantee lower emissions
- Politically unpopular

Fig. 19-17, p. 516

Trade-Offs: Cap and Trade Policies

Trade-Offs

Cap and Trade Policies

Advantages

Clear legal limit on emissions

Rewards cuts in emissions

Record of success

Low expense for consumers

Disadvantages

Revenues not predictable

Vulnerable to cheating

Rich polluters can keep polluting

Puts variable price on carbon

Fig. 19-18, p. 516

Trade-Offs

Cap and Trade Policies

Advantages

- Clear legal limit on emissions
- Rewards cuts in emissions
- Record of success
- Low expense for consumers

Disadvantages

- Revenues not predictable
- Vulnerable to cheating
- Rich polluters can keep polluting
- Puts variable price on carbon

Fig. 19-18, p. 516

Science Focus: What Is a Pollutant?

- Pollutant:
  - A chemical or any other agent that proves harmful to the health, survival, or activities of humans or other organisms
  - Carbon dioxide now classified as a pollutant
  - Concentration of carbon dioxide as the key factor

Governments Can Enter into International Climate Negotiations

- The Kyoto Protocol
  - 1997: Treaty to slow climate change
  - Reduce emissions of CO_2, CH_4, and N_2O by 2012 to 5.2% of 1990 levels
  - Not signed by the U.S.

- 2009 Copenhagen
  - Nonbinding agreement

Some Governments Are Leading the Way

- Costa Rica: goal to be carbon neutral by 2030
- China and India must change energy habits
- U.S. cities and states taking initiatives to reduce carbon emissions
  - California
  - Portland

Some Companies and Schools Are Reducing Their Carbon Footprints (1)

- Major global companies reducing greenhouse gas emissions
  - Alcoa
  - DuPont
  - IBM
  - Toyota
  - GE
  - Wal-Mart
    - Fluorescent light bulbs
    - Auxiliary power units on truck fleets

Some Companies and Schools Are Reducing Their Carbon Footprints (2)

- Colleges and universities reducing greenhouse gas emissions
  - Oberlin College, Ohio, U.S.
  - 25 Colleges in Pennsylvania, U.S.
  - Yale University, CT, U.S.

- What is your carbon footprint?

- What can you do?

What Can You Do? Reducing CO_2 Emissions

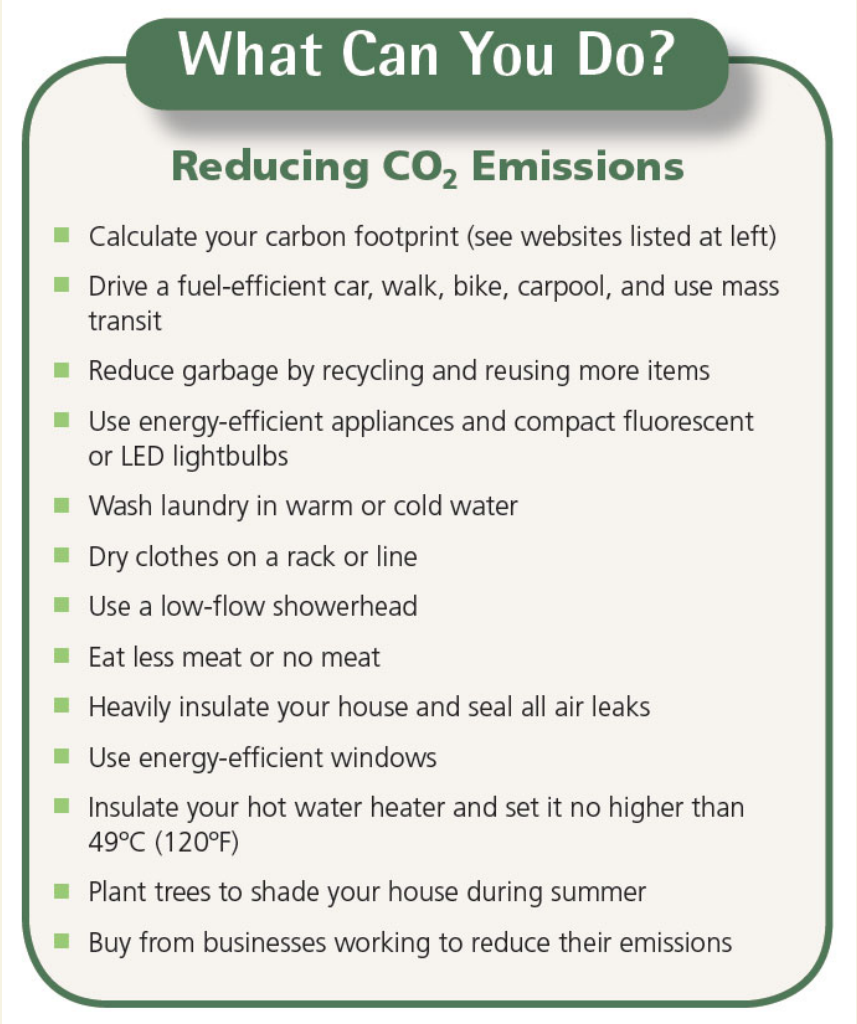


Fig. 19-19, p. 519

We Can Prepare for Climate Disruption (1)

- Reduce greenhouse gas emissions as much as possible
- Move people from low-lying coastal areas
- Take measures against storm surges at coast
- Cooling centers for heat waves

We Can Prepare for Climate Disruption (2)

- Prepare for more intense wildfires
- Water conservation, and desalination plants

Ways to Prepare for the Possible Long-Term Harmful Effects of Climate Disruption

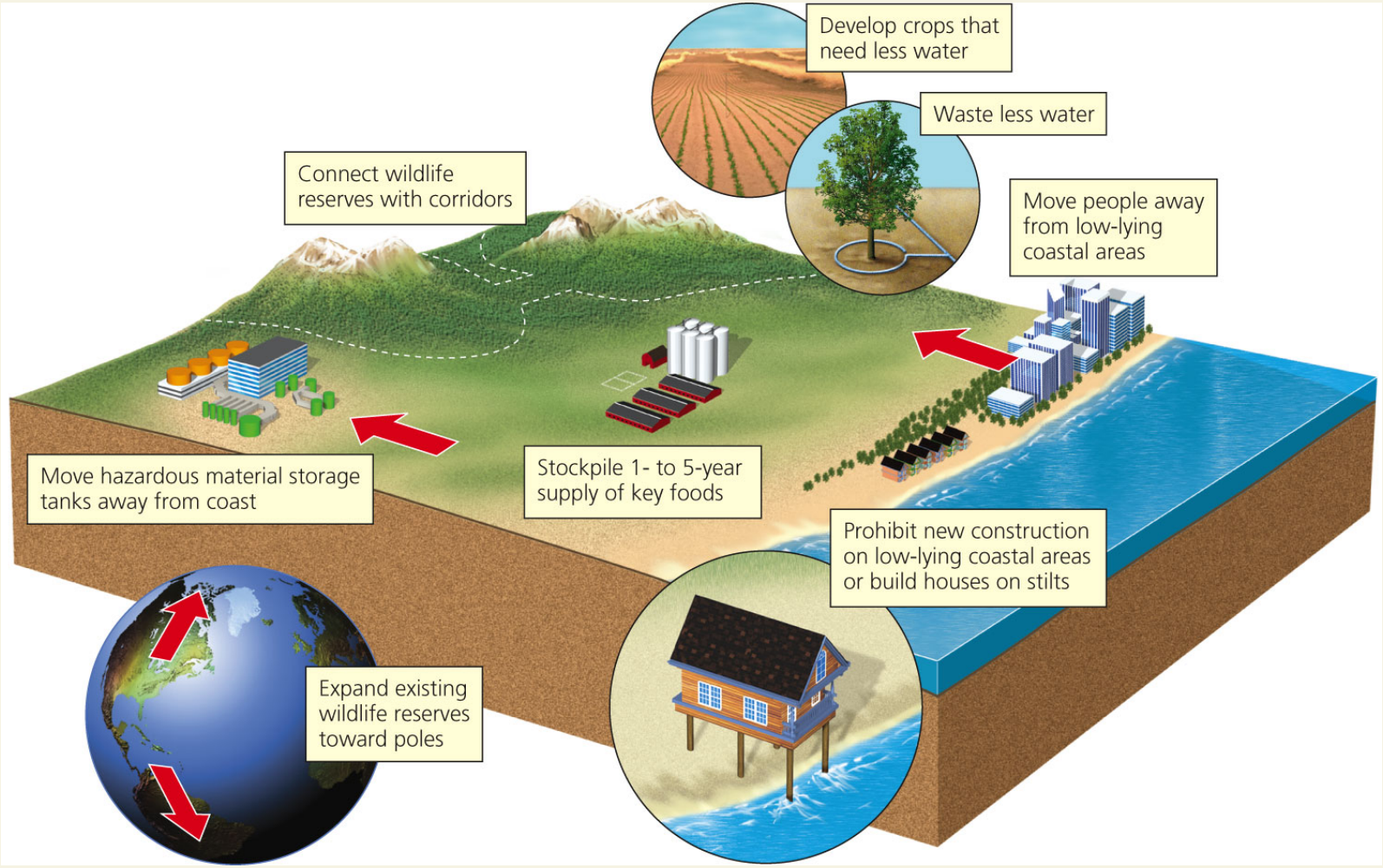


Fig. 19-20, p. 520

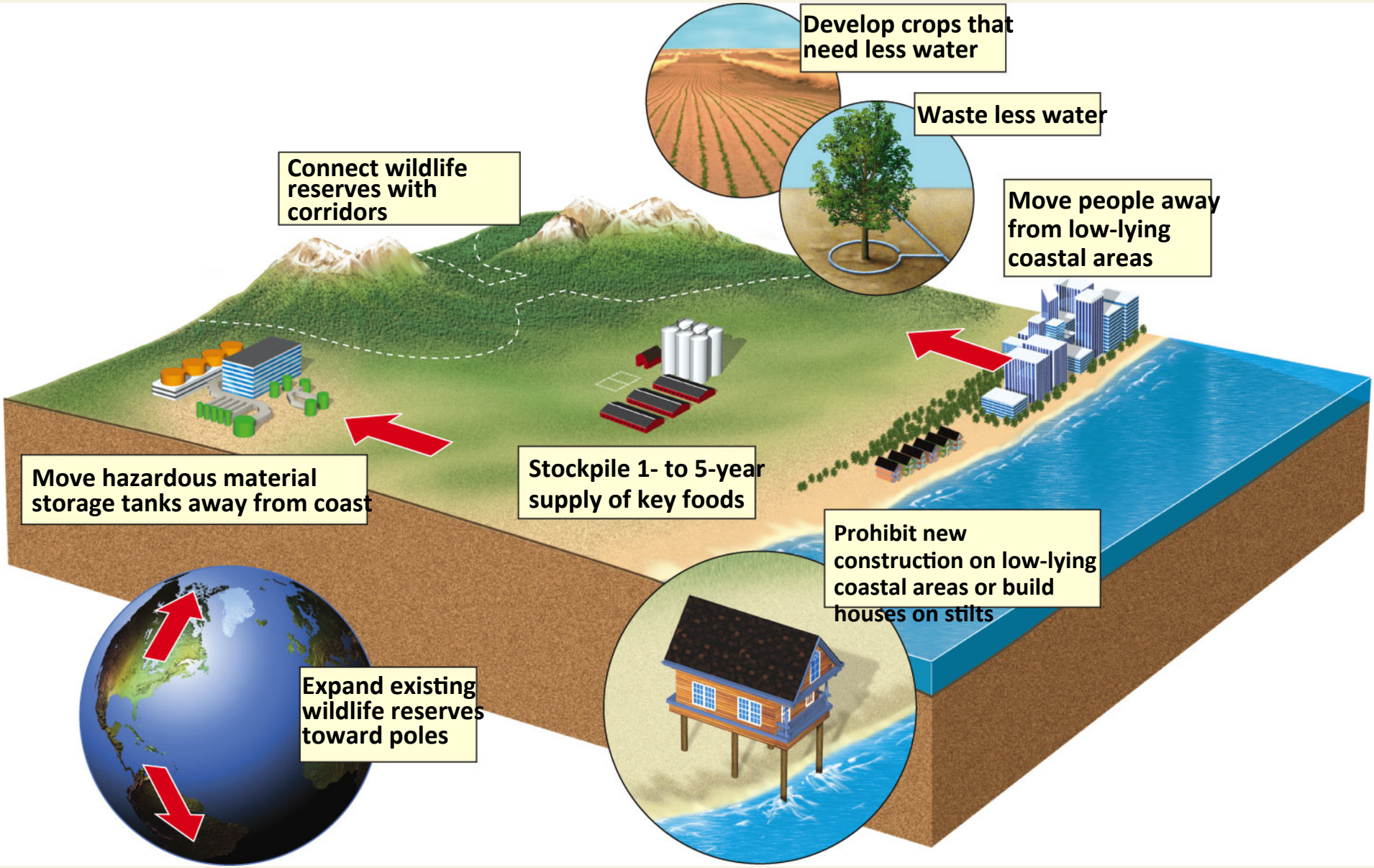


Fig. 19-20, p. 520

A No-Regrets Strategy

- What if climate models are wrong and there is no serious threat of climate disruption?

- No-regrets strategy
  - Environmental benefits
  - Health benefits
  - Economic benefits
  - Reduce pollution and energy use
  - Decrease deforestation
  - Promote biodiversity

19-4 How Have We Depleted O_3 in the Stratosphere and What Can We Do?

- ***Concept 19-4A*** *Our widespread use of certain chemicals has reduced ozone levels in the stratosphere, which has allowed more harmful ultraviolet radiation to reach the earth's surface.*

- ***Concept 19-4B*** *To reverse ozone depletion, we must stop producing ozone-depleting chemicals and adhere to the international treaties that ban such chemicals.*

Our Use of Certain Chemicals Threatens the Ozone Layer

- Ozone thinning
  - Seasonal depletion in the stratosphere
    - Antarctica and Arctic
    - Affects Australia, New Zealand, South America, South Africa
- 1984: Rowland and Molina
  - CFCs were depleting O_3
- Other ozone-depleting chemicals

Natural Capital Degradation: Massive Ozone Thinning over Antarctica in 2009

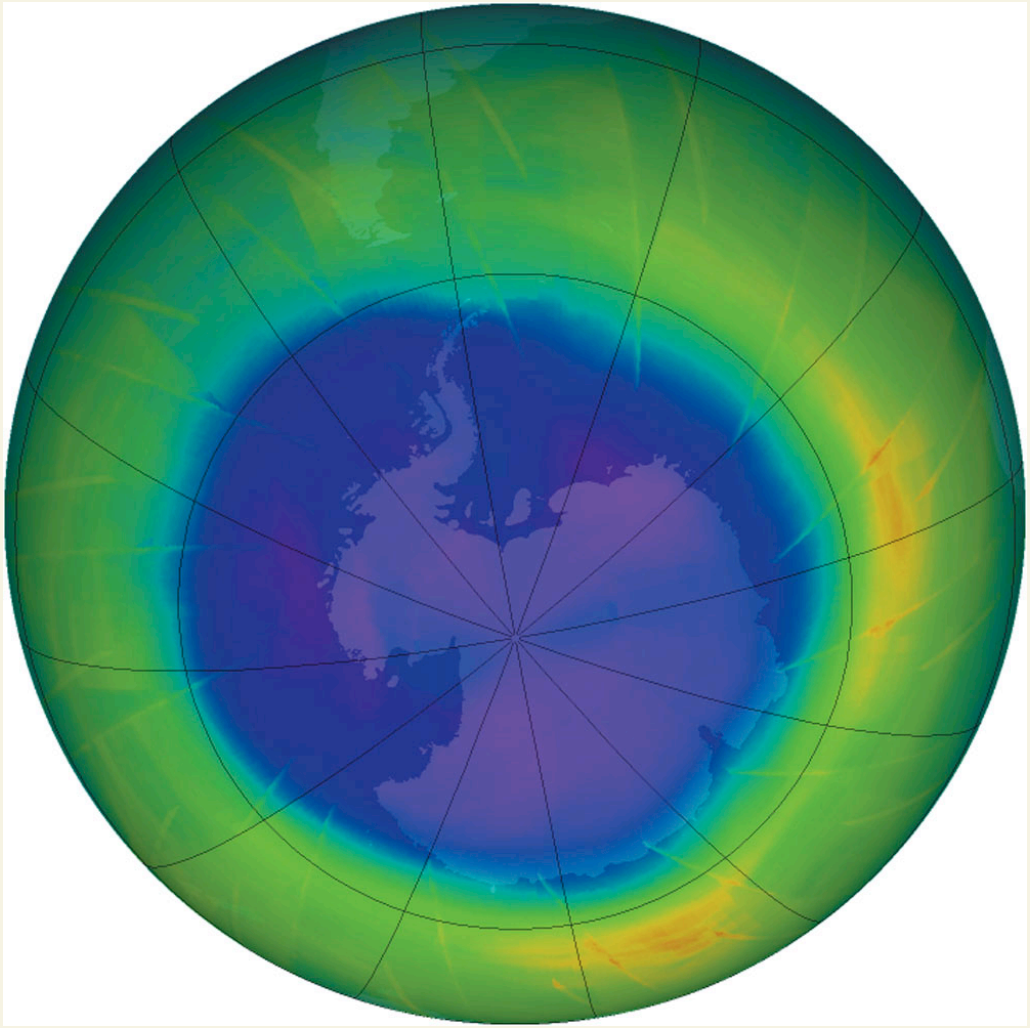


Fig. 19-21, p. 521

Individuals Matter: Rowland and Moline—A Scientific Story of Courage and Persistence

- Research
  - CFCs are persistent in the atmosphere
  - Rise into the stratosphere over 11-20 years
  - Break down under high-energy UV radiation
    - Halogens produced accelerate the breakdown of O_3 to O_2
  - Each CFC molecule can last 65-385 years

- 1988: Dupont stopped producing CFCs

- 1995: Nobel Prize in chemistry

Why Should We Worry about Ozone Depletion?

- Damaging UV-A and UV-B radiation
  - Increase eye cataracts and skin cancer
- Impair or destroy phytoplankton
  - Significance?

Natural Capital Degradation: Effects of Ozone Depletion

Natural Capital Degradation

Effects of Ozone Depletion

Human Health

- Worse sunburns
- More eye cataracts and skin cancers
- Immune system suppression

Food and Forests

- Reduced yields for some crops
- Reduced seafood supplies from reduced phytoplankton
- Decreased forest productivity for UV-sensitive tree species

Climate Change

- While in troposphere, CFCs act as greenhouse gases

Wildlife

- Increased eye cataracts in some species
- Decreased populations of aquatic species sensitive to UV radiation
- Reduced populations of surface phytoplankton
- Disrupted aquatic food webs from reduced phytoplankton

Air Pollution and Materials

- Increased acid deposition
- Increased photochemical smog
- Degradation of outdoor paints and plastics

Fig. 19-22, p. 522

What Can You Do? Reducing Exposure to UV Radiation

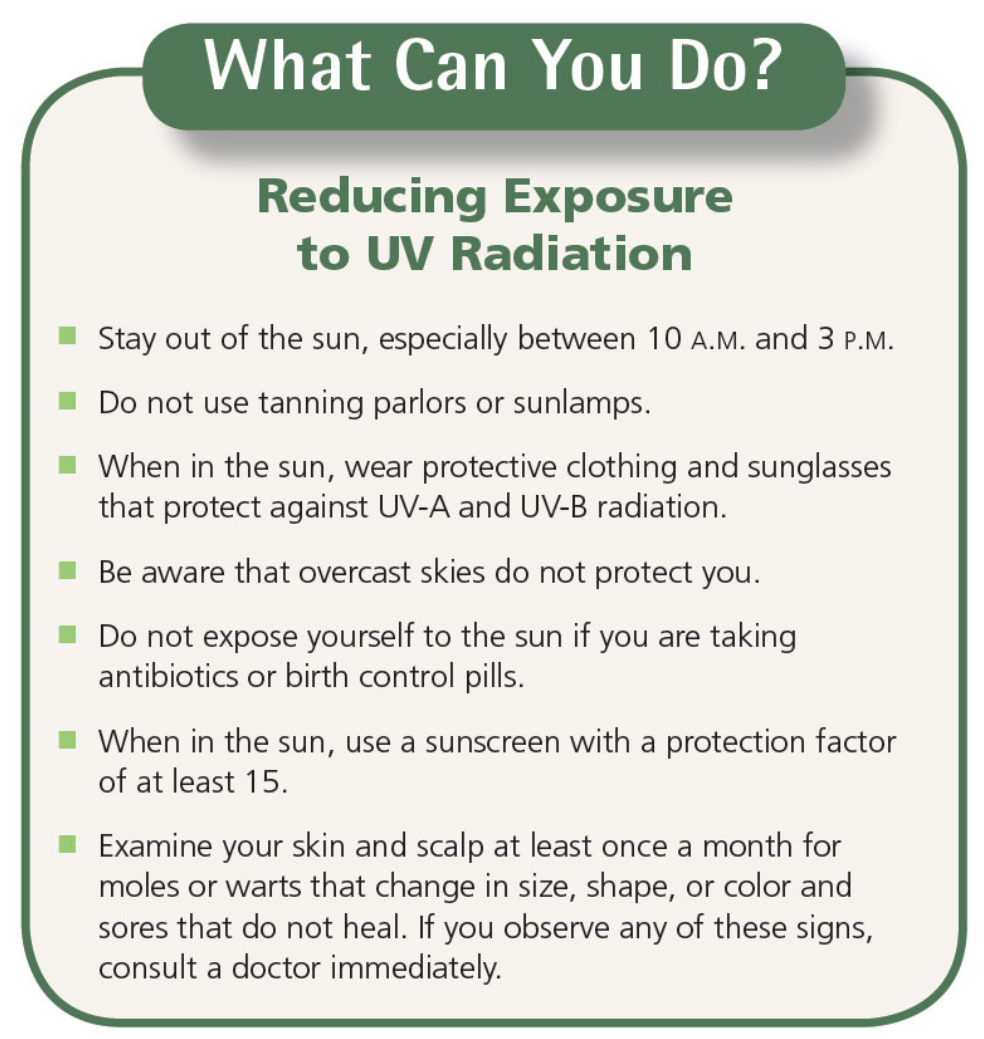


Fig. 19-23, p. 523

We Can Reverse Stratospheric Ozone Depletion (1)

- Stop producing all ozone-depleting chemicals
- 60–100 years of recovery of the O_3 layer
- 1987: Montreal Protocol
- 1992: Copenhagen Protocol
- Ozone protocols: prevention is the key

We Can Reverse Stratospheric Ozone Depletion (2)

- Substitutes for CFCs are available
- More are being developed
- HCFC-22
  - Substitute chemical
  - May still be causing ozone depletion
  - 2009: U.S. asks UN for mandatory reductions in HFC emissions through Montreal Protocol

Three Big Ideas

1. Considerable scientific evidence indicates that the earth's atmosphere is warming, mostly because of human activities, and that this is likely to lead to significant climate disruption during this century that could have severe and long-lasting harmful consequences.

Three Big Ideas

2. Reducing the projected harmful effects of rapid climate disruption during this century requires emergency action to increase energy efficiency, sharply reduce greenhouse gas emissions, rely more on renewable energy resources, and slow population growth.

3. We need to continue phasing out the use of chemicals that have reduced ozone levels in the stratosphere and allowed more harmful ultraviolet radiation to reach earth's surface.