

# Chapter 20

## Climate Change and Ozone Depletion



# Chapter Overview Questions

- How have the earth's temperature and climate changed in the past?
- How might the earth's temperature change in the future?
- What factors influence the earth's average temperature?
- What are some possible beneficial and harmful effects of a warmer earth?

# Chapter Overview Questions (cont'd)

- How can we slow projected increases in the earth's temperature or adapt to such changes?
- How have human activities depleted ozone in the stratosphere, and why should we care?

# Updates Online

The latest references for topics covered in this section can be found at the book companion website. Log in to the book's e-resources page at [www.thomsonedu.com](http://www.thomsonedu.com) to access InfoTrac articles.

- InfoTrac: Upset about offsets; Emissions offsets. *The Economist* (US), August 5, 2006 v380 i8489 p53US.
- InfoTrac: Geologist seeks answers in Valley's house-sized rocks. *Anchorage Daily News*, August 2, 2006.
- InfoTrac: Capital Pollution Solution? Jeff Goodell. *The New York Times Magazine*, July 30, 2006 p34(L).
- Union of Concerned Scientists: Human Fingerprints
- Science Daily: Deep-sea Sediments Could Safely Store Man-made Carbon Dioxide
- Discovery Channel: Global Warming

# Video: Kyoto Protocol

- This video clip is available in CNN Today Videos for Environmental Science, 2004, Volume VII. Instructors, contact your local sales representative to order this volume, while supplies last.

# Video: Melting Glaciers

- This video clip is available in CNN Today Videos for Environmental Science, 2004, Volume VII. Instructors, contact your local sales representative to order this volume, while supplies last.

# Video: Global Warming

- This video clip is available in CNN Today Videos for Environmental Science, 2004, Volume VII. Instructors, contact your local sales representative to order this volume, while supplies last.

# Core Case Study: Studying a Volcano to Understand Climate Change



- NASA scientist correctly predicted that the 1991 Philippines explosion would cool the average temperature of the earth by  $0.5\text{C}^{\circ}$  over a 15 month period and then return to normal by 1995.



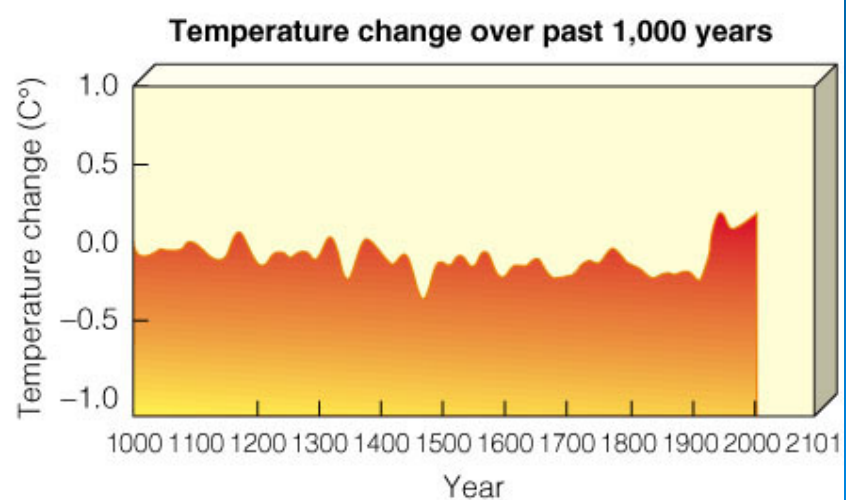
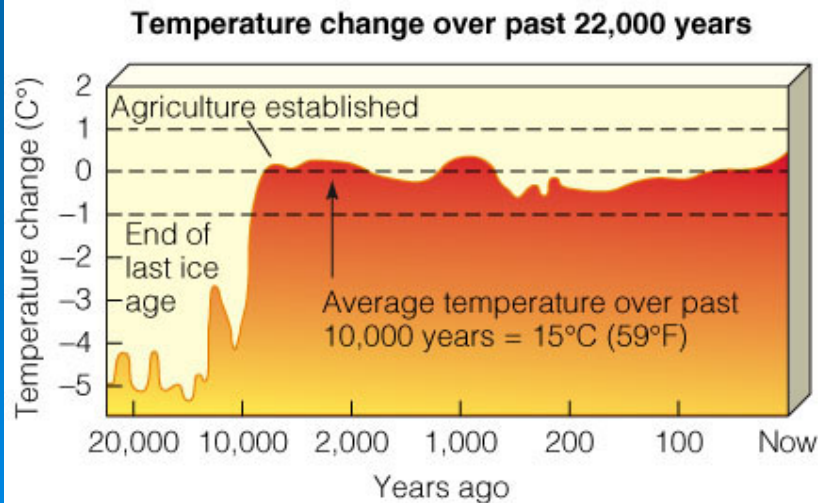
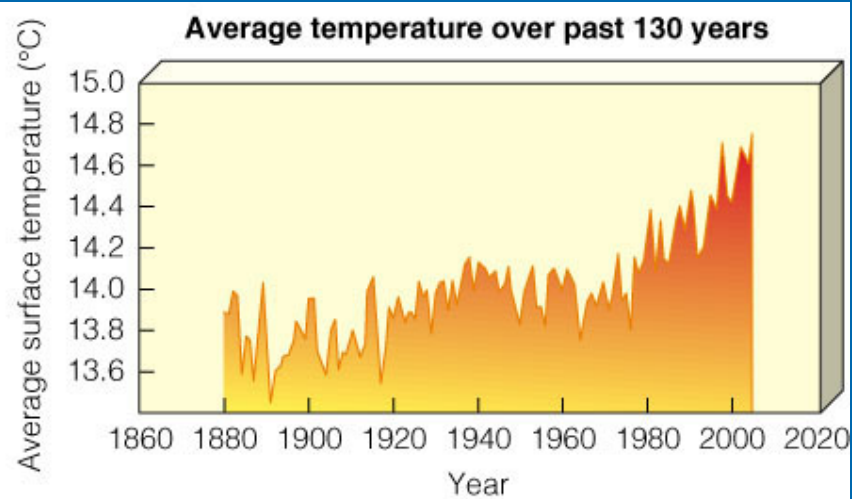
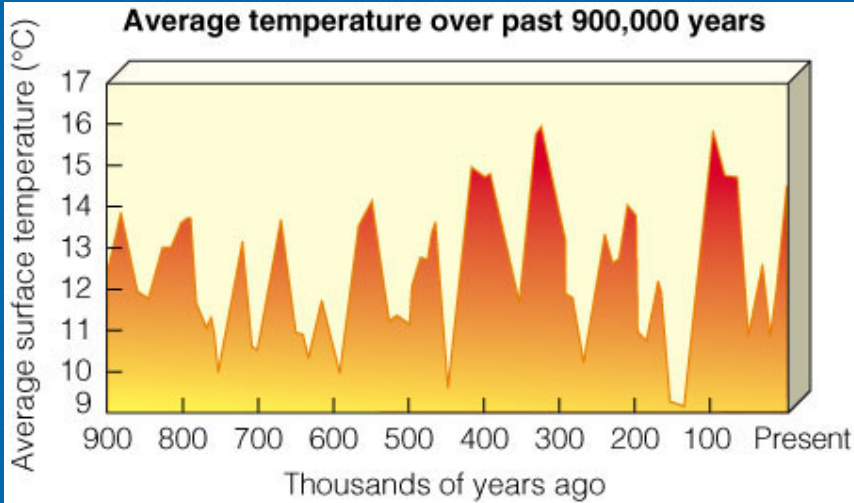
# Core Case Study: Studying a Volcano to Understand Climate Change

- The NASA model was correct.
  - The success convince scientists and policy makers that climate model projections should be taken seriously.
  - Other climate models have shown that global temperatures are likely to rise several degrees during this century.

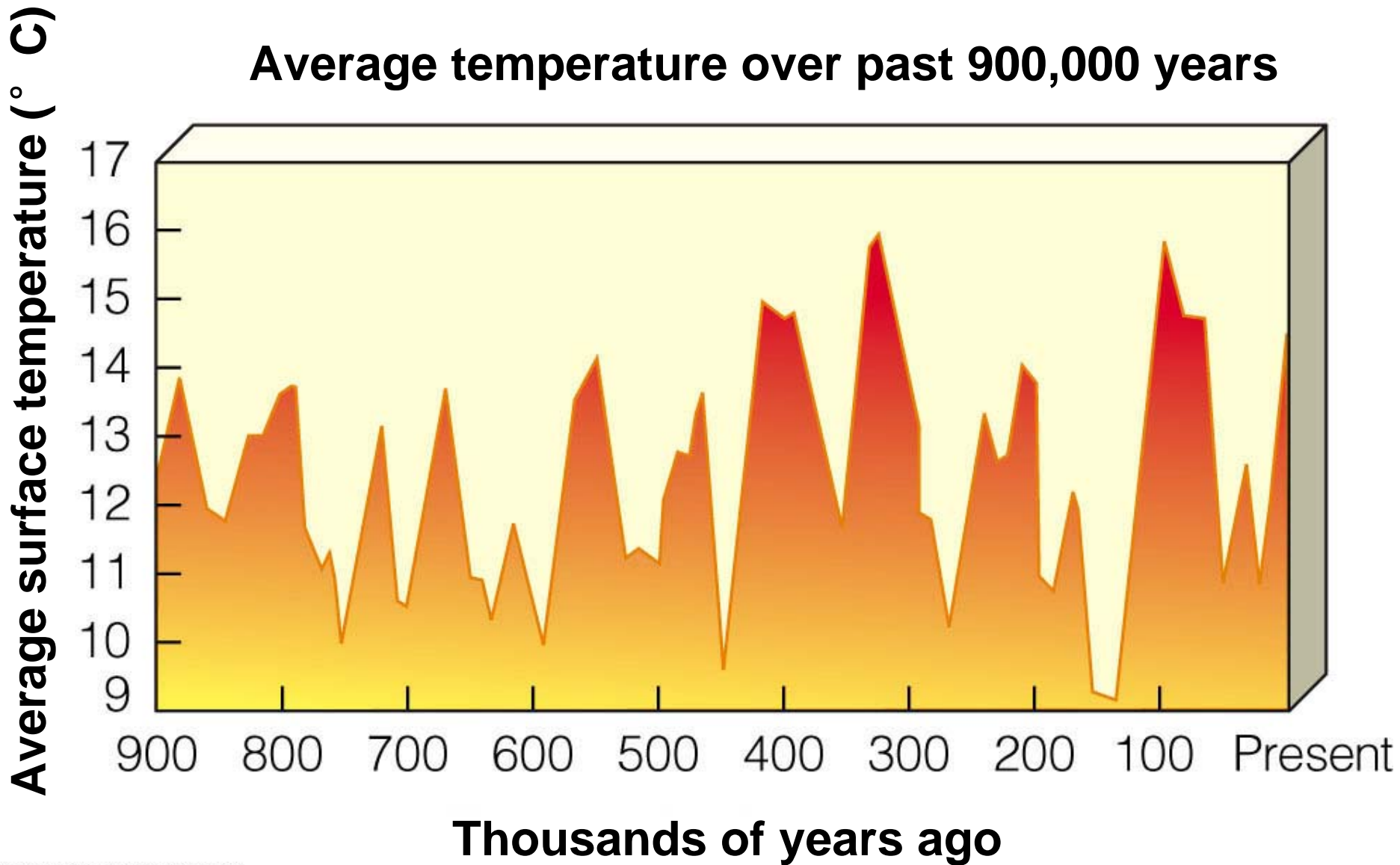
# PAST CLIMATE AND THE GREENHOUSE EFFECT

- Over the past 900,000 years, the troposphere has experienced prolonged periods of global cooling and global warming.
- For the past 1,000 years, temperatures have remained fairly stable but began to rise during the last century.

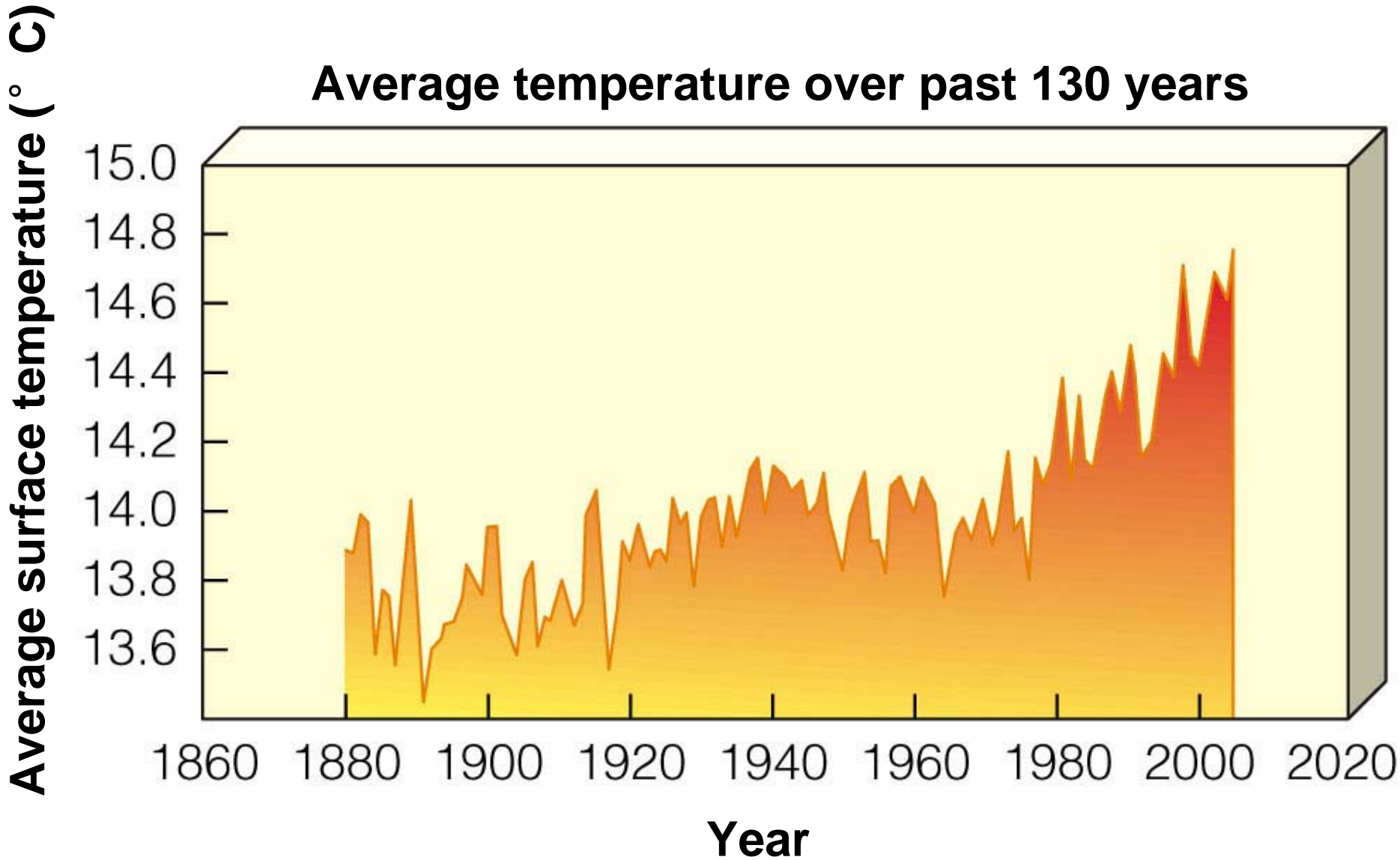
# PAST CLIMATE AND THE GREENHOUSE EFFECT



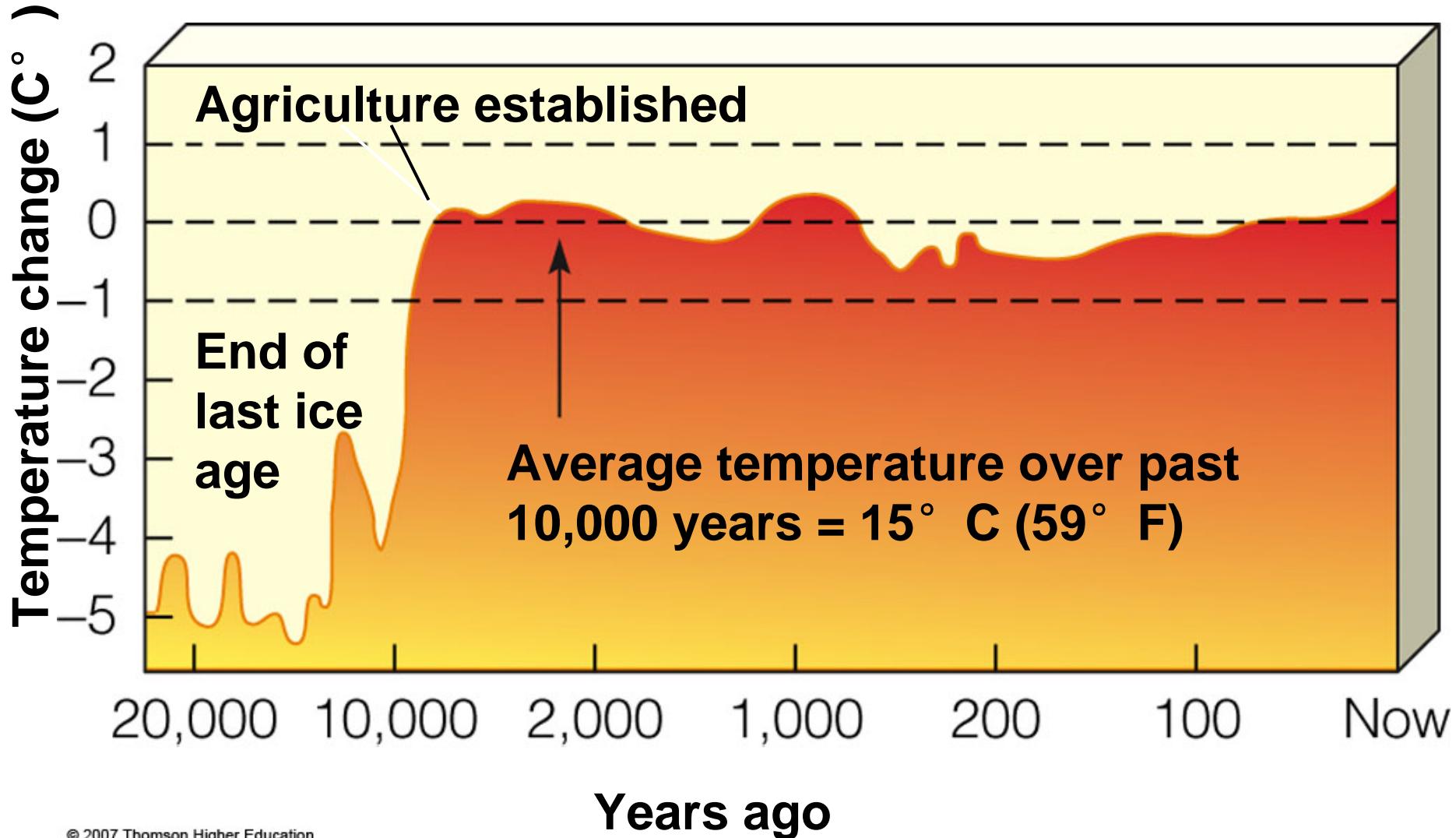
## Average temperature over past 900,000 years



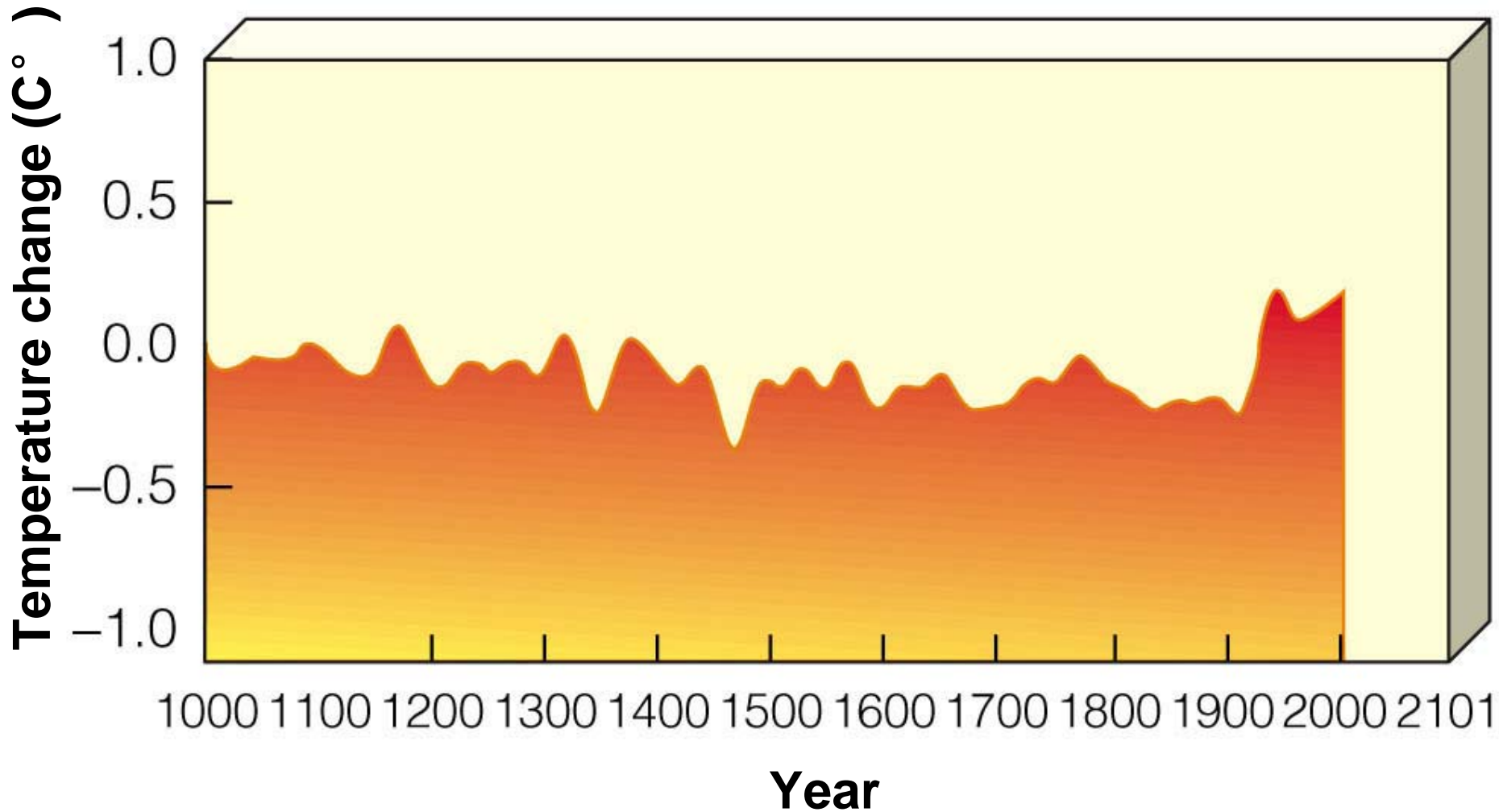
## Average temperature over past 130 years



# Temperature change over past 22,000 years



## Temperature change over past 1,000 years



# How Do We Know What Temperatures Were in the Past?



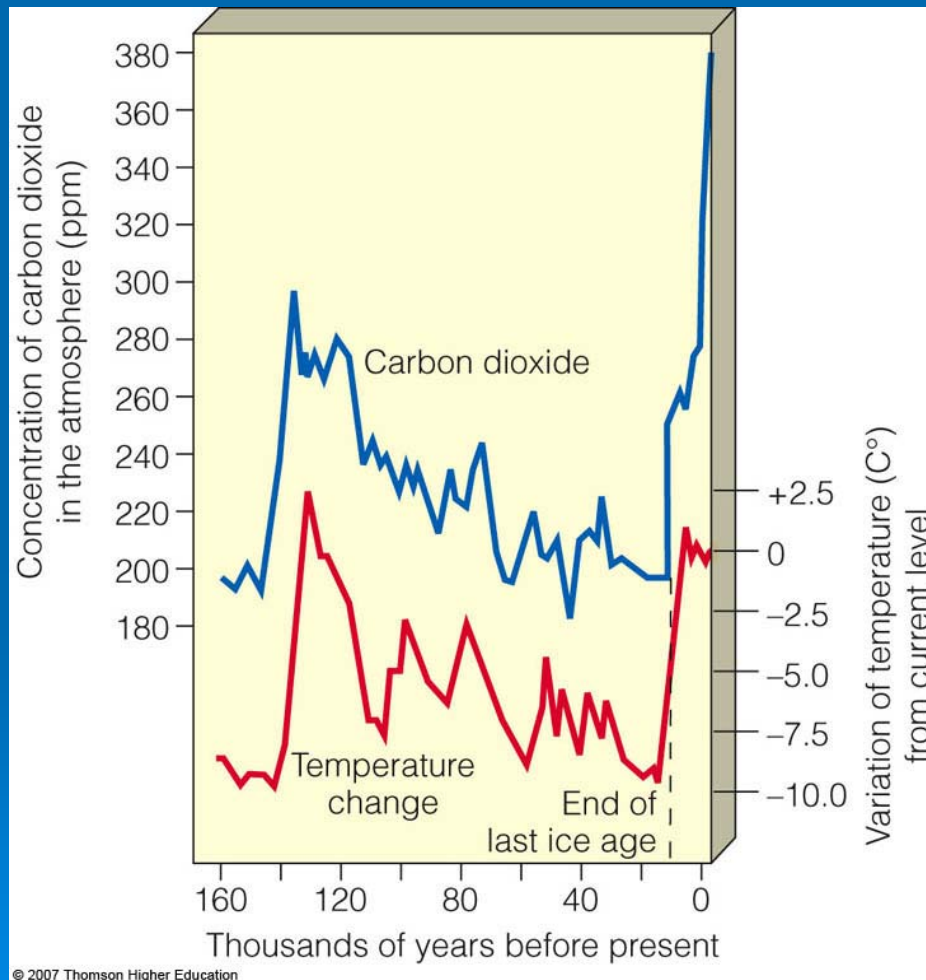
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- Scientists analyze tiny air bubbles trapped in ice cores learn about past:
  - *troposphere composition.*
  - *temperature trends.*
  - *greenhouse gas concentrations.*
  - *solar, snowfall, and forest fire activity.*

Figure 20-3



# How Do We Know What Temperatures Were in the Past?



- In 2005, an ice core showed that CO<sub>2</sub> levels in the troposphere are the highest they have been in 650,000 years.

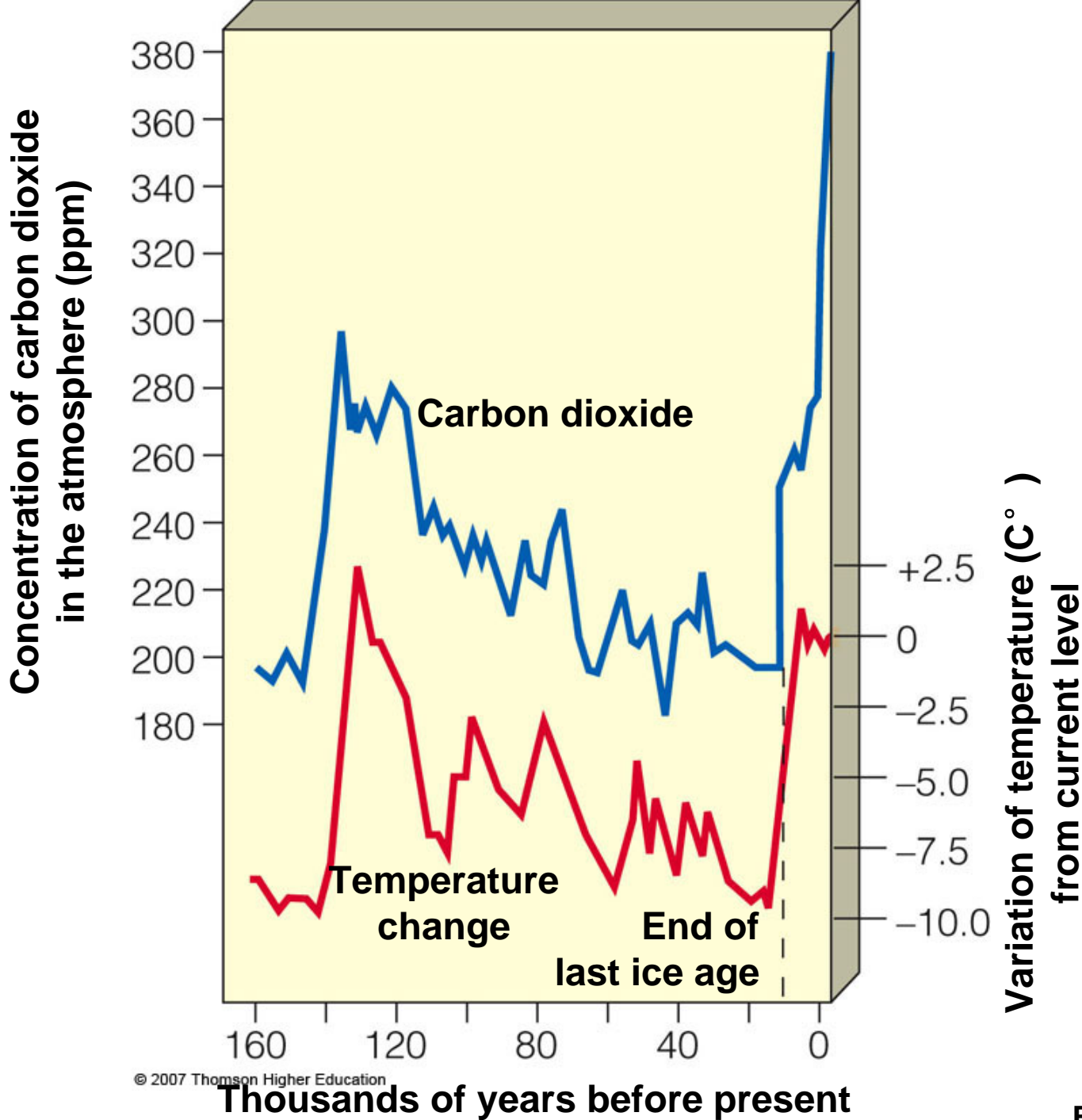


Fig. 20-4, p. 466

# The Natural Greenhouse Effect

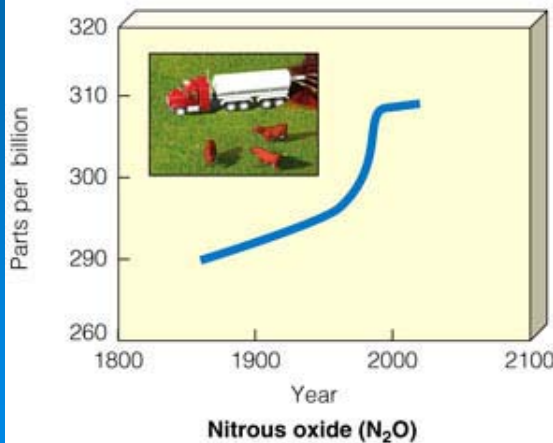
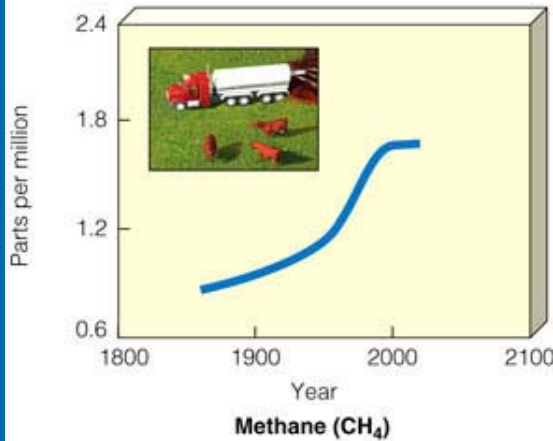
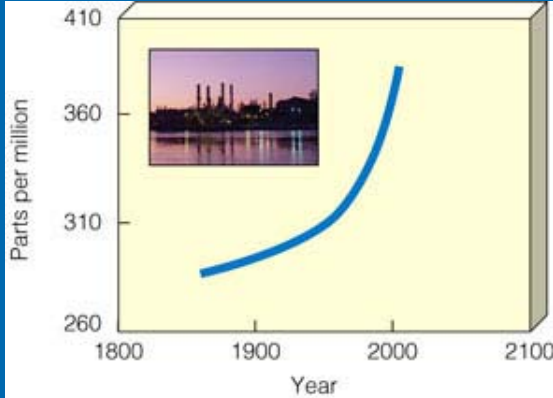
- Three major factors shape the earth's climate:
  - The sun.
  - Greenhouse effect that warms the earth's lower troposphere and surface because of the presence of **greenhouse gases**.
  - Oceans store CO<sub>2</sub> and heat, evaporate and receive water, move stored heat to other parts of the world.
  - Natural cooling process through water vapor in the troposphere (heat rises).

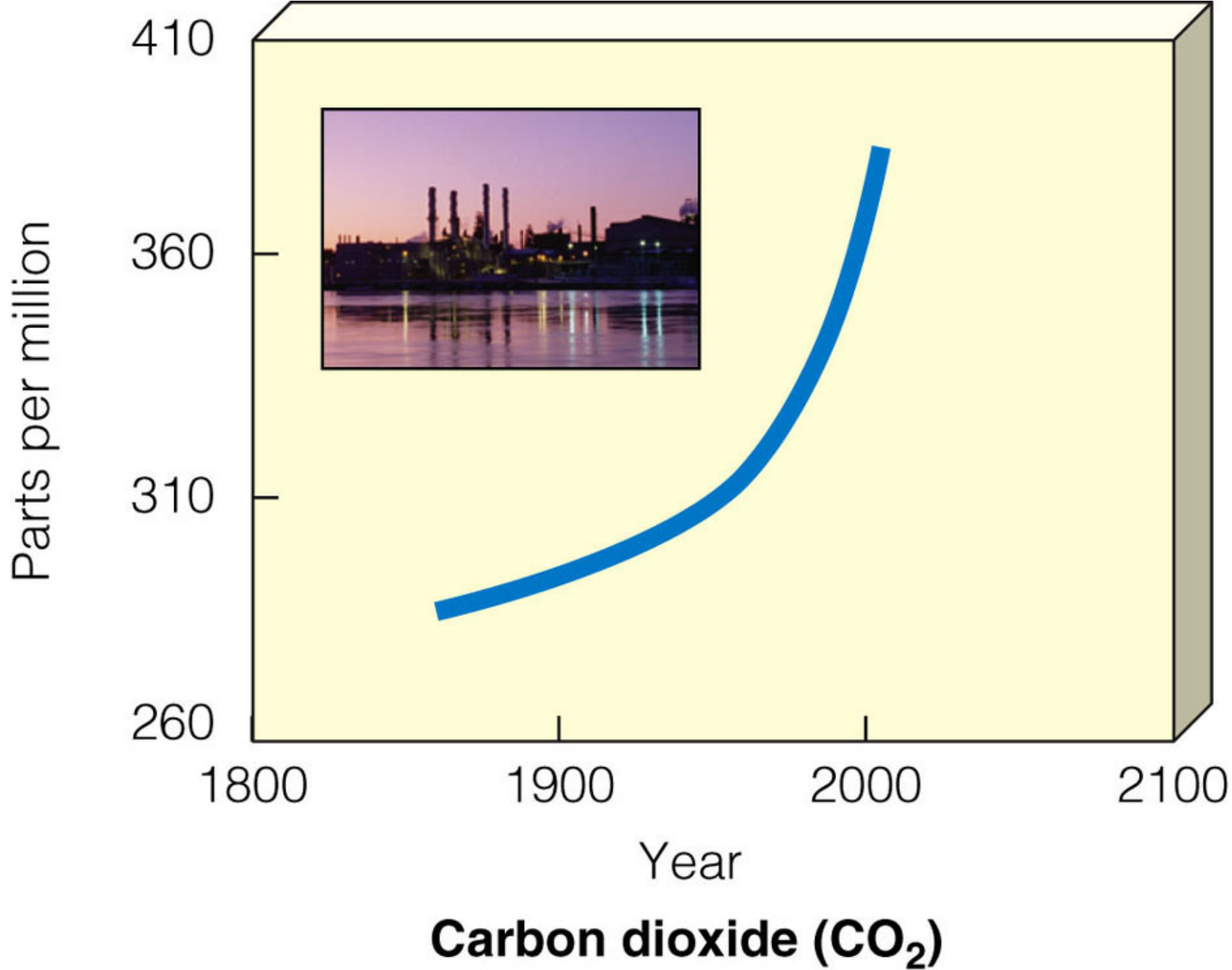
# Major Greenhouse Gases

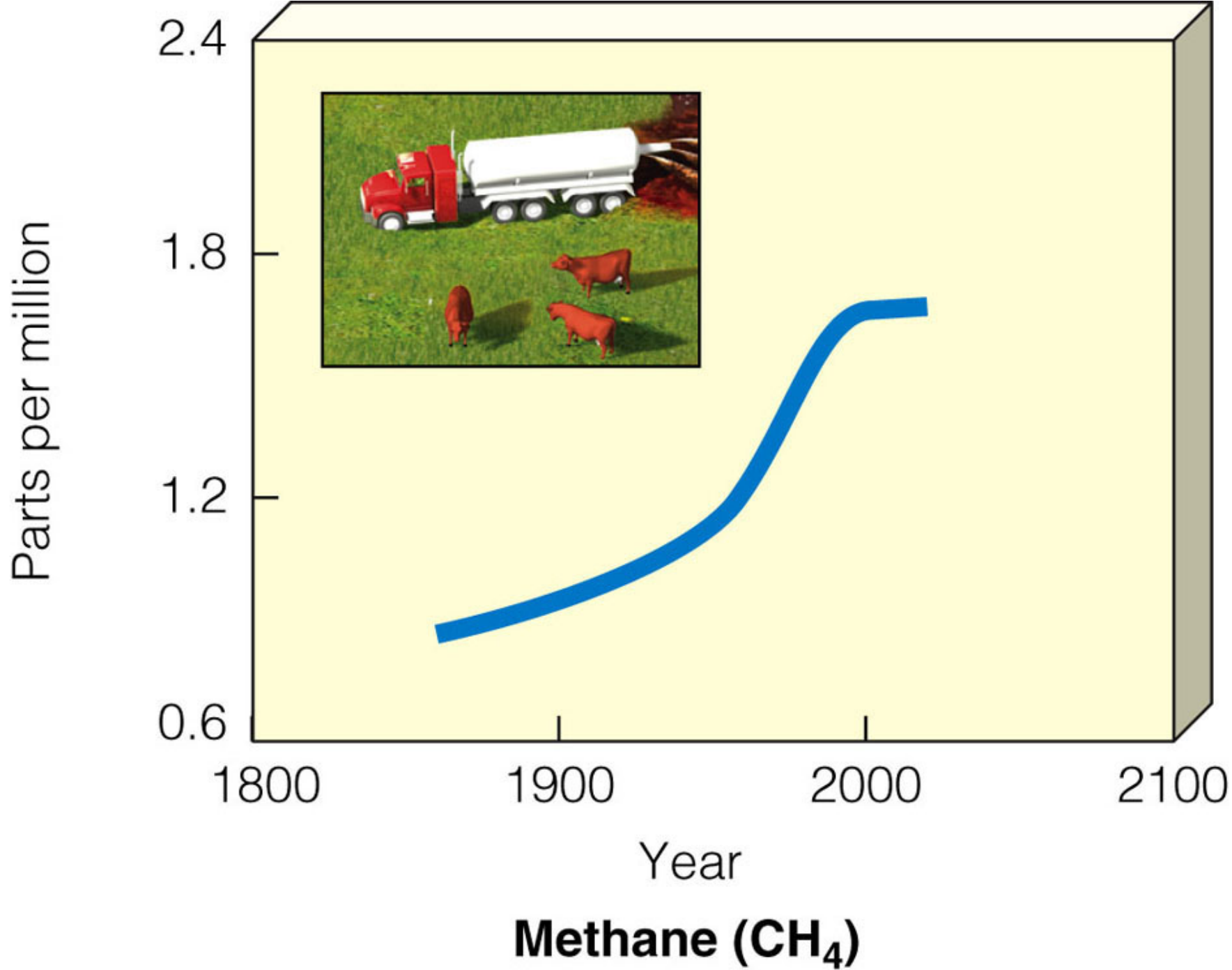
- The major greenhouse gases in the lower atmosphere are water vapor, carbon dioxide, methane, and nitrous oxide.
  - These gases have always been present in the earth's troposphere in varying concentrations.
  - Fluctuations in these gases, plus changes in solar output are the major factors causing the changes in tropospheric temperature over the past 400,000 years.

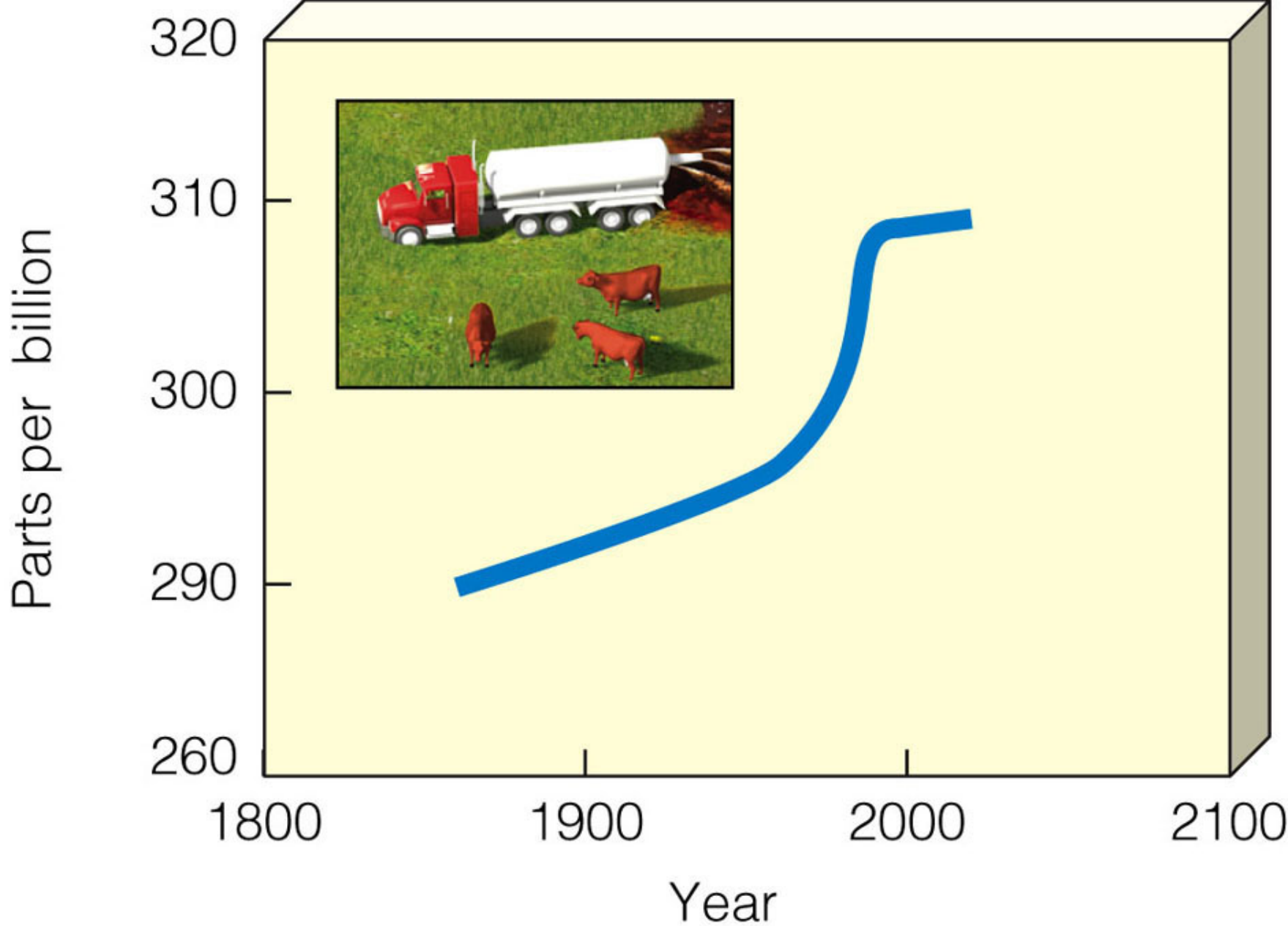
# Major Greenhouse Gases

- Increases in average concentrations of three greenhouse gases in the troposphere between 1860 and 2004, mostly due to fossil fuel burning, deforestation, and agriculture.









### Nitrous oxide (N<sub>2</sub>O)



# CLIMATE CHANGE AND HUMAN ACTIVITIES

- Evidence that the earth's troposphere is warming, mostly because of human actions:
  - The 20<sup>th</sup> century was the hottest century in the past 1000 years.
  - Since 1900, the earth's average tropospheric temperature has risen  $0.6\text{ C}^{\circ}$  .
  - Over the past 50 years, Arctic temperatures have risen almost twice as fast as those in the rest of the world.
  - Glaciers and floating sea ice are melting and shrinking at increasing rates.

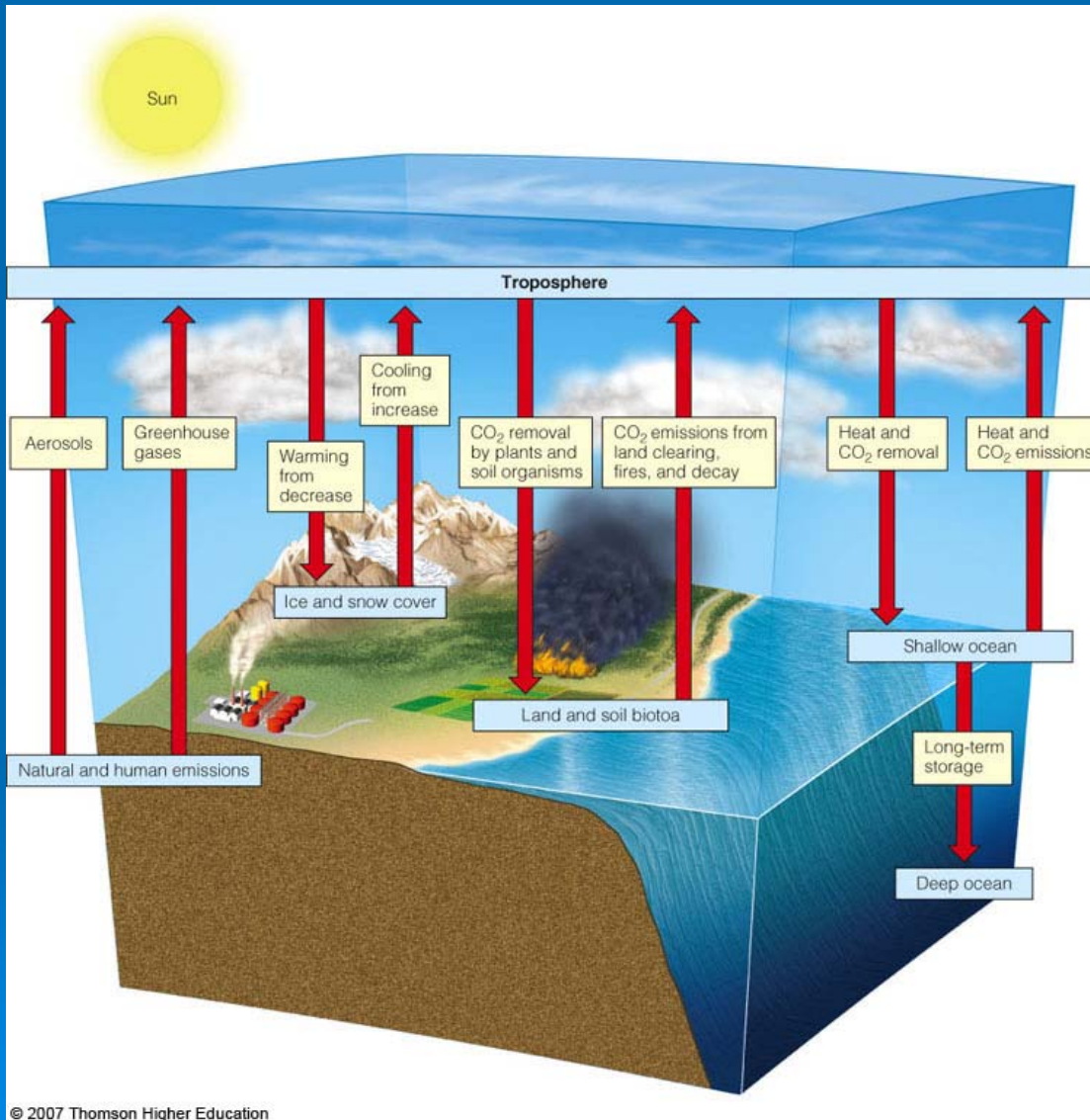
# CLIMATE CHANGE AND HUMAN ACTIVITIES

- Warmer temperatures in Alaska, Russia, and the Arctic are melting permafrost releasing more CO<sub>2</sub> and CH<sub>4</sub> into the troposphere.
- During the last century, the world's sea level rose by 10-20 cm, mostly due to runoff from melting and land-based ice and the expansion of ocean water as temperatures rise.

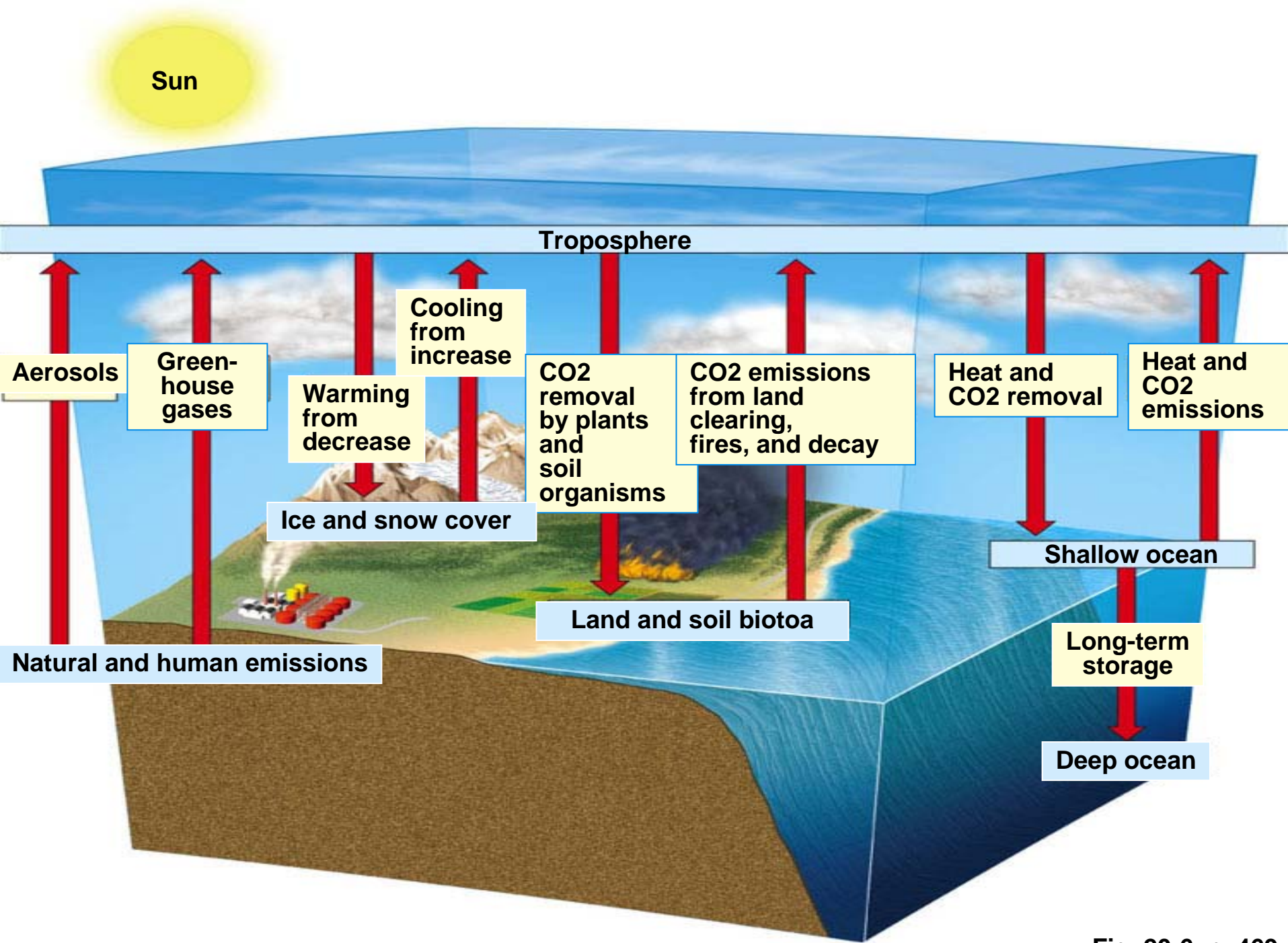
# The Scientific Consensus about Future Climate Change

- There is strong evidence that human activities will play an important role in changing the earth's climate during this century.
  - Coupled General Circulation Models (CGCMs) couple, or combine, the effects of the atmosphere and the oceans on climate.

# CGCM of the Earth's Climate

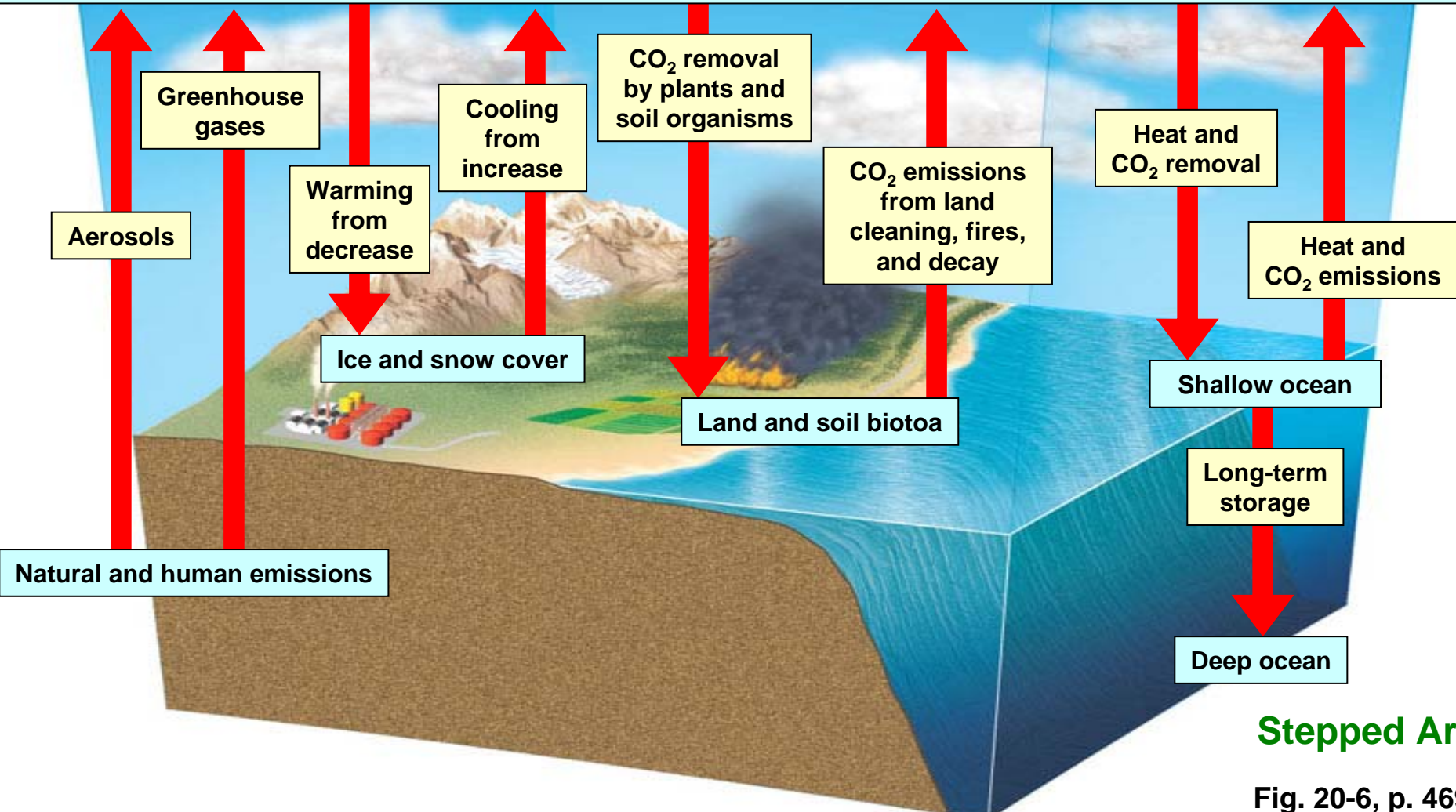


- Simplified model of major processes that interact to determine the average temperature and greenhouse gas content of the troposphere.



Sun

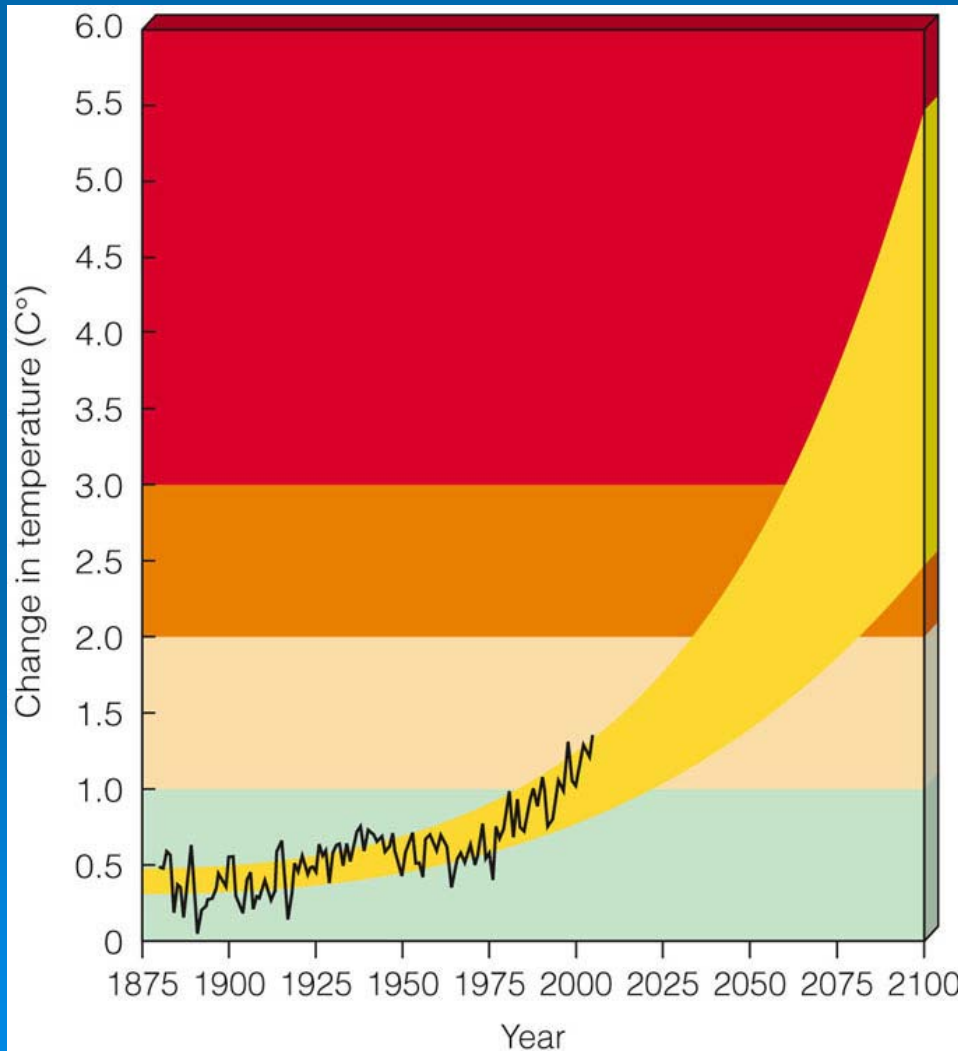
Troposphere



Stepped Art

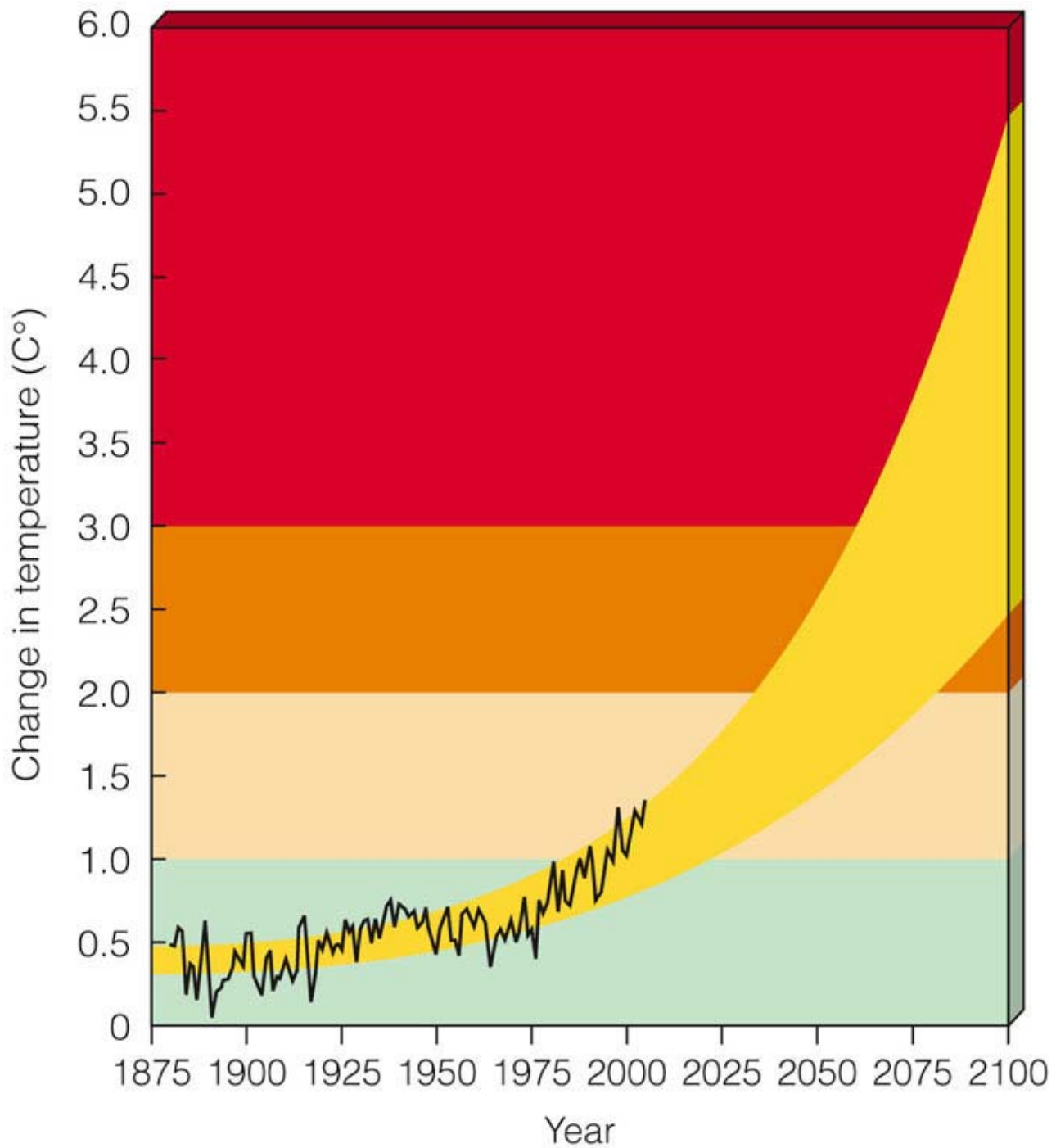
Fig. 20-6, p. 469

# The Scientific Consensus about Future Climate Change



- Measured and projected changes in the average temperature of the atmosphere.

Figure 20-7





# How Would You Vote?

To conduct an instant in-class survey using a classroom response system, access “JoinIn Clicker Content” from the PowerLecture main menu for Living in the Environment.

- Do you believe that we will experience significant global warming during this century?
  - a. No. Claims for significant global warming during this century are based on unreliable climate models.
  - b. Yes. Even with the uncertainties, the models still indicate significant global warming during this century.

# Why Should We Be Concerned about a Warmer Earth?

- A rapid increase in the temperature of the troposphere during this century would give us little time to deal with its harmful effects.
- As a prevention strategy scientists urge to cut global CO<sub>2</sub> emissions in half over the next 50 years.
  - This could prevent changes in the earth's climate system that would last for tens of thousands of years.

# FACTORS AFFECTING THE EARTH'S TEMPERATURE

- Some factors can amplify (positive feedback) and some can dampen (negative feedback) projected global warming.
- There is uncertainty about how much CO<sub>2</sub> and heat the oceans can remove from the troposphere and how long the heat and CO<sub>2</sub> might remain there.
- Warmer temperatures create more clouds that could warm or cool the troposphere.

# Effects of Higher CO<sub>2</sub> Levels on Photosynthesis

- Increased CO<sub>2</sub> in the troposphere can increase plant photosynthesis (PS) but:
  - The increase in PS would slow as the plants reach maturity.
  - Carbon stored by the plants would be returned to the atmosphere as CO<sub>2</sub> when the plants die.
  - Increased PS decreases the amount of carbon stored in the soil.
  - Tree growth may temporarily slow CO<sub>2</sub> emissions in the S. Hemisphere but is likely to increase CO<sub>2</sub> emissions in the N. Hemisphere.

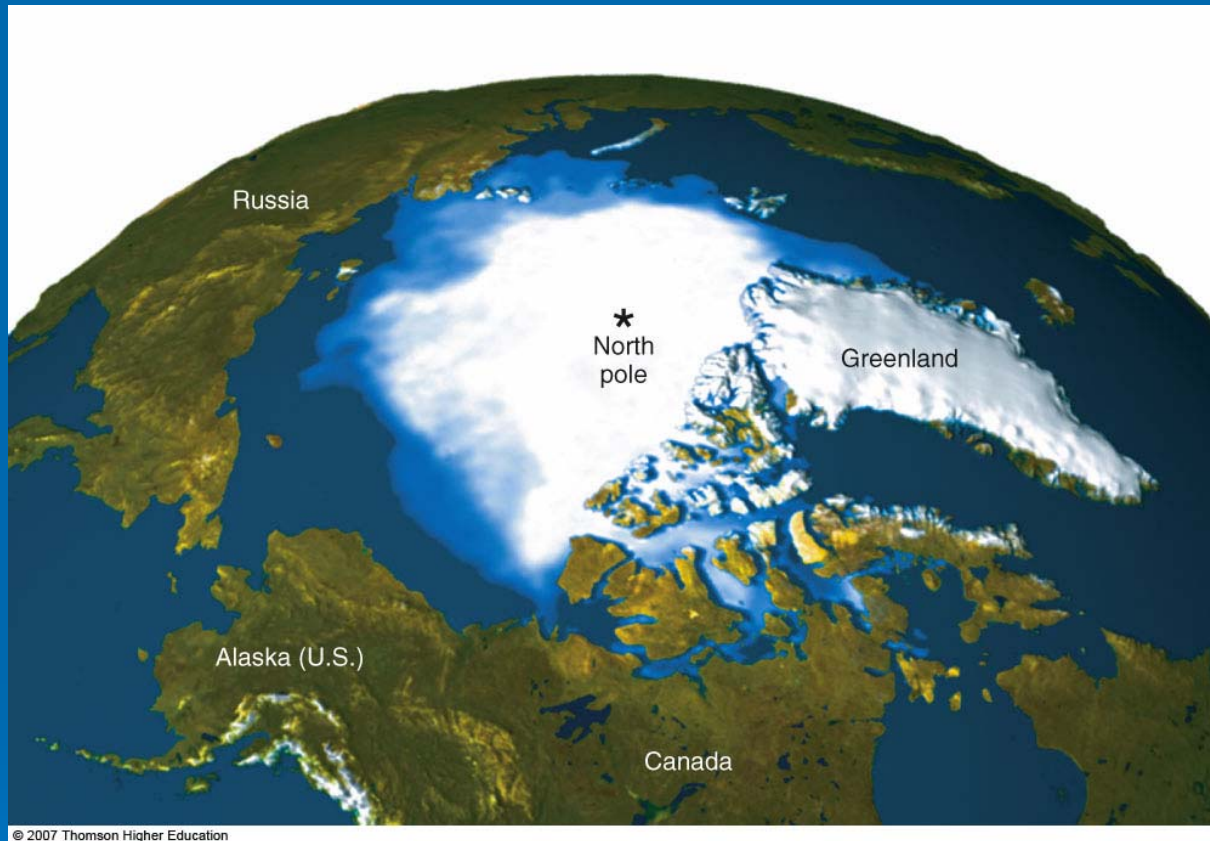
# FACTORS AFFECTING THE EARTH'S TEMPERATURE

- Aerosol and soot pollutants produced by human activities can warm or cool the atmosphere, but such effects will decrease with any decline in outdoor air pollution.
- Warmer air can release methane gas stored in bogs, wetlands, and tundra soils and accelerate global warming.

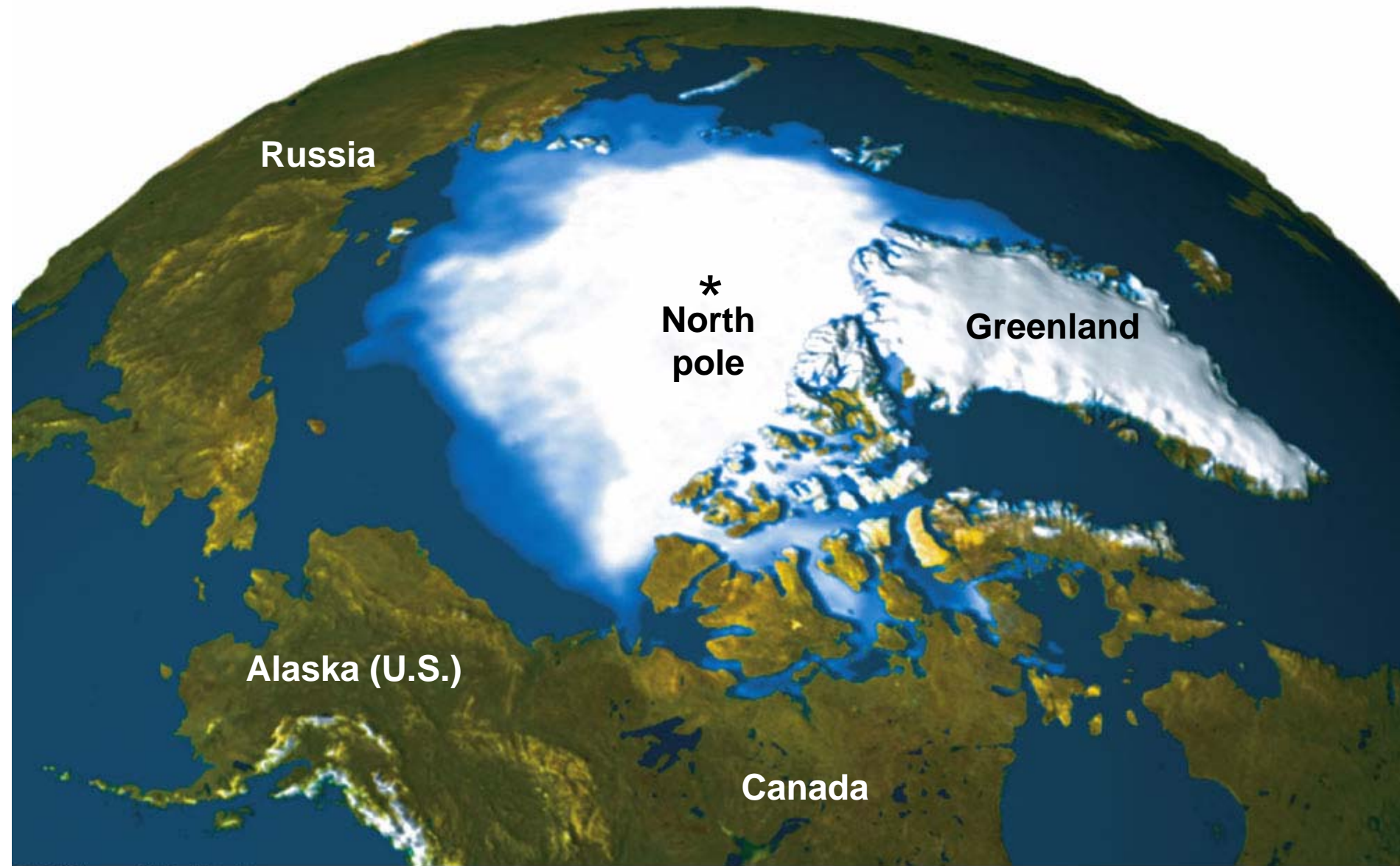
# EFFECTS OF GLOBAL WARMING

- A warmer climate would have beneficial and harmful effects but poor nations in the tropics would suffer the most.
- Some of the world's floating ice and land-based glaciers are slowly melting and are helping warm the troposphere by reflecting less sunlight back into space.

# EFFECTS OF GLOBAL WARMING



- Between 1979 and 2005, average Arctic sea ice dropped 20% (as shown in blue hues above).



Russia

\*  
North  
pole

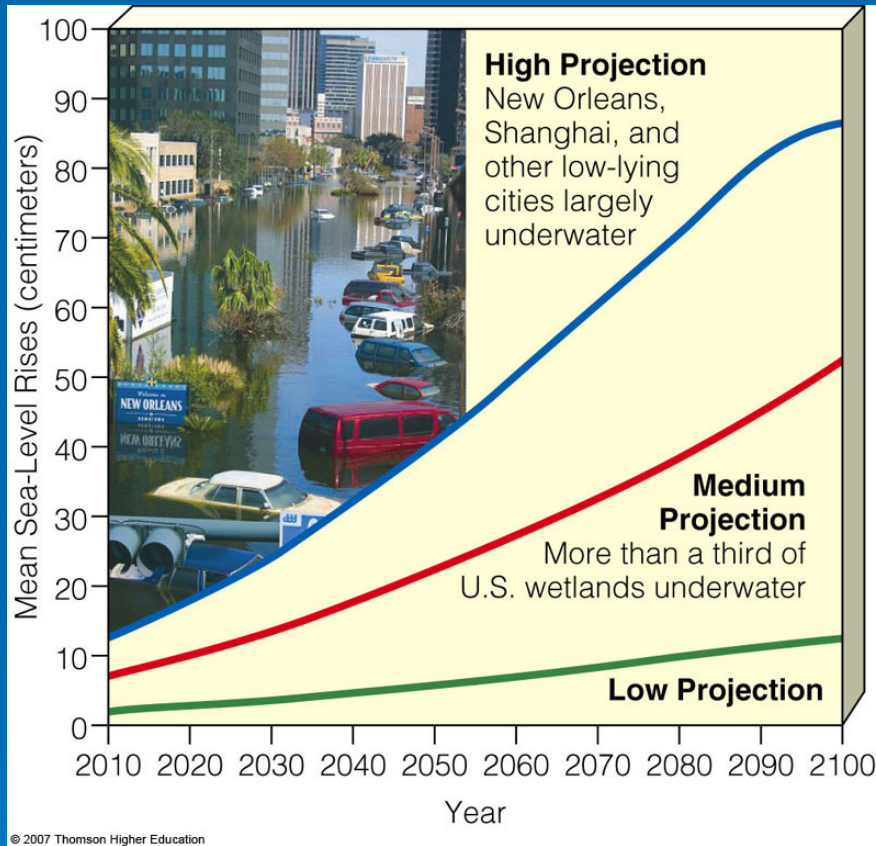
Greenland

Alaska (U.S.)

Canada



# Rising Sea Levels



- During this century rising seas levels are projected to flood low-lying urban areas, coastal estuaries, wetlands, coral reefs, and barrier islands and beaches.

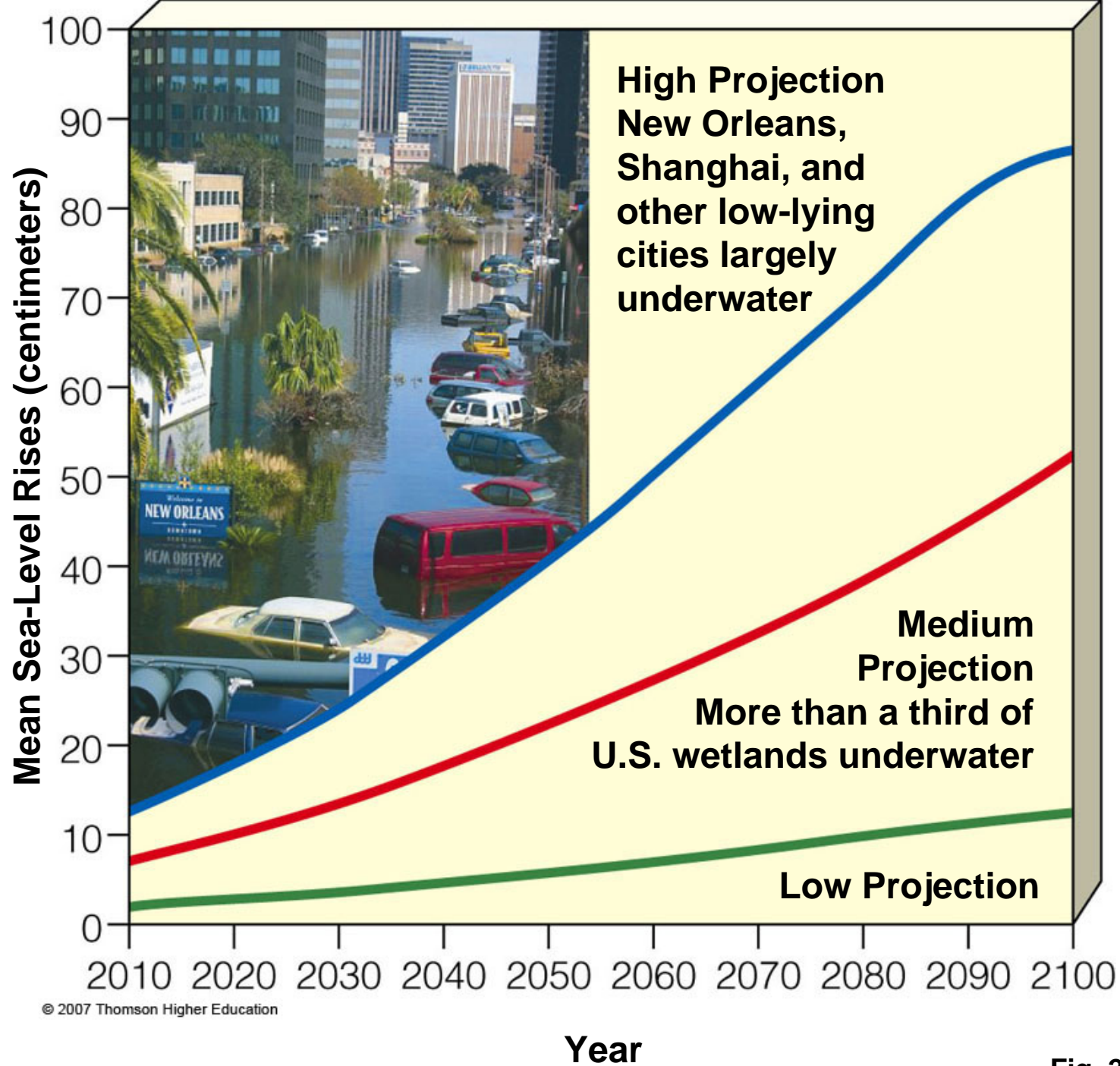
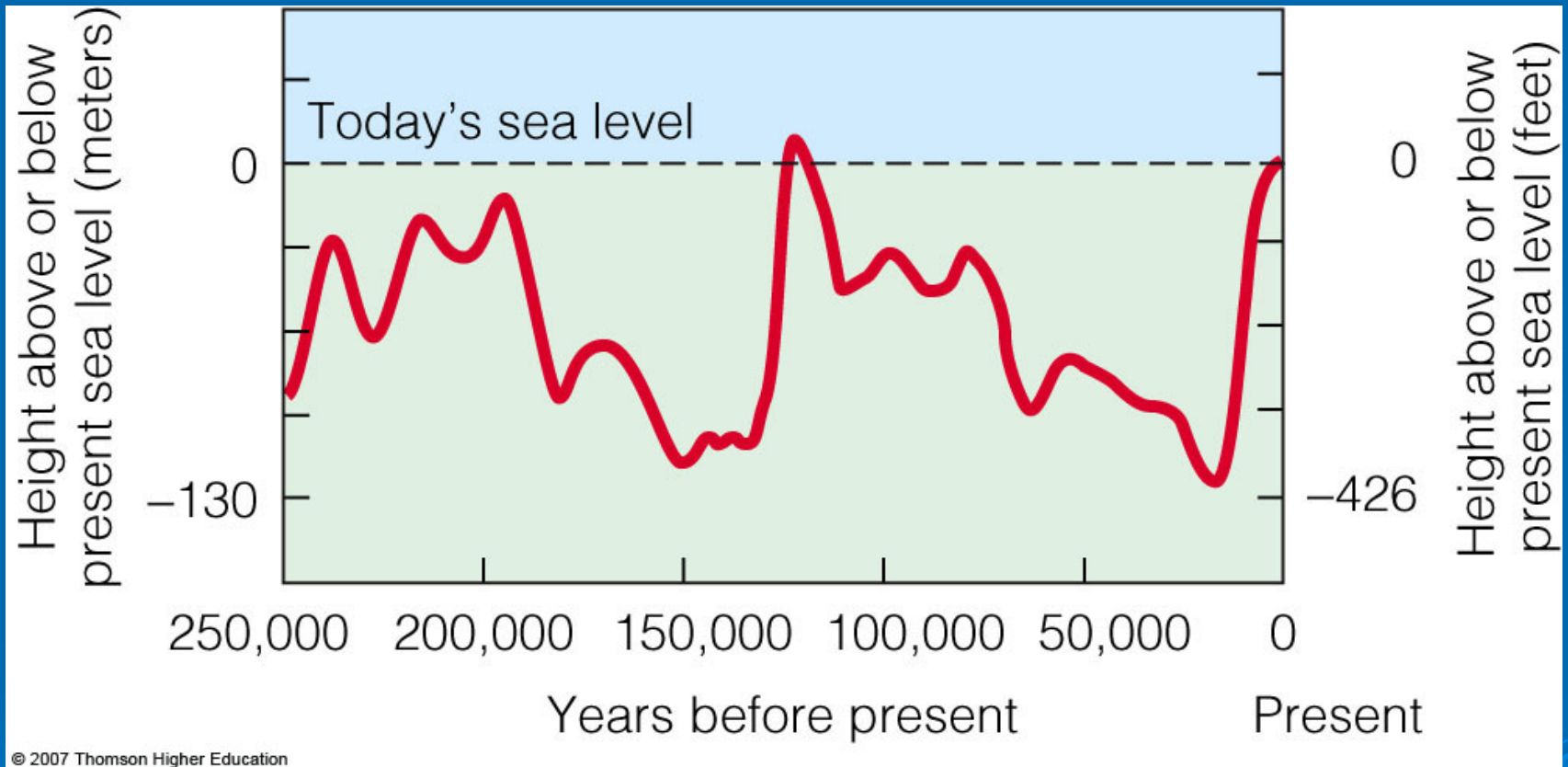
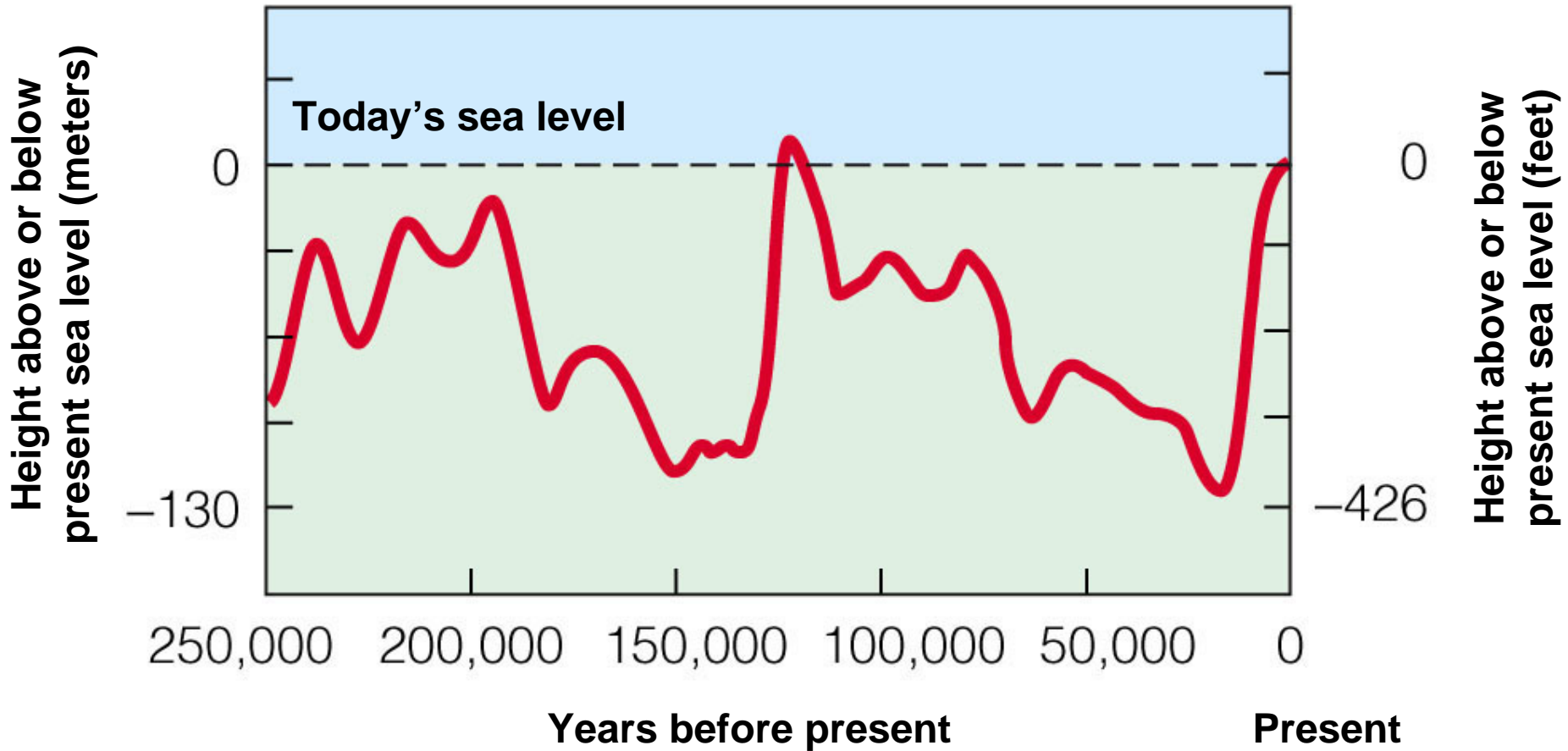


Fig. 20-10, p. 475

# Rising Sea Levels



- Changes in average sea level over the past 250,000 years based on data from ocean cores.



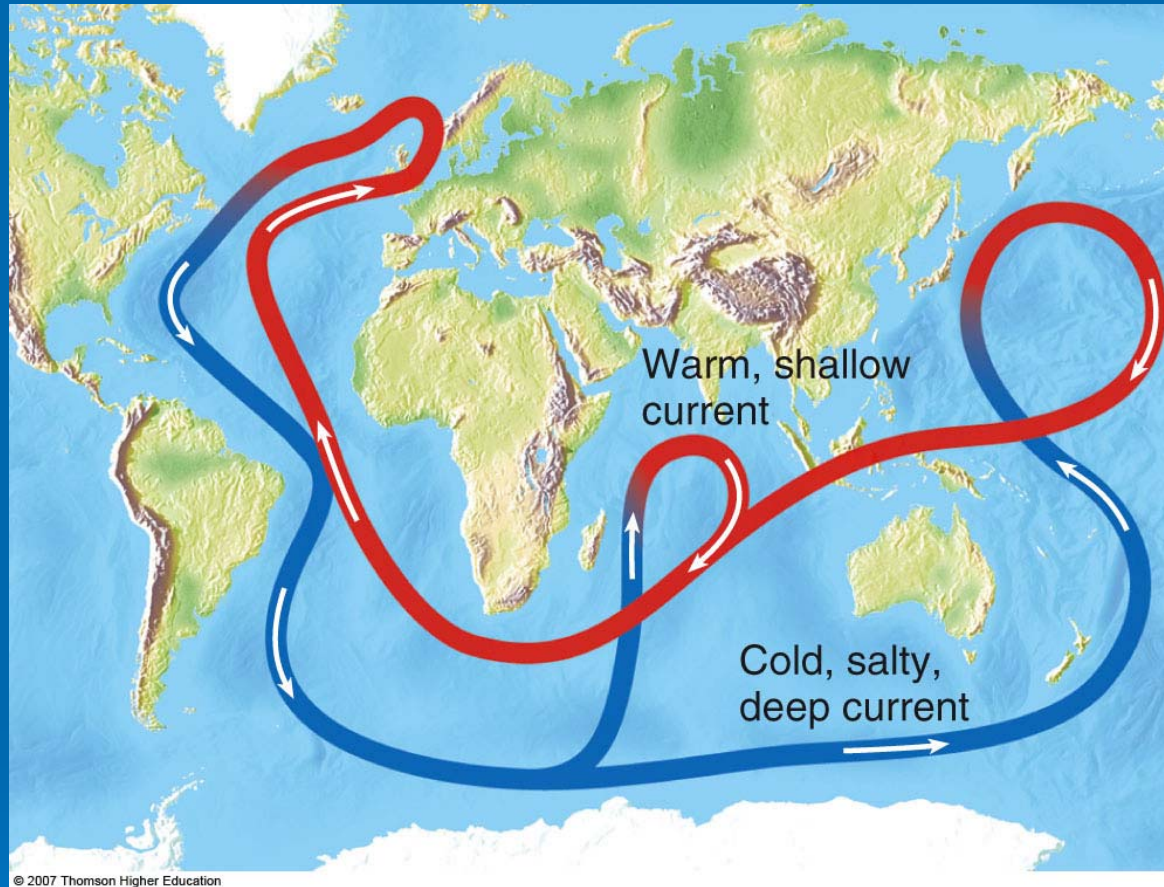
# Rising Sea Levels



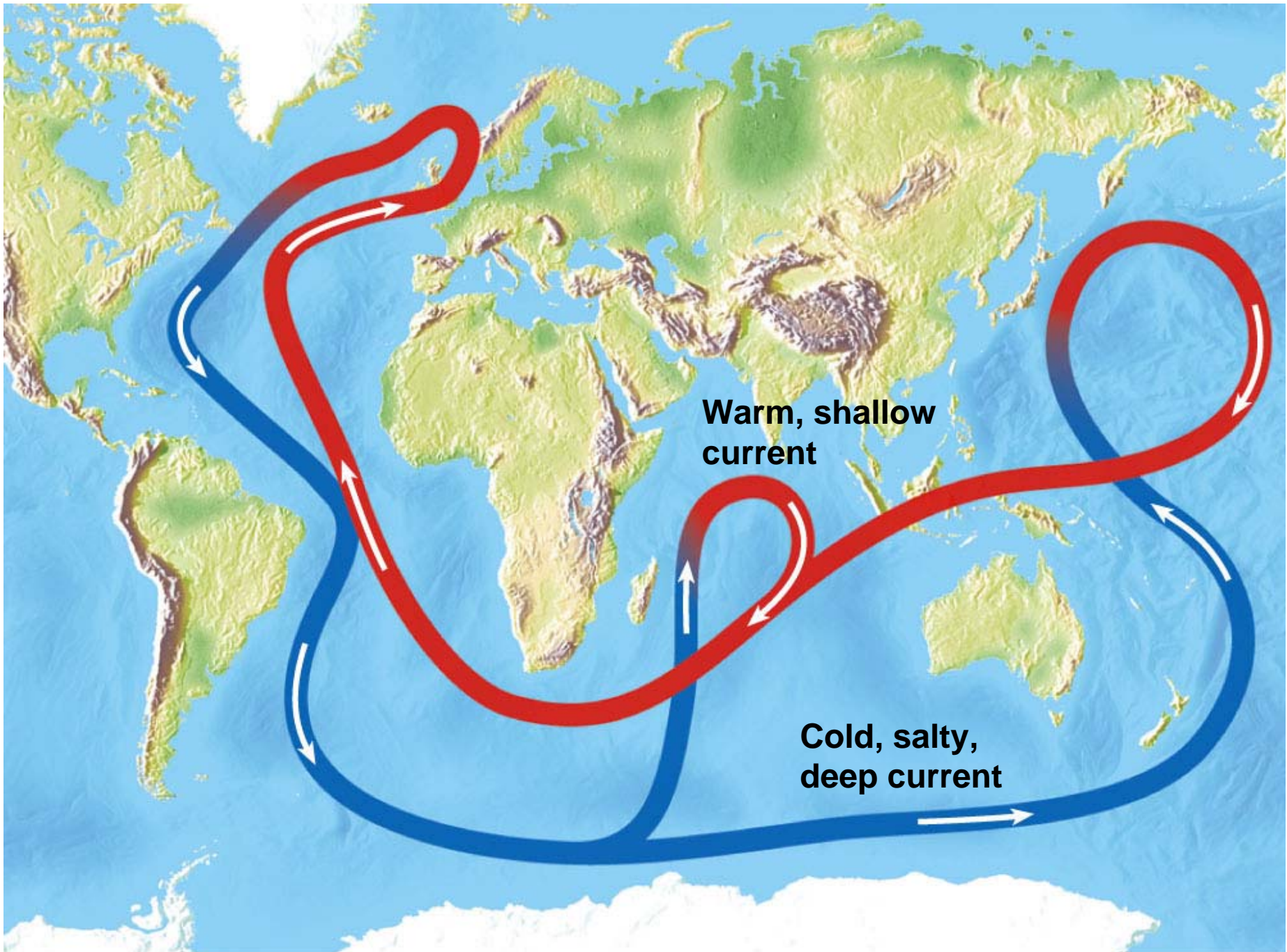
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- If seas levels rise by 9-88cm during this century, most of the Maldives islands and their coral reefs will be flooded.

# Changing Ocean Currents



- Global warming could alter ocean currents and cause both excessive warming and severe cooling.

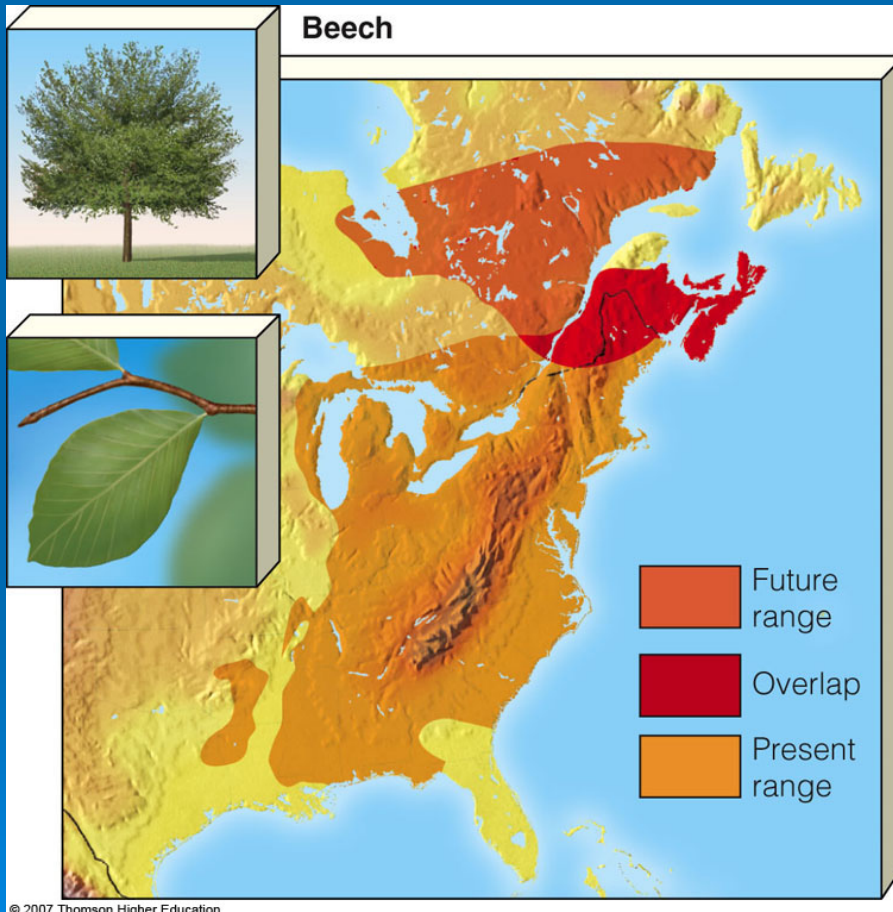


# EFFECTS OF GLOBAL WARMING

- A warmer troposphere can decrease the ability of the ocean to remove and store CO<sub>2</sub> by decreasing the nutrient supply for phytoplankton and increasing the acidity of ocean water.
- Global warming will lead to prolonged heat waves and droughts in some areas and prolonged heavy rains and increased flooding in other areas.

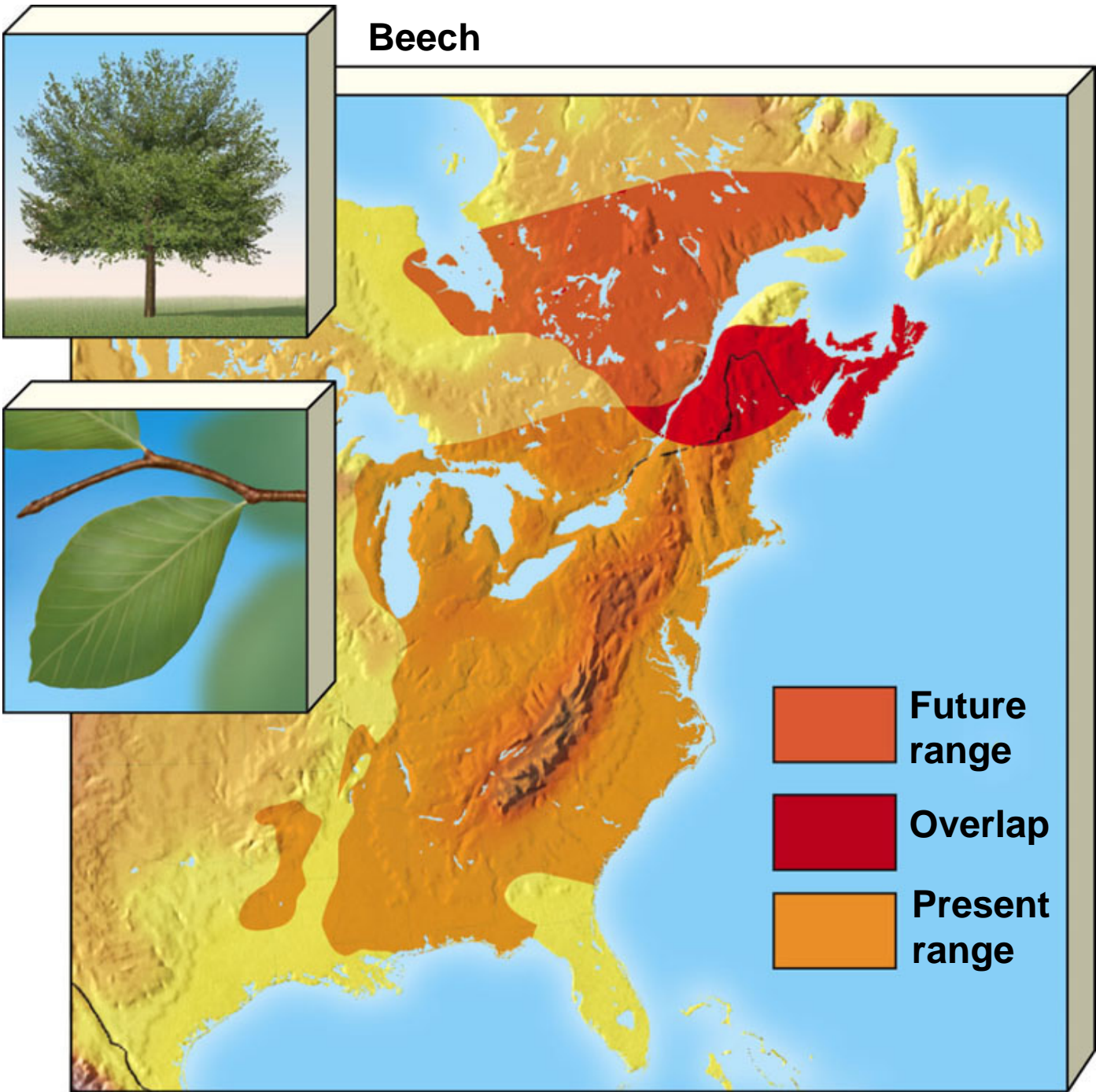


# Effects on Biodiversity: Winners and Losers



- Possible effects of global warming on the geographic range of beech trees based on ecological evidence and computer models.

# Beech



# EFFECTS OF GLOBAL WARMING

- In a warmer world, agricultural productivity may increase in some areas and decrease in others.
- Crop and fish production in some areas could be reduced by rising sea levels that would flood river deltas.
- Global warming will increase deaths from:
  - Heat and disruption of food supply.
  - Spread of tropical diseases to temperate regions.
  - Increase the number of environmental refugees.

# DEALING WITH GLOBAL WARMING

- Climate change is such a difficult problem to deal with because:
  - The problem is global.
  - The effects will last a long time.
  - The problem is a long-term political issue.
  - The harmful and beneficial impacts of climate change are not spread evenly.
  - Many actions that might reduce the threat are controversial because they can impact economies and lifestyles.

# DEALING WITH GLOBAL WARMING

- Two ways to deal with global warming:
  - **Mitigation** that reduces greenhouse gas emissions.
  - **Adaptation**, where we recognize that some warming is unavoidable and devise strategies to reduce its harmful effects.



# How Would You Vote?

To conduct an instant in-class survey using a classroom response system, access “JoinIn Clicker Content” from the PowerLecture main menu for Living in the Environment.

- Should we take serious action now to help slow global warming?
  - a. No. We should not waste money until we can develop strategies based on sound data.
  - b. Yes. The situation is serious and calls for a no-regrets strategy.

## Solutions

### Global Warming

#### Prevention

#### Cleanup

**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**

**Limit urban sprawl**

**Reduce poverty**

**Slow population growth**



**Remove CO<sub>2</sub> from smoke stack and vehicle emissions**

**Store (sequester) CO<sub>2</sub> by planting trees**

**Sequester CO<sub>2</sub> deep underground**

**Sequester CO<sub>2</sub> in soil by using no-till cultivation and taking <sup>L</sup> cropland out of production**

**Sequester CO<sub>2</sub> in the deep ocean**

**Repair leaky natural gas pipelines and facilities**

**Use animal feeds that reduce CH<sub>4</sub> emissions by <sup>L</sup> belching cows**

# Solutions: Reducing the Threat

- We can improve energy efficiency, rely more on carbon-free renewable energy resources, and find ways to keep much of the CO<sub>2</sub> we produce out of the troposphere.

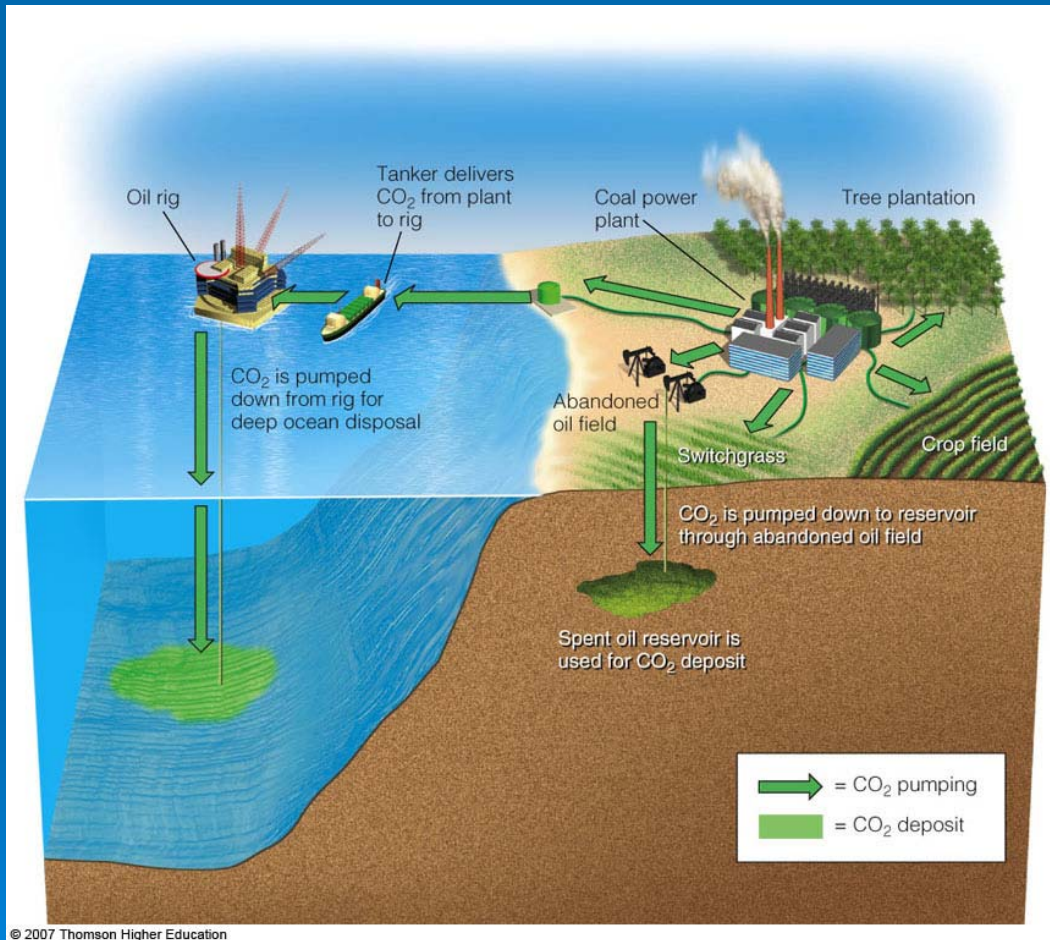


# How Would You Vote?

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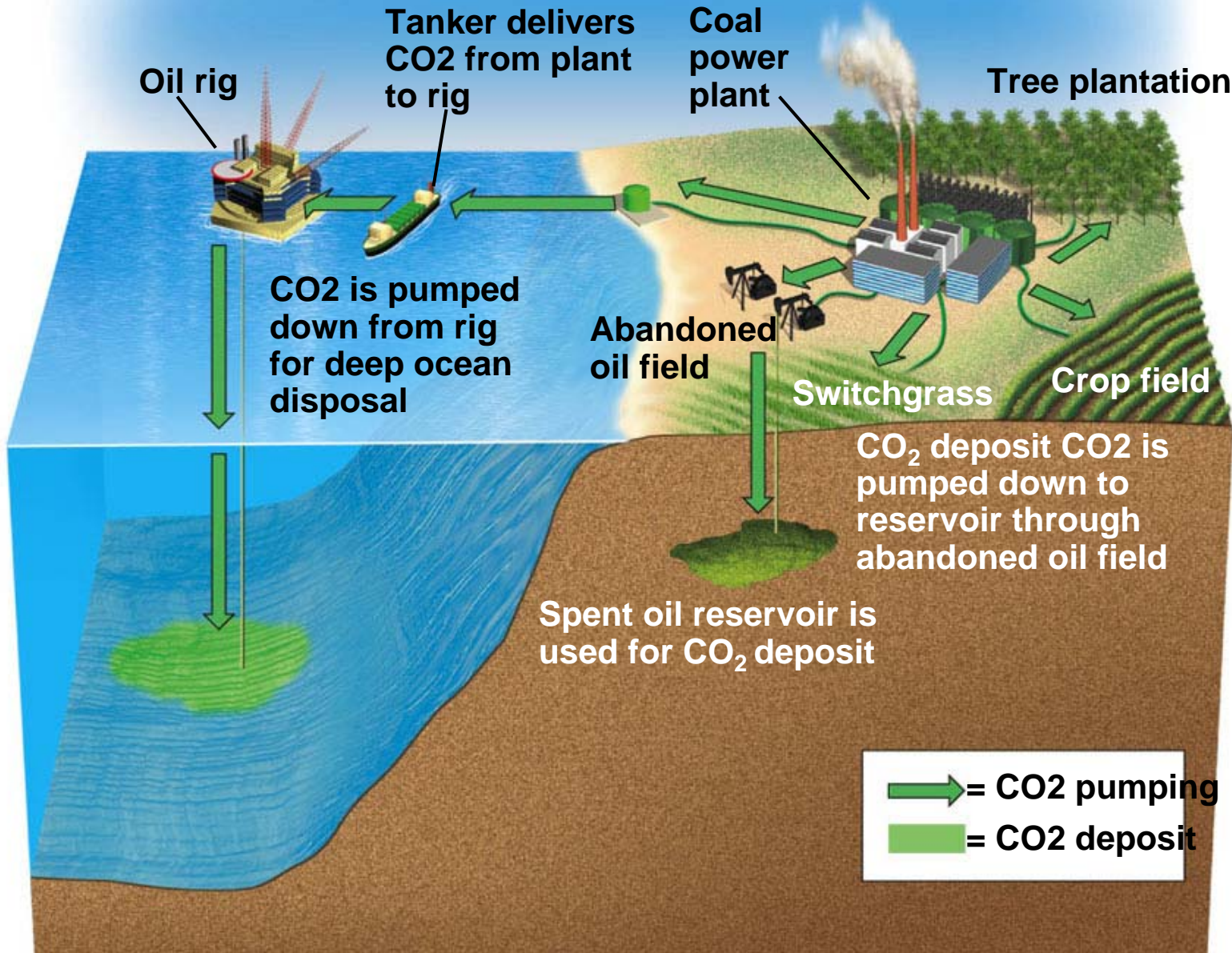
- Should we phase out the use of fossil fuels over the next fifty years?
  - a. No. Fossil fuels are too valuable to our society.
  - b. Yes. Fossil fuels release too much air pollution, including greenhouse gases.

# Removing and Storing CO<sub>2</sub>



- Methods for removing CO<sub>2</sub> from the atmosphere or from smokestacks and storing (sequestering) it.

# Spent oil reservoir is used for Crop field



# DEALING WITH GLOBAL WARMING

- Governments can tax greenhouse gas emissions and energy use, increase subsidies and tax breaks for saving energy, and decrease subsidies and tax breaks for fossil fuels.
- A crash program to slow and adapt to global warming now is very likely to cost less than waiting and having to deal with its harmful effects later.

# WHAT IS BEING DONE TO REDUCE GREENHOUSE GAS EMISSIONS?

- Getting countries to agree on reducing their greenhouse emissions is difficult.
- A 2006 poll showed that 83% of Americans want more leadership from federal government on dealing with global warming.

# International Climate Negotiations: The Kyoto Protocol

- Treaty on global warming which first phase went into effect January, 2005 with 189 countries participating.
- It requires 38 participating developed countries to cut their emissions of CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O to 5.2% below their 1990 levels by 2012.
- Developing countries were excluded.
  - The U.S. did not sign, but California and Maine are participating.
  - U.S. did not sign because developing countries such as China, India and Brazil were excluded.

# How Would You Vote?

To conduct an instant in-class survey using a classroom response system, access “JoinIn Clicker Content” from the PowerLecture main menu for Living in the Environment.

- Should the United States participate in the Kyoto Protocol?
  - a. No. Americans spend enough on environmental cleanup and should not take on the burden of this treaty.
  - b. Yes. We should participate, but only if India, China, and all other nations fairly participate.
  - c. Yes. As the leading emitter of greenhouse gases, the U.S. should set an example for other nations.

# Moving Beyond the Kyoto Protocol

- Countries could work together to develop a new international approach to slowing global warming.
  - The Kyoto Protocol will have little effect on future global warming without support and action by the U.S., China, and India.



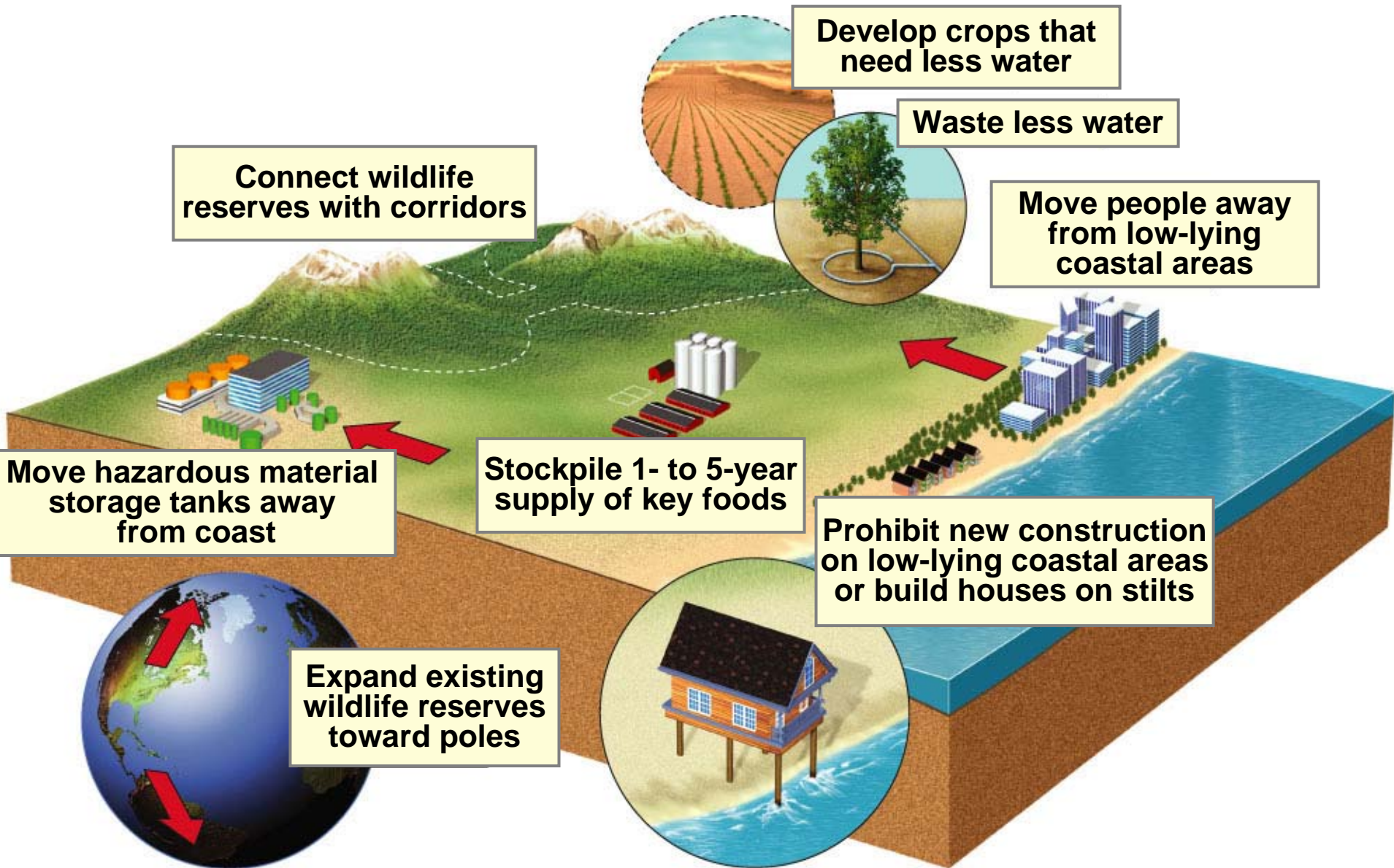
# Actions by Some Countries, States, and Businesses

- In 2005, the EU proposed a plan to reduce CO<sub>2</sub> levels by 1/3<sup>rd</sup> by 2020.
- California has adopted a goal of reducing its greenhouse gas emission to 1990 levels by 2020, and 80% below by 2050.
- Global companies (BP, IBM, Toyota) have established targets to reduce their greenhouse emissions 10-65% to 1990 levels by 2010.

## What Can You Do?

### Reducing CO<sub>2</sub> Emissions

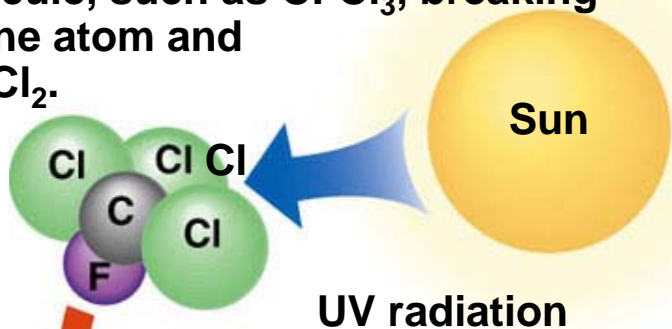
- **Drive a fuel-efficient car, walk, bike, carpool, and use mass transit**
- **Use energy-efficient windows**
- **Use energy-efficient appliances and lights**
- **Heavily insulate your house and seal all drafts**
- **Reduce garbage by recycling and reuse**
- **Insulate your hot water heater**
- **Use compact fluorescent bulbs**
- **Plant trees to shade your house during summer**
- **Set water heater no higher than 49° C (120° F)**
- **Wash laundry in warm or cold water**
- **Use low-flow shower head**
- **Buy products from companies that are trying to reduce their impact on climate**
- **Demand that the government make climate change an urgent priority**



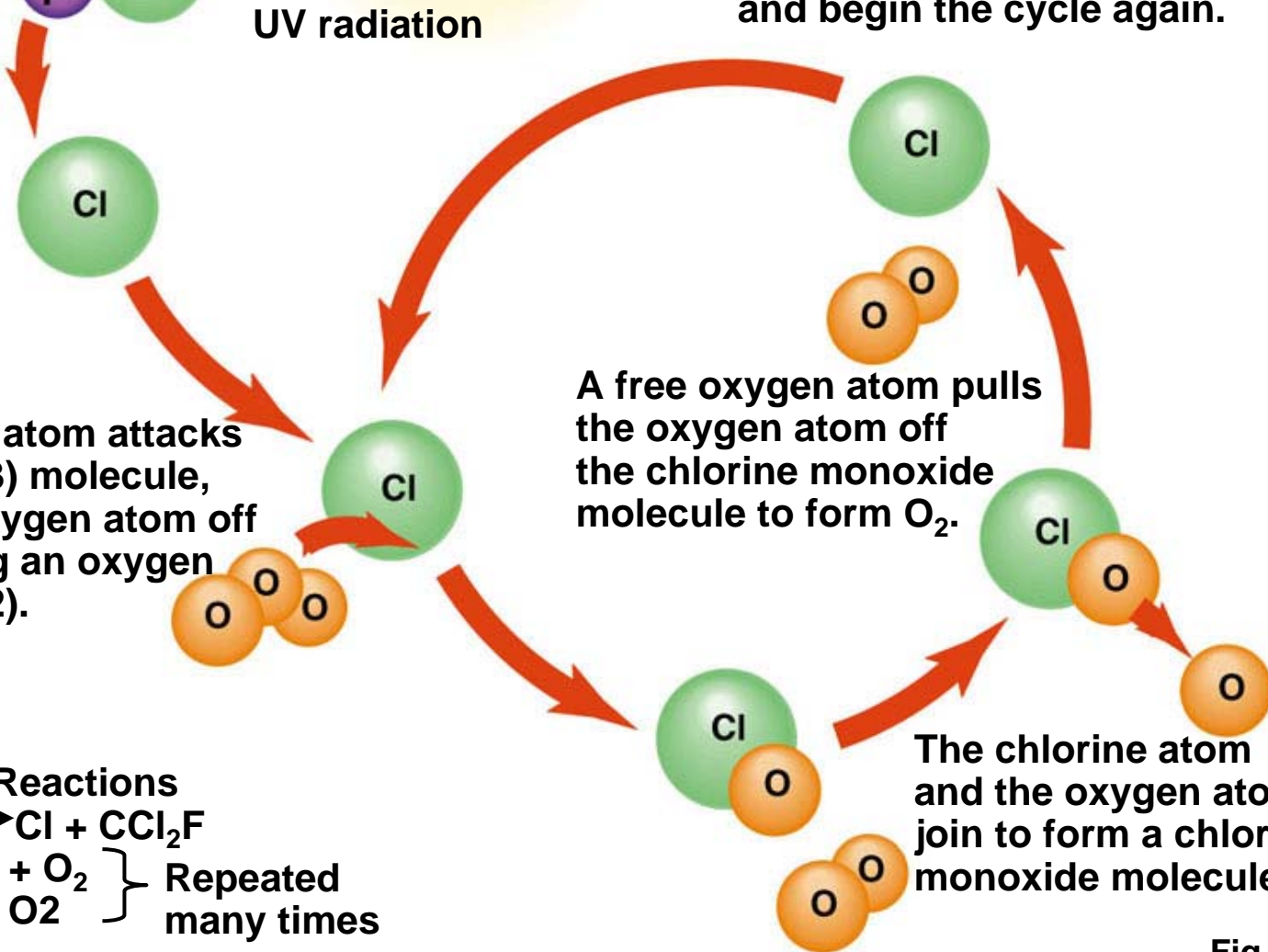
# OZONE DEPLETION IN THE STRATOSPHERE

- Less ozone in the stratosphere allows for more harmful UV radiation to reach the earth's surface.
  - The ozone layer keeps about 95% of the sun's harmful UV radiation from reaching the earth's surface.
  - Chlorofluorocarbon (CFCs) have lowered the average concentrations of ozone in the stratosphere.
  - In 1988 CFCs were no longer manufactured.

Ultraviolet light hits a chlorofluorocarbon (CFC) molecule, such as  $\text{CFCl}_3$ , breaking off a chlorine atom and leaving  $\text{CFCl}_2$ .



Once free, the chlorine atom is off to attack another ozone molecule and begin the cycle again.

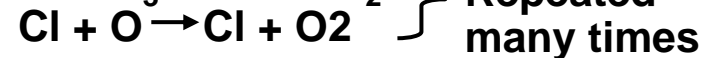
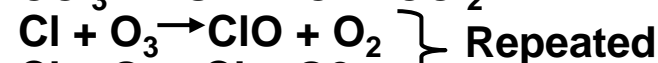
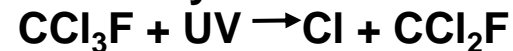


The chlorine atom attacks an ozone ( $\text{O}_3$ ) molecule, pulling an oxygen atom off it and leaving an oxygen molecule ( $\text{O}_2$ ).

A free oxygen atom pulls the oxygen atom off the chlorine monoxide molecule to form  $\text{O}_2$ .

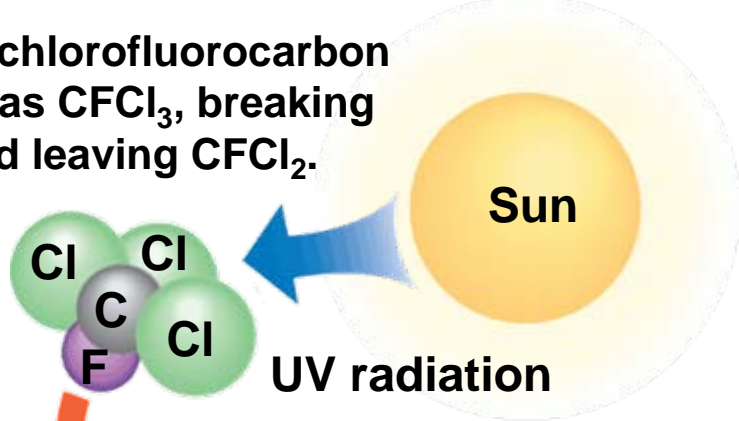
The chlorine atom and the oxygen atom join to form a chlorine monoxide molecule ( $\text{ClO}$ ).

### Summary of Reactions



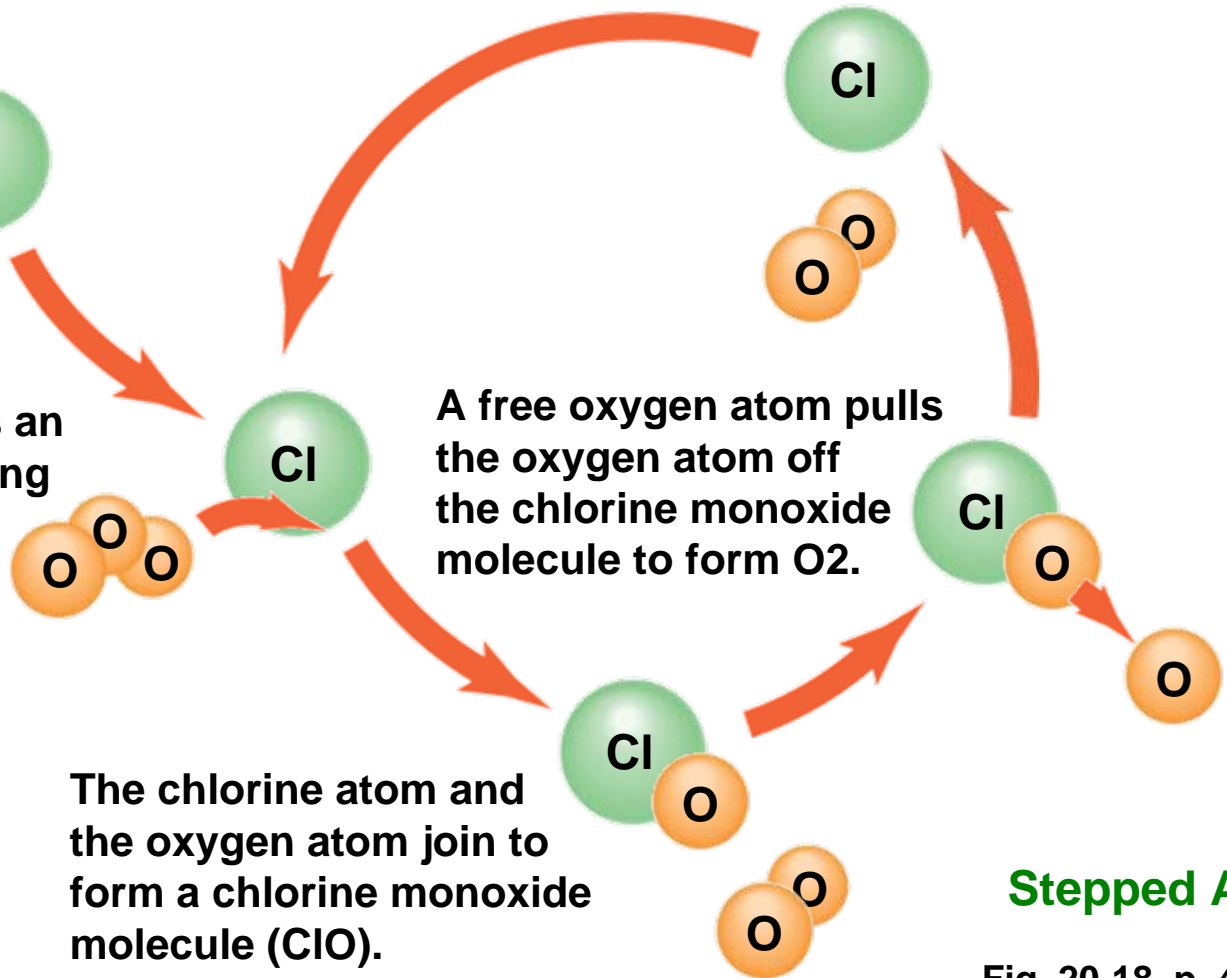
Repeated many times

Ultraviolet light hits a chlorofluorocarbon (CFC) molecule, such as  $\text{CFCl}_3$ , breaking off a chlorine atom and leaving  $\text{CFCl}_2$ .



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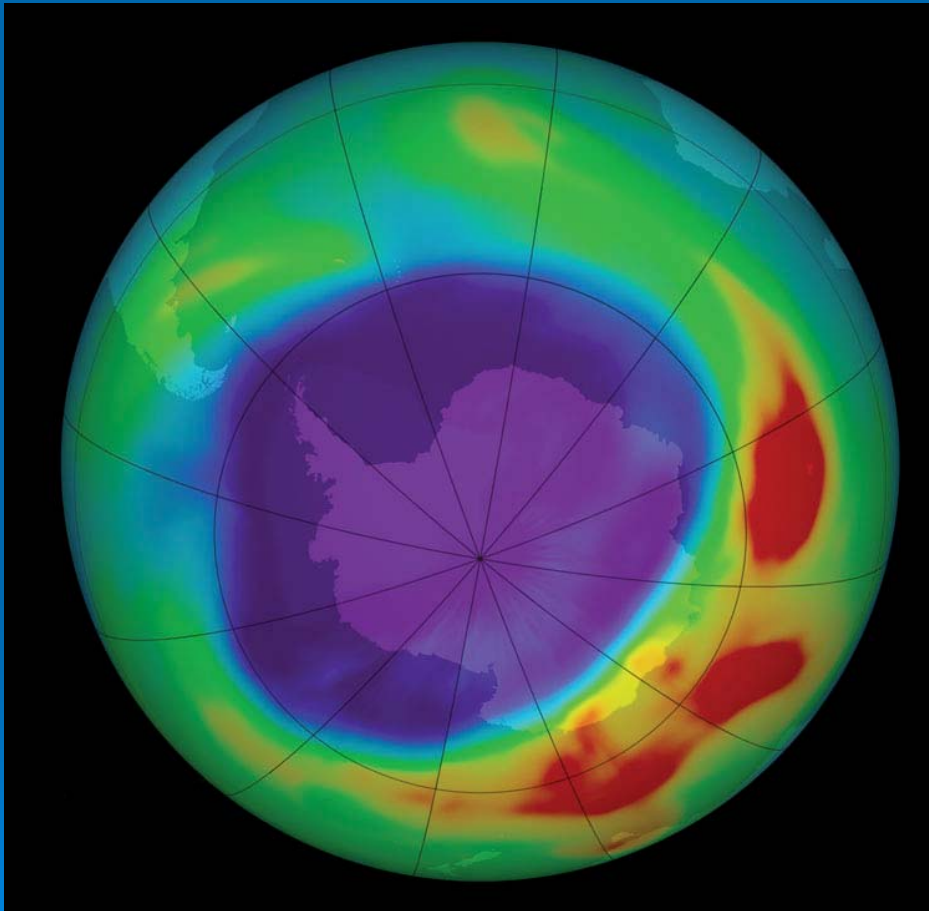


A free oxygen atom pulls the oxygen atom off the chlorine monoxide molecule to form  $\text{O}_2$ .

The chlorine atom and the oxygen atom join to form a chlorine monoxide molecule ( $\text{ClO}$ ).

Stepped Art

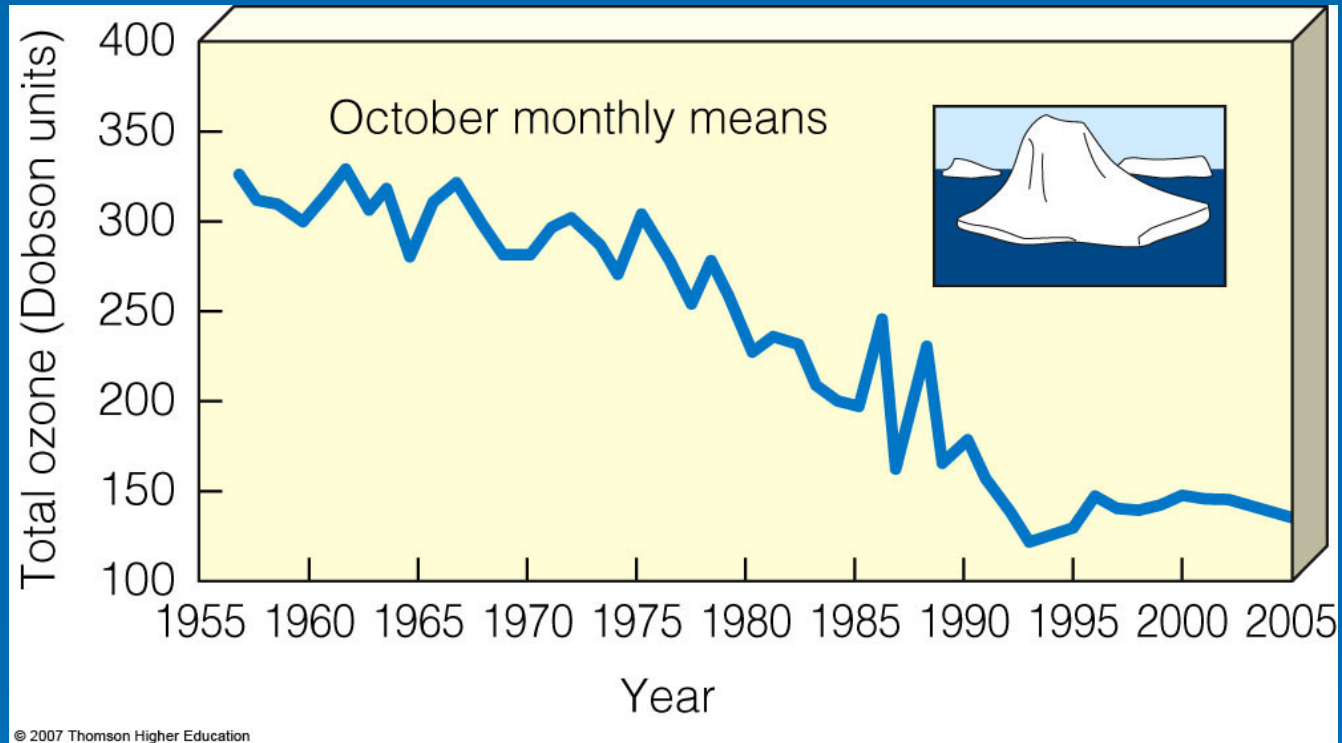
# OZONE DEPLETION IN THE STRATOSPHERE



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- During four months of each year up to half of the ozone in the stratosphere over Antarctica and a smaller amount over the Arctic is depleted.

# OZONE DEPLETION IN THE STRATOSPHERE



- Since 1976, in Antarctica, ozone levels have markedly decreased during October and November.



# OZONE DEPLETION IN THE STRATOSPHERE

- **Ozone thinning**: caused by CFCs and other ozone depleting chemicals (ODCs).
  - Increased UV radiation reaching the earth's surface from ozone depletion in the stratosphere is harmful to human health, crops, forests, animals, and materials such as plastic and paints.

### **Human Health**

- **Worse sunburn**
- **More eye cataracts**
- **More 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**

### **Wildlife**

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

### **Air Pollution and Materials**

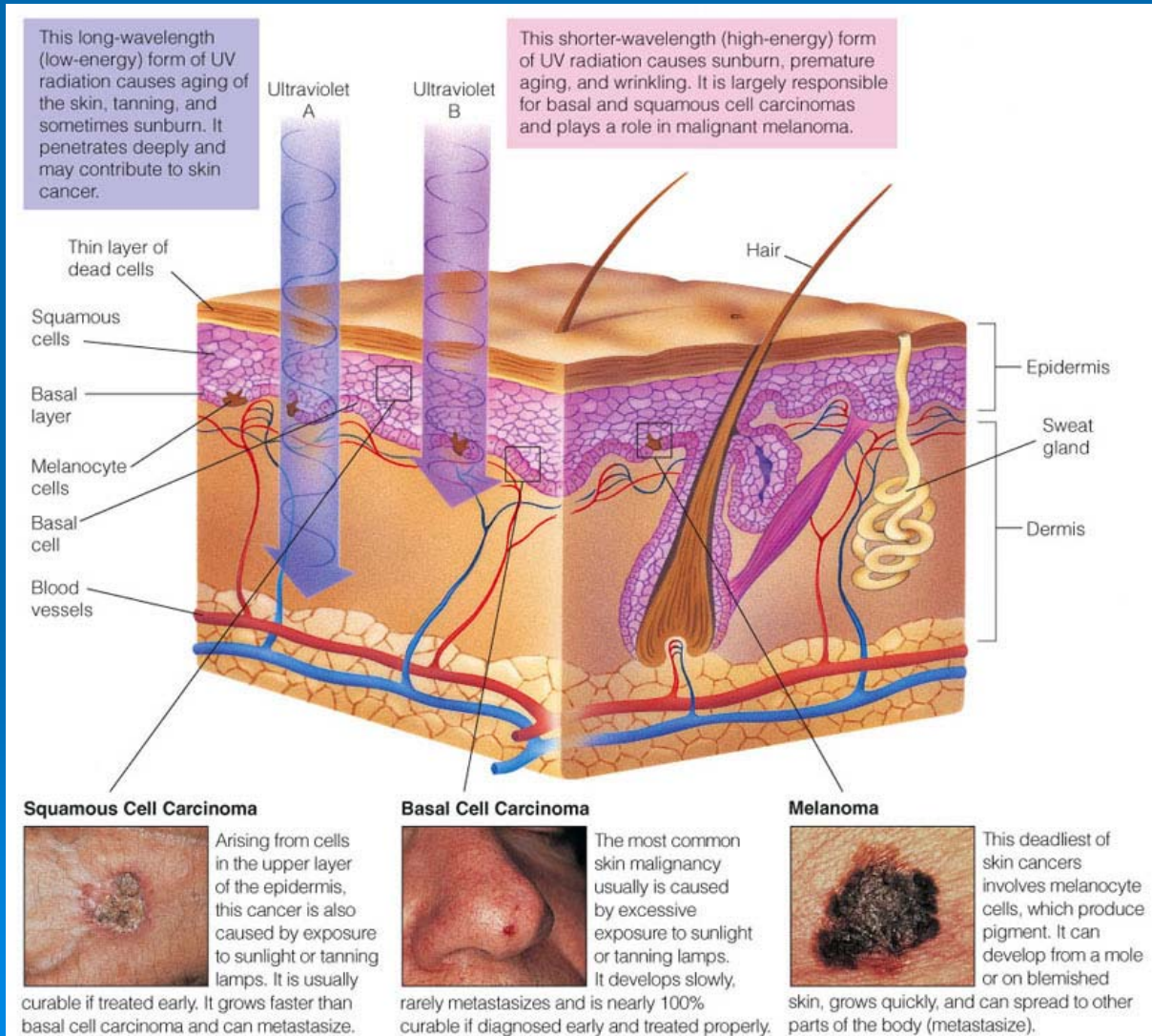
- **Increased acid deposition**
- **Increased photochemical smog**
- **Degradation of outdoor paints and plastics**

Fig. 20-21, p. 488

### **Global Warming**

- **Accelerated warming because of decreased ocean uptake of CO<sub>2</sub> from atmosphere by phytoplankton and CFCs acting as greenhouse gases**

# Case Study: Skin Cancer

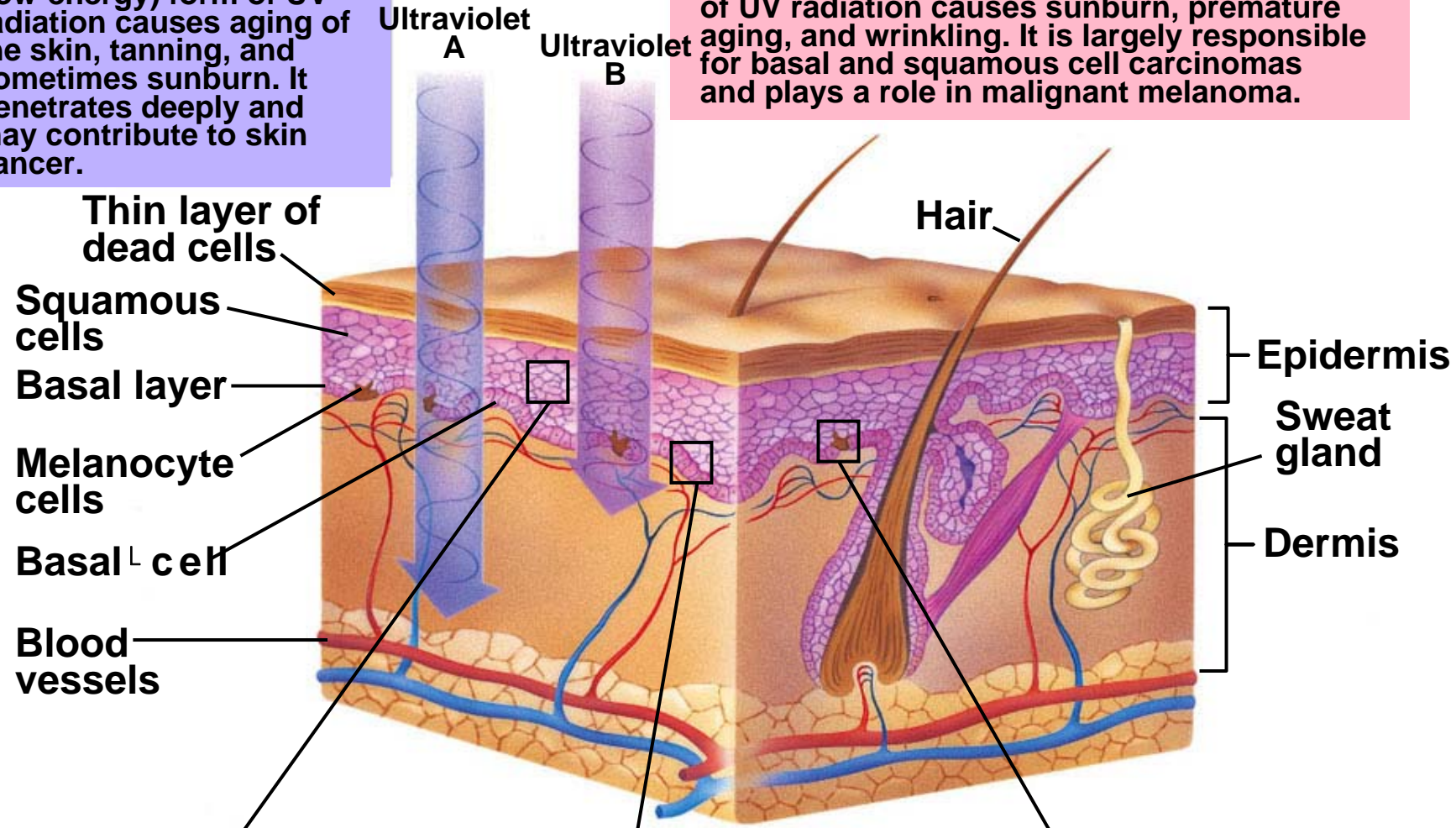


➤ Structure of the human skin and relationship between radiation and skin cancer.

Figure 20-22

This long-wavelength (low-energy) form of UV radiation causes aging of the skin, tanning, and sometimes sunburn. It penetrates deeply and may contribute to skin cancer.

This shorter-wavelength (high-energy) form of UV radiation causes sunburn, premature aging, and wrinkling. It is largely responsible for basal and squamous cell carcinomas and plays a role in malignant melanoma.



**Squamous Cell Carcinoma**



**Basal Cell Carcinoma**



**Melanoma**

# PROTECTING THE OZONE LAYER

## What Can You Do?

### Reducing Exposure to UV Radiation

- Stay out of the sun, especially between 10 A.M. and 3 P.M.
- Do not use tanning parlors or sunlamps.
- When in the sun, wear protective clothing and sunglasses that protect against UV-A and UV-B radiation.
- Be aware that overcast skies do not protect you.
- Do not expose yourself to the sun if you are taking antibiotics or birth control pills.
- Use a sunscreen with a protection factor of 15 or 30 anytime you are in the sun if you have light skin.
- Examine your skin and scalp at least once a month for moles or warts that change in size, shape, or color or sores that keep oozing, bleeding, and crusting over. If you observe any of these signs, consult a doctor immediately.

➤ To reduce ozone depletion, we must stop producing all ozone-depleting chemicals.

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