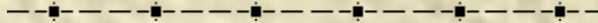




# Air Quality Issues



## Chapter 16

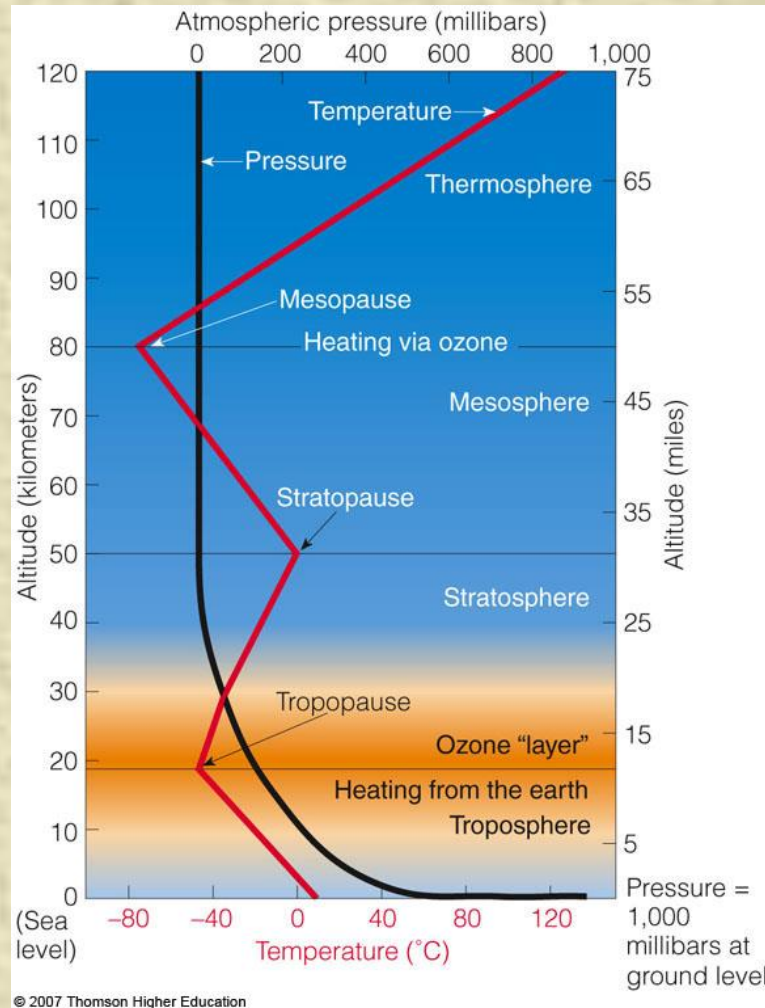


# What are the different layers of the atmosphere?

---

- Which layer do we live in?
- In which layer does weather occur?
- Which layer contains the protective ozone layer?

# STRUCTURE AND SCIENCE OF THE ATMOSPHERE



- The atmosphere consists of several layers with different temperatures, pressures, and compositions.

Figure 19-2



# Composition of the Atmosphere

---

- Components – Oxygen 21%, Nitrogen 78%
- Other gases (argon, carbon dioxide, methane and water vapor 1%)
- Layers – troposphere, stratosphere, mesosphere, thermosphere, exosphere  
(Most of the atmosphere is held close to the earth by gravity = farther away is less dense)

# Composition of the Atmosphere (cont.)

- 
- Primary Pollutants – methane, ozone, dust particles, microorganisms, and chlorofluorocarbons (CFC's)
  - Causes of Primary Pollutants – factories, cars, wind and soil, volcanoes, forest fires, pollen, decaying plants, salt particles from the sea, and refrigerants.



# STRUCTURE AND SCIENCE OF THE ATMOSPHERE

---

- The atmosphere's innermost layer (troposphere) is made up mostly of nitrogen and oxygen, with smaller amounts of water vapor and CO<sub>2</sub>.
- Ozone in the atmosphere's second layer (stratosphere) filters out most of the sun's UV radiation that is harmful to us and most other species.



# The Earth's Atmosphere

## Troposphere

---

- 75% of mass of atmosphere
- 0 to 11 miles in altitude
- 78% nitrogen, 21% oxygen
- Location of Earth's weather
- Temperature decreases with altitude until the next layer is reached, where there is a sudden rise in temperature



# Stratosphere

---

- 11 miles to 30 miles in altitude
- Calm
- Temperature increases with altitude
- Contains 1000x the ozone of the rest of the atmosphere; ozone forms in an equilibrium reaction when oxygen is converted to  $O_3$  by lightning and/or sunlight
- 99% of ultraviolet radiation (especially UV-B) is absorbed by the stratosphere





# Weather

---

- Weather is the condition in the atmosphere at a given place and time.
- It includes temperature, atmospheric pressure, precipitation, cloudiness, humidity, and wind.

# CLIMATE: A BRIEF INTRODUCTION

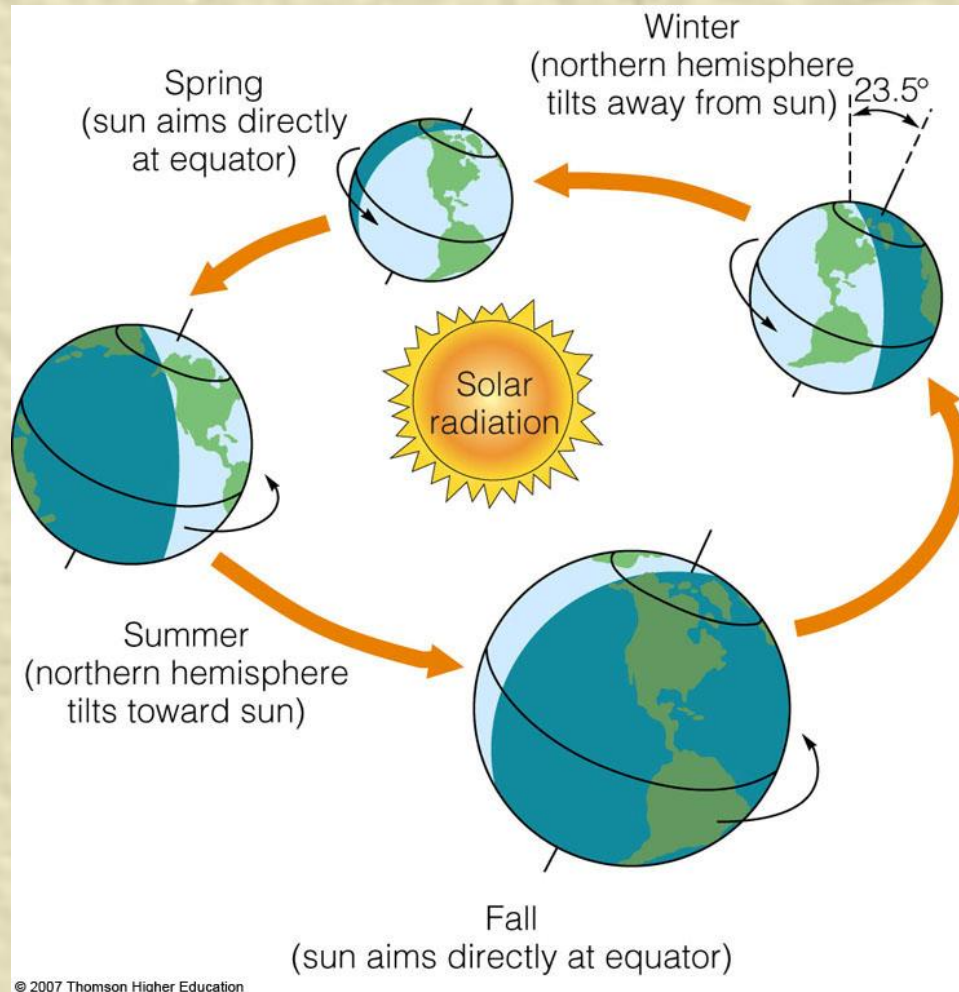
---

- Climate is a region's average weather conditions over a long time.

- Latitude and elevation help determine climate.



# Solar Energy and Global Air Circulation: Distributing Heat



- Global air circulation is affected by the uneven heating of the earth's surface by solar energy, seasonal changes in temperature and precipitation.

Figure 5-3

# Air Pressure

## Definition

---

- Air pressure is pressure exerted by the weight of Earth's atmosphere. At sea level it is equal to 14.69 pounds per square inch.
- A barometer is used to measure atmospheric pressure.



# Air Pressure

## Pressure Gradient

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- This changes from high to low. On a map there is an arrow to show this. A higher pressure gradient means stronger winds (the isobars on a weather map would be drawn closer together).

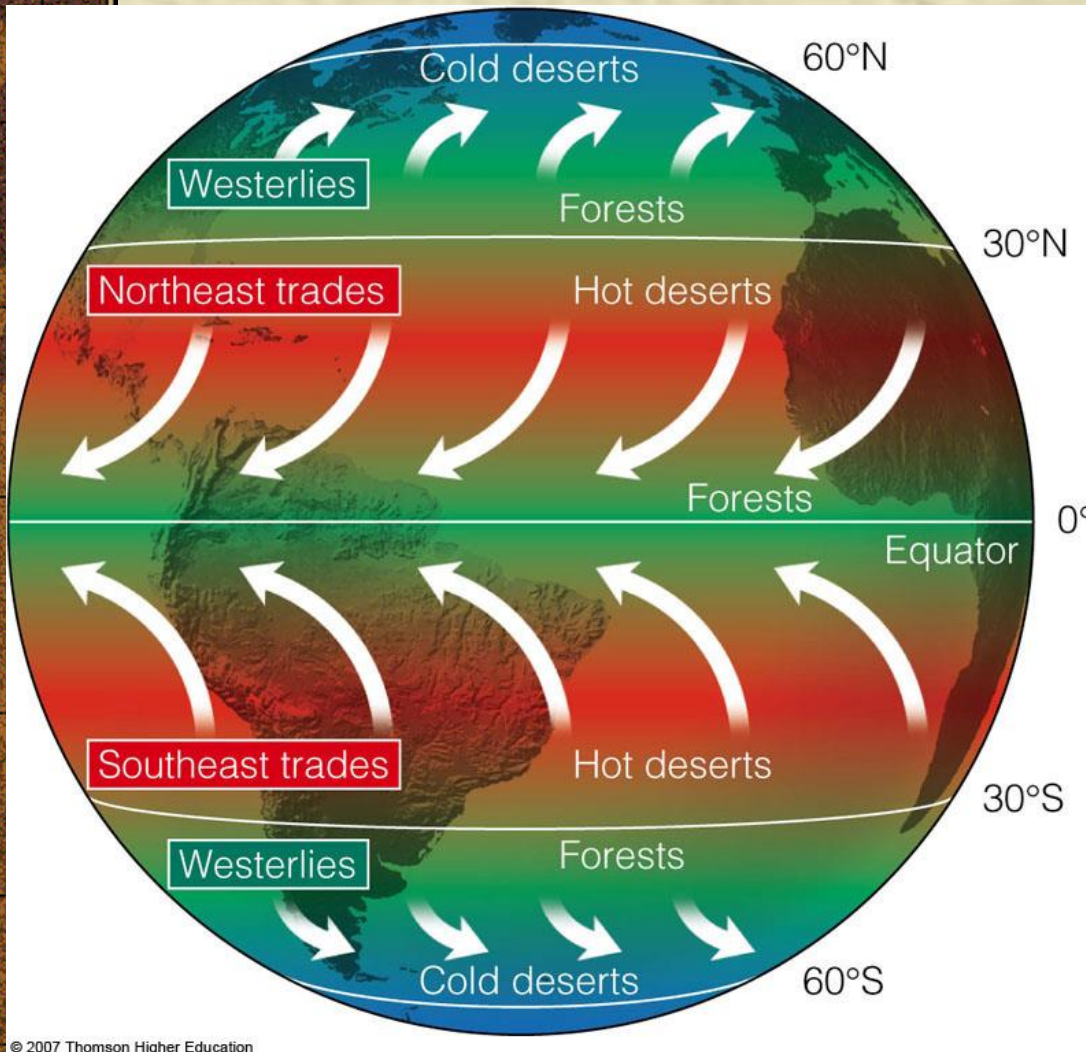
# Wind

## Cause

- 
- Wind is caused by the pressure gradient force. High pressure means more air, and low pressure means less air. The air moves from high to low, causing wind.

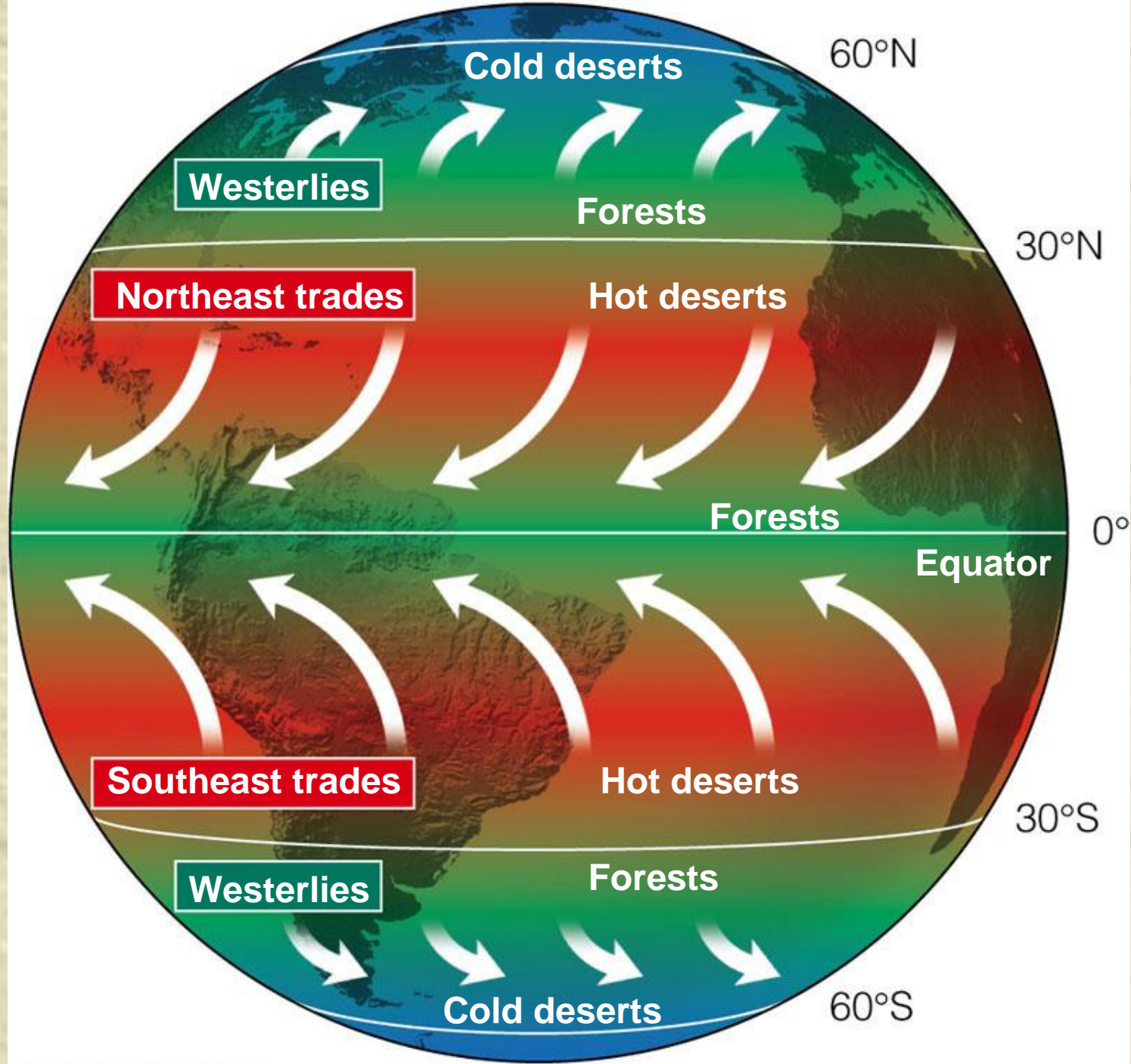


# Coriolis Effect



- Global air circulation is affected by the rotation of the earth on its axis.

Figure 5-4

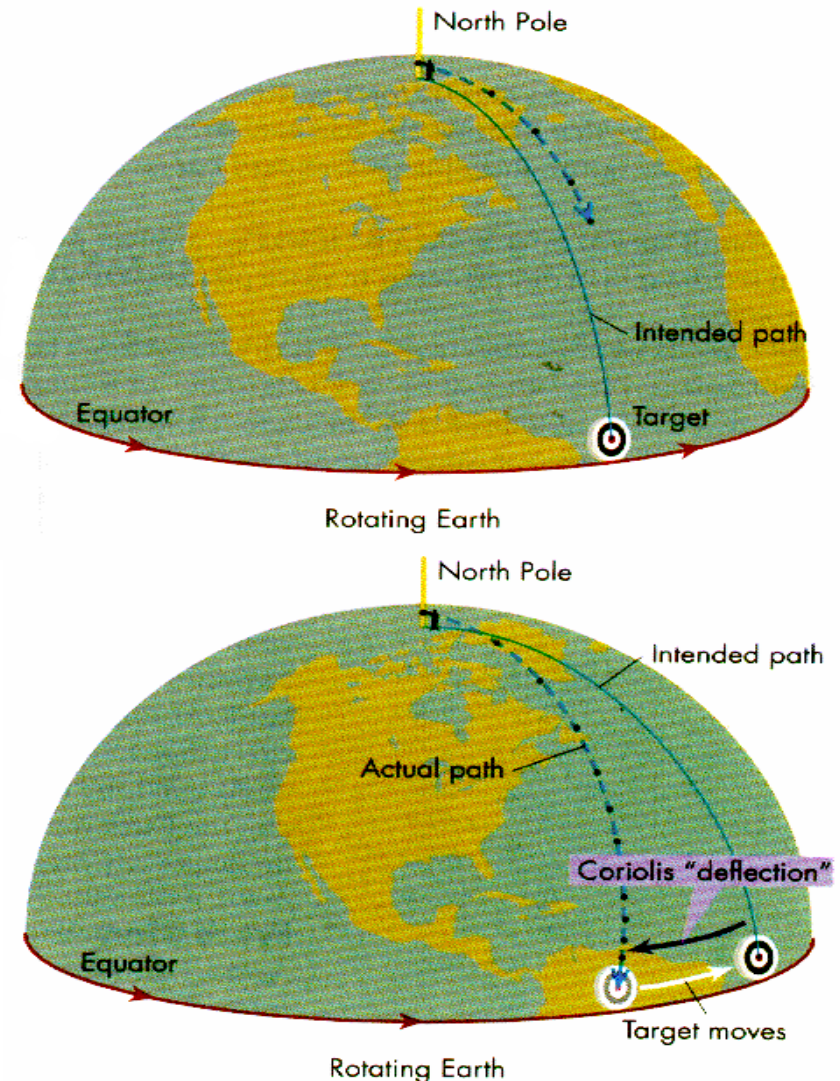




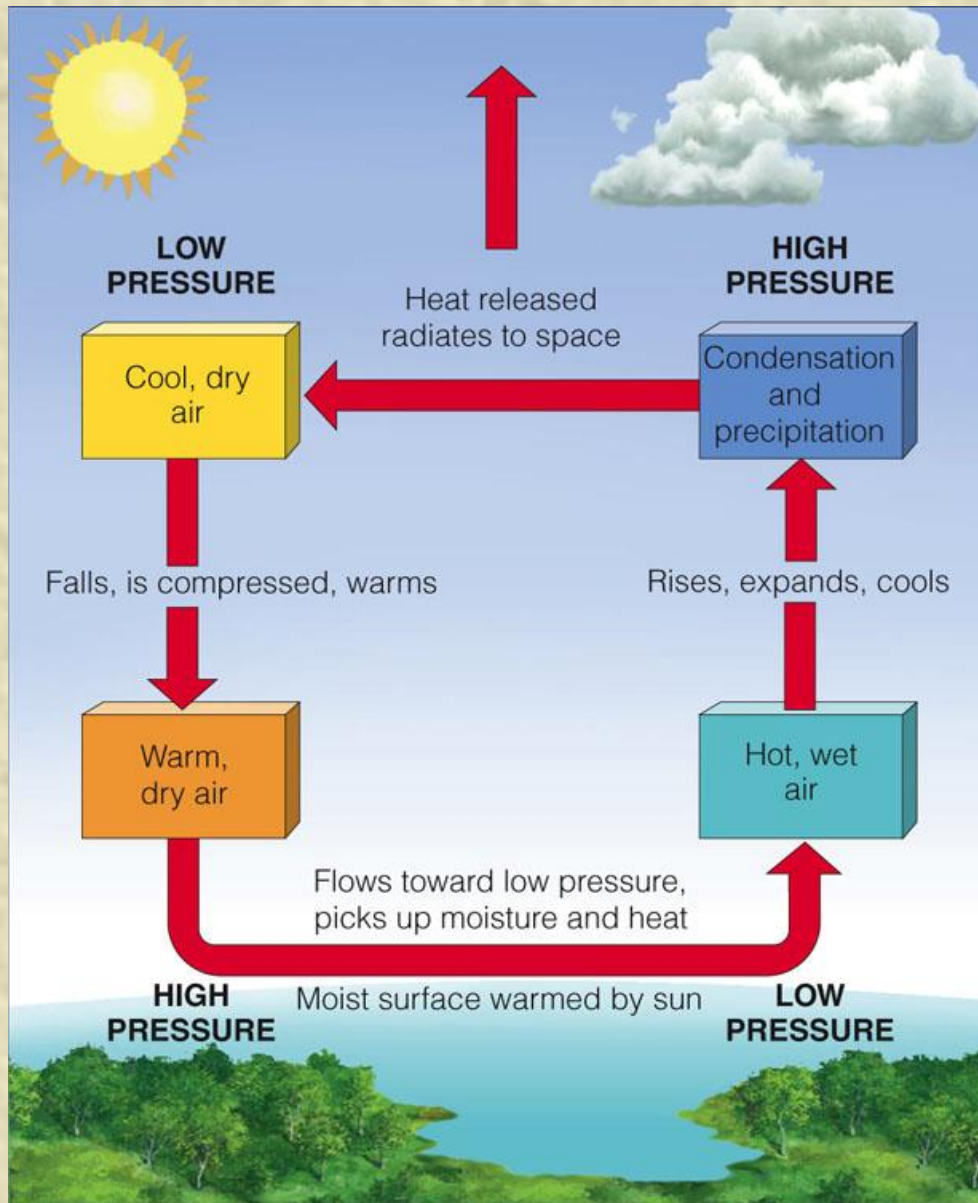
# Wind

## The Coriolis Effect

- Forces in the atmosphere, created by the rotation of the Earth on its axis, that deflect winds to the right in the N. Hemisphere and to the left in the S. Hemisphere.



# Convection Currents



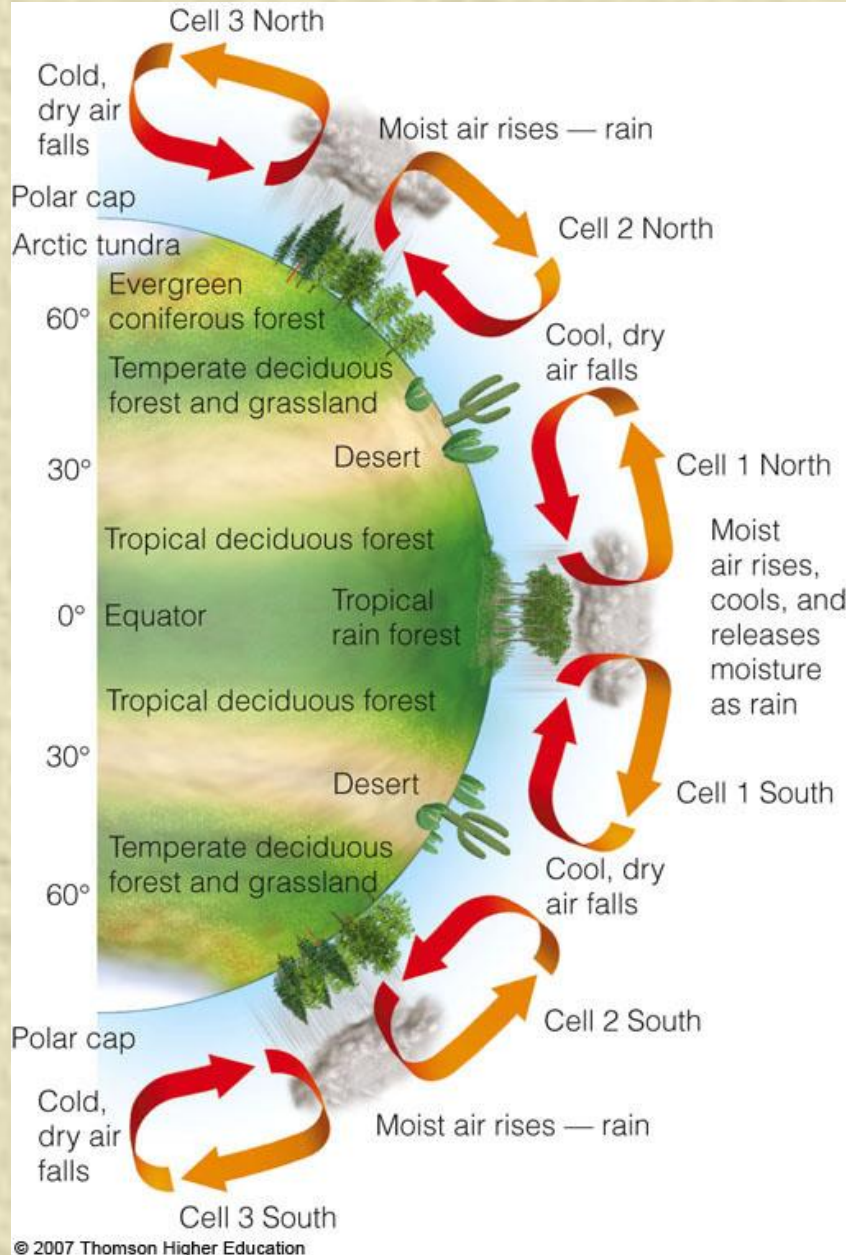
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- Global air circulation is affected by the properties of air, water, and land.

Figure 5-5



# Convection Cells



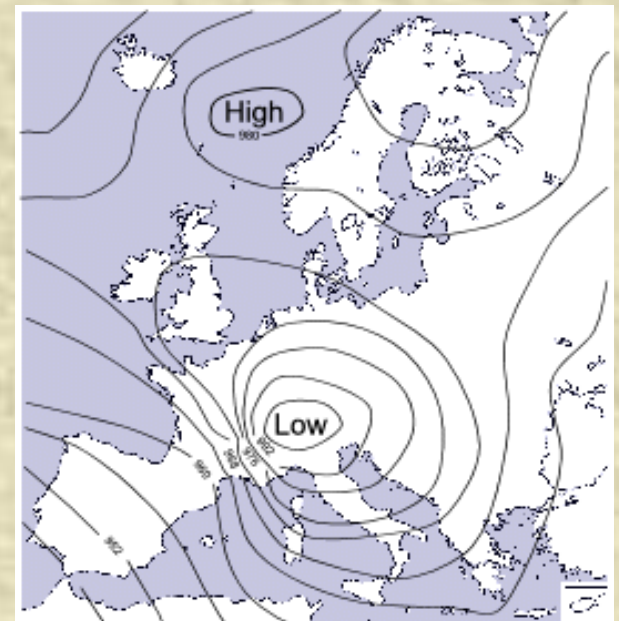
- Heat and moisture are distributed over the earth's surface by vertical currents, which form six giant convection cells at different latitudes.

Figure 5-6

# Wind

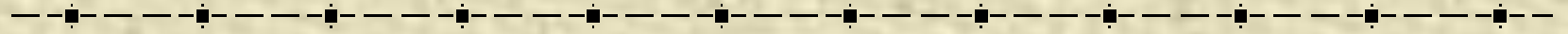
## Friction

- This is a combination of the pressure gradient force and the coriolis effect. Friction at the Earth's surface causes winds to turn a little. Friction runs parallel to the isobar.





# Circulation Patterns



- Wind that rises at the equator.
- As air rises, it spreads out north & south, then cools and sinks at 30 degrees.
- This is why most of the world's deserts are found at 30 degrees.
- These are called the horse latitudes because early settlers would get stuck here in their boats & couldn't move. They would finally throw their horses overboard to lighten the load & get moving again.



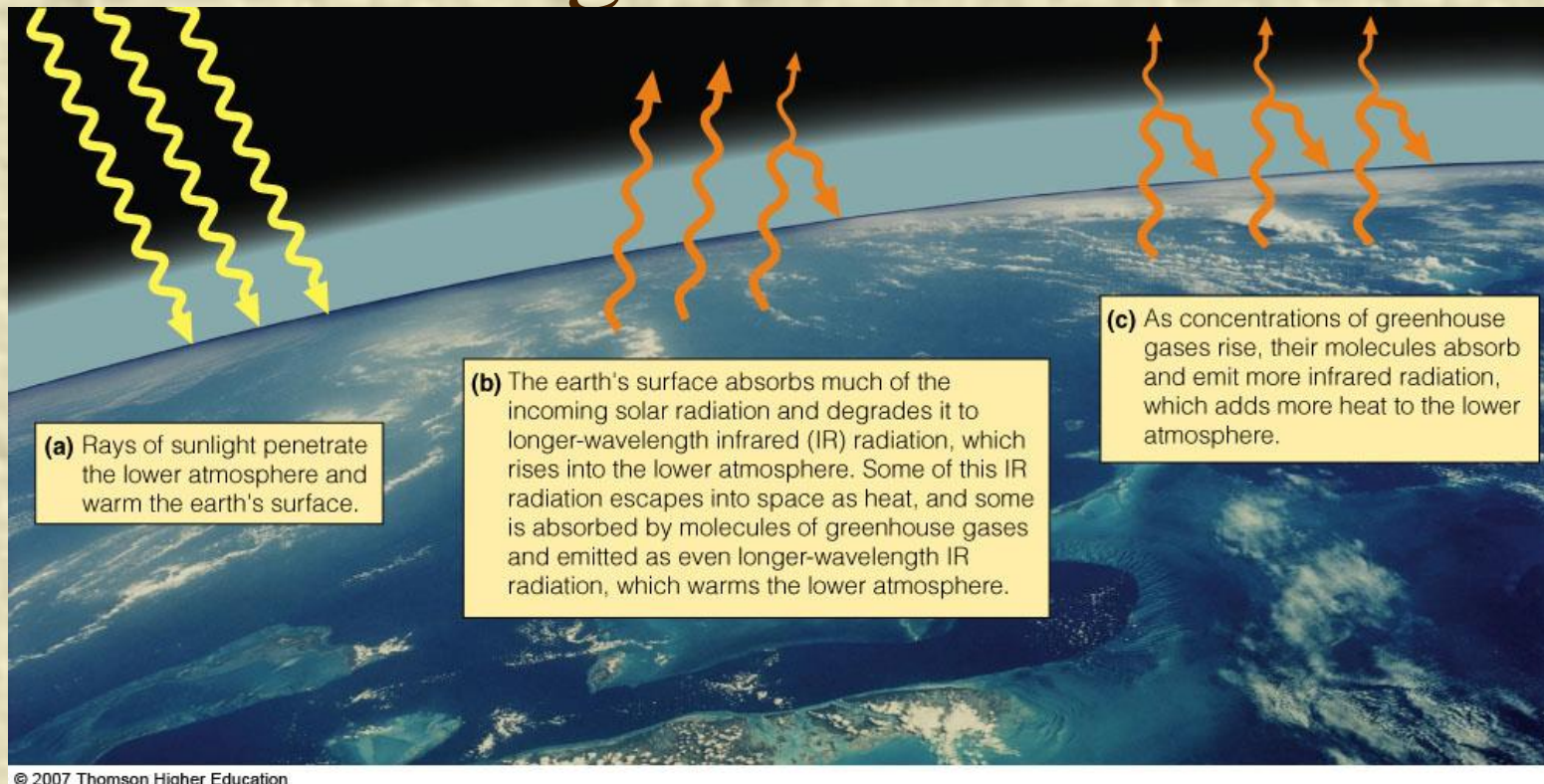
# Convection Cells

---

- Ocean water transfers heat to the atmosphere, especially near the hot equator.
- This creates convection cells that transport heat and water from one area to another.
- The resulting convection cells circulate air, heat, and moisture both vertically and from place-to-place in the troposphere, leading to different climates & patterns of vegetation.



# Ocean Currents: Distributing Heat and Nutrients



- Ocean currents influence climate by distributing heat from place to place and mixing and distributing nutrients.

Figure 5-7



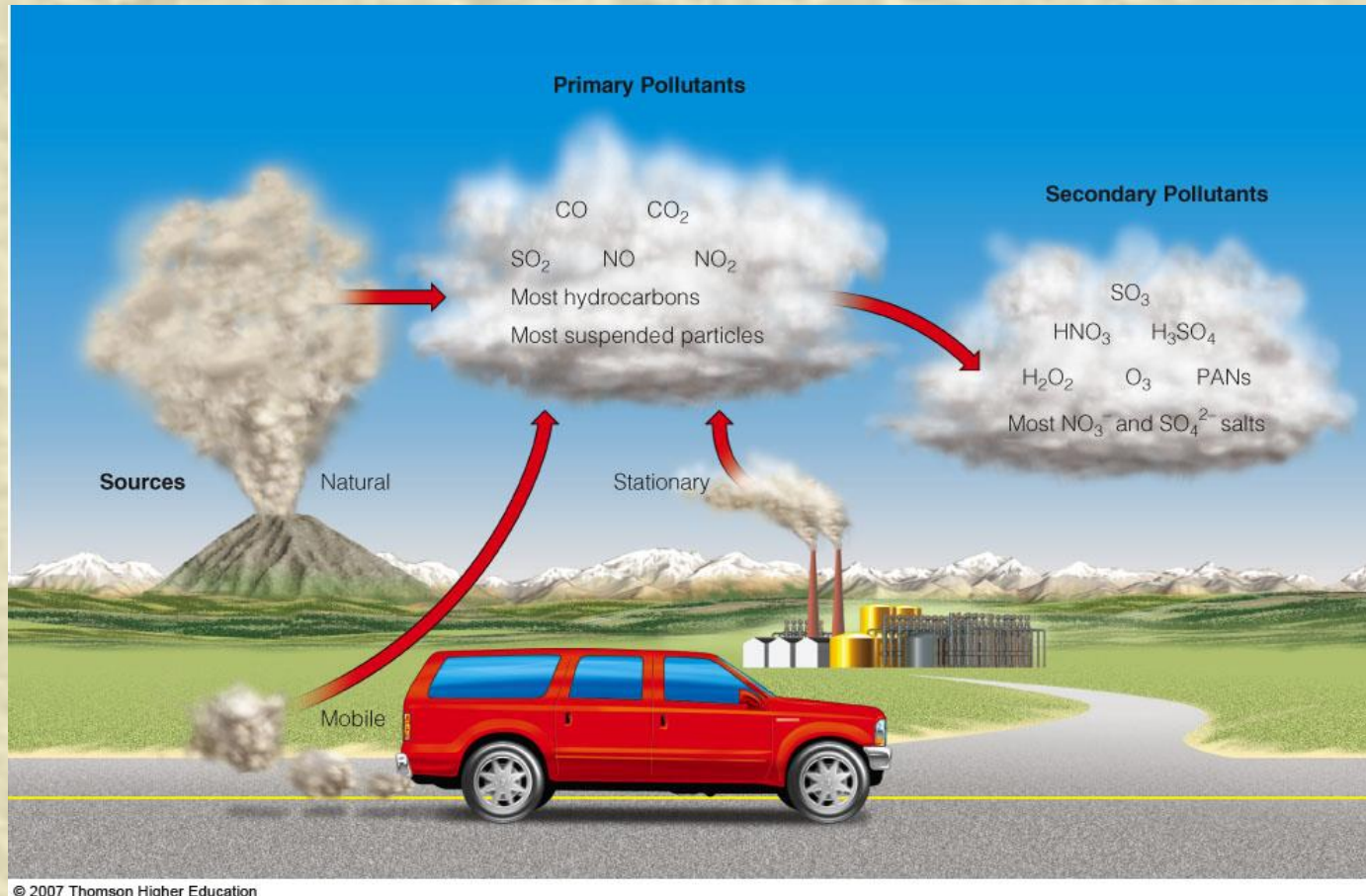
# Ocean Currents: Distributing Heat and Nutrients

---

- Global warming:
  - Considerable scientific evidence and climate models indicate that large inputs of greenhouse gases from anthropogenic activities into the troposphere can enhance the natural greenhouse effect and change the earth's climate in your lifetime.

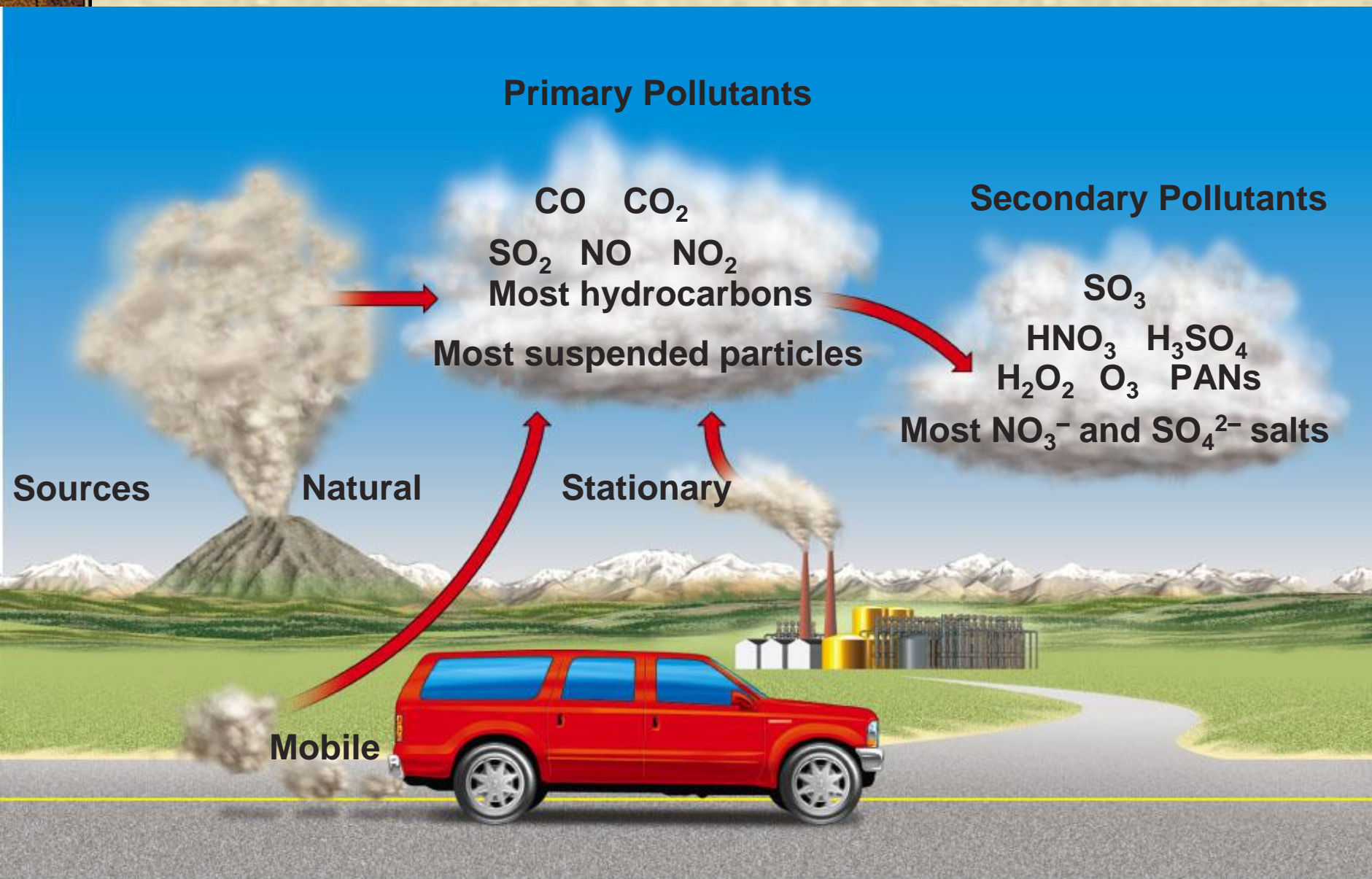


# AIR POLLUTION



- Some primary air pollutants may react with one another or with other chemicals in the air to form secondary air pollutants.

Figure 19-3





# Major Air Pollutants

---

- *Carbon oxides:*

- Carbon monoxide (CO) is a highly toxic gas that forms during the incomplete combustion of carbon-containing materials.
- 93% of carbon dioxide (CO<sub>2</sub>) in the troposphere occurs as a result of the carbon cycle.
- 7% of CO<sub>2</sub> in the troposphere occurs as a result of human activities (mostly burning fossil fuels).
  - It is not regulated as a pollutant under the U.S. Clean Air Act.

# Major Air Pollutants

---

- *Nitrogen oxides* and *nitric acid*:
  - Nitrogen oxide (NO) forms when nitrogen and oxygen gas in air react at the high-combustion temperatures in automobile engines and coal-burning plants. NO can also form from lightening and certain soil bacteria.
    - NO reacts with air to form NO<sub>2</sub>.
    - NO<sub>2</sub> reacts with water vapor in the air to form nitric acid (HNO<sub>3</sub>) and nitrate salts (NO<sub>3</sub><sup>-</sup>) which are components of acid deposition.



# Major Air Pollutants

---

- *Sulfur dioxide ( $SO_2$ )* and *sulfuric acid*:
  - About one-third of  $SO_2$  in the troposphere occurs naturally through the sulfur cycle.
  - Two-thirds come from human sources, mostly combustion ( $S + O_2 \rightarrow SO_2$ ) of sulfur-containing coal and from oil refining and smelting of sulfide ores.
  - $SO_2$  in the atmosphere can be converted to sulfuric acid ( $H_2SO_4$ ) and sulfate salts ( $SO_4^{2-}$ ) that return to earth as a component of acid deposition.

# Major Air Pollutants

---

- *Suspended particulate matter (SPM):*
  - Consists of a variety of solid particles and liquid droplets small and light enough to remain suspended in the air.
  - The most harmful forms of SPM are fine particles (PM-10, with an average diameter < 10 micrometers) and ultrafine particles (PM-2.5).
  - According to the EPA, SPM is responsible for about 60,000 premature deaths a year in the U.S.



# Major Air Pollutants

---

- *Ozone ( $O_3$ ):*

- Is a highly reactive gas that is a major component of photochemical smog.
- It can
  - Cause and aggravate respiratory illness.
  - Can aggravate heart disease.
  - Damage plants, rubber in tires, fabrics, and paints.

# Major Air Pollutants

- ***Volatile organic compounds (VOCs):***
  - Naturally, most are hydrocarbons emitted by the leaves of many plants and methane.
  - Anthropogenic causes: about two thirds of global methane emissions comes from human sources and VOCs (including benzene) from automobiles.
  - Other VOCs include industrial solvents such as trichlorethylene (TCE), benzene, and vinyl chloride.
    - Long-term exposure to benzene can cause cancer, blood disorders, and immune system damage.






# Major Air Pollutants

---

- *Radon (Rn):*

- Is a naturally occurring radioactive gas found in some types of soil and rock.
- It can seep into homes and buildings sitting above such deposits.



# Secondary Pollutants

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Form when primary  
pollutants react

---



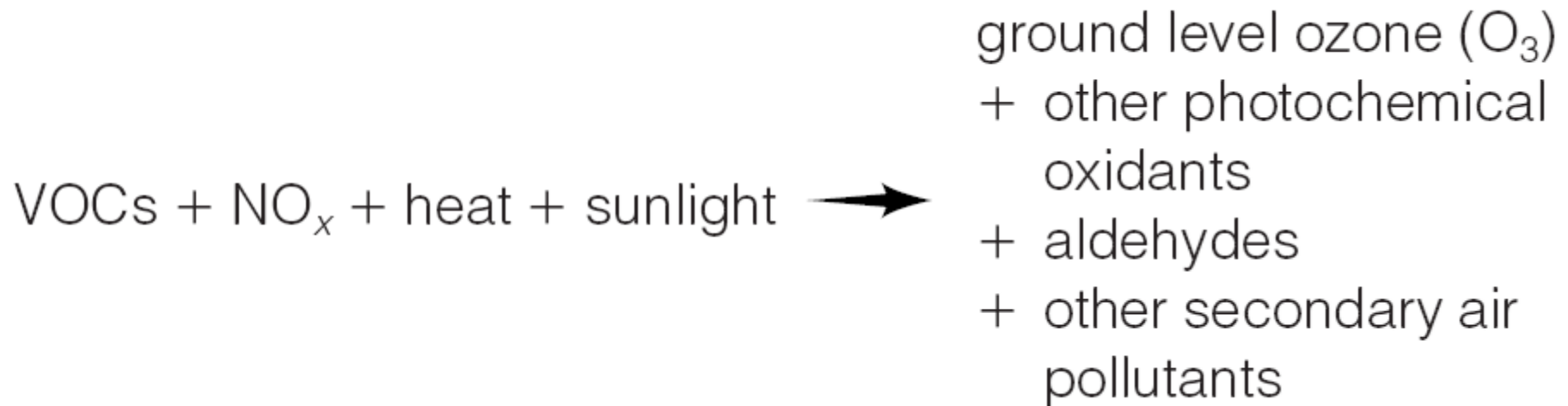
# URBAN OUTDOOR AIR POLLUTION

---

- Industrial smog is a mixture of sulfur dioxide, droplets of sulfuric acid, and a variety of suspended solid particles emitted mostly by burning coal.
  - In most developed countries where coal and heavy oil is burned, industrial smog is not a problem due to reasonably good pollution control or with tall smokestacks that transfer the pollutant to rural areas.

# Sunlight plus Cars Equals Photochemical Smog

---



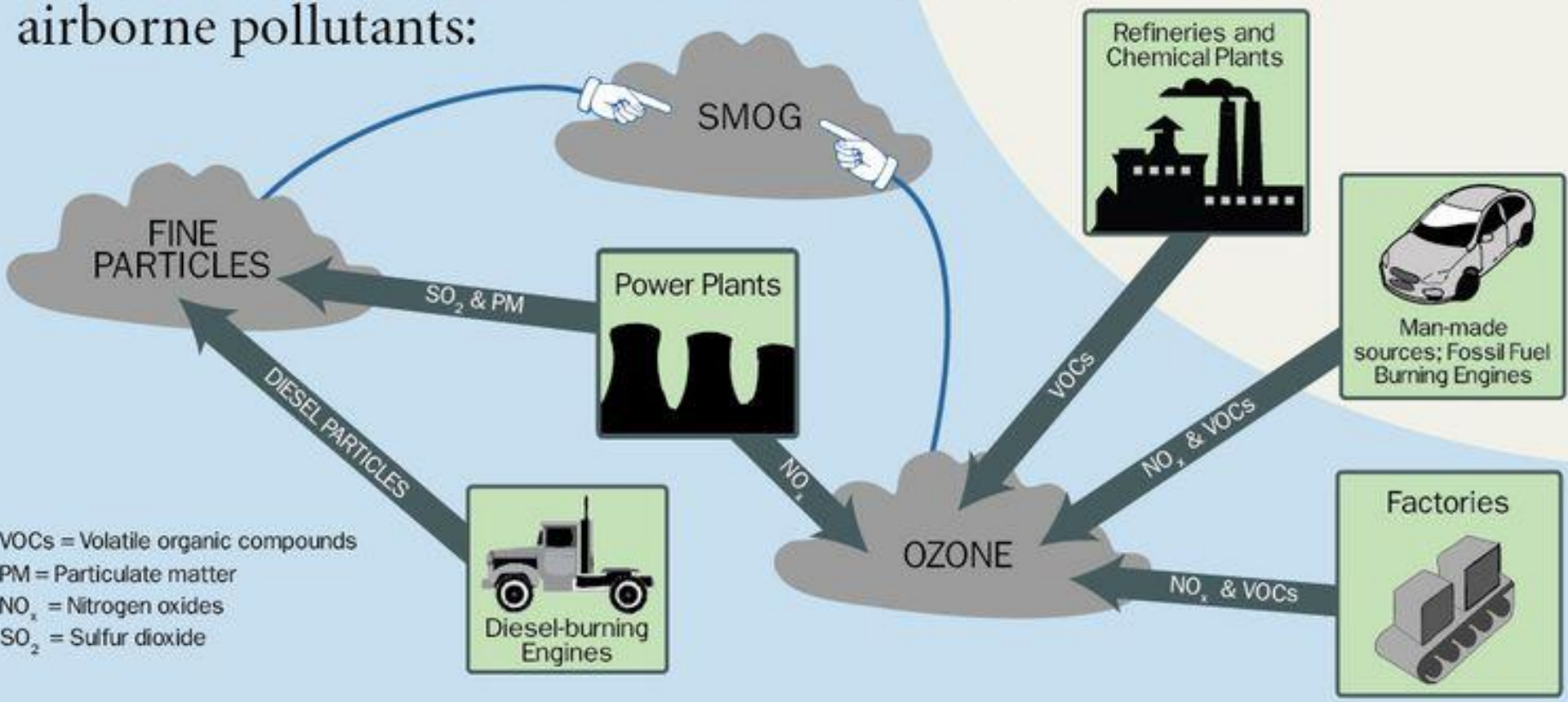
- Photochemical smog is a mixture of air pollutants formed by the reaction of nitrogen oxides and **volatile organic compounds** under the influence of sunlight.





# What is Smog?

Photochemical smog is created when sunlight reacts with certain airborne pollutants:



VOCs = Volatile organic compounds  
PM = Particulate matter  
 $\text{NO}_x$  = Nitrogen oxides  
 $\text{SO}_2$  = Sulfur dioxide



# Sunlight plus Cars Equals Photochemical Smog

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- Mexico City is one of the many cities in sunny, warm, dry climates with many motor vehicles that suffer from photochemical smog.

Figure 19-4

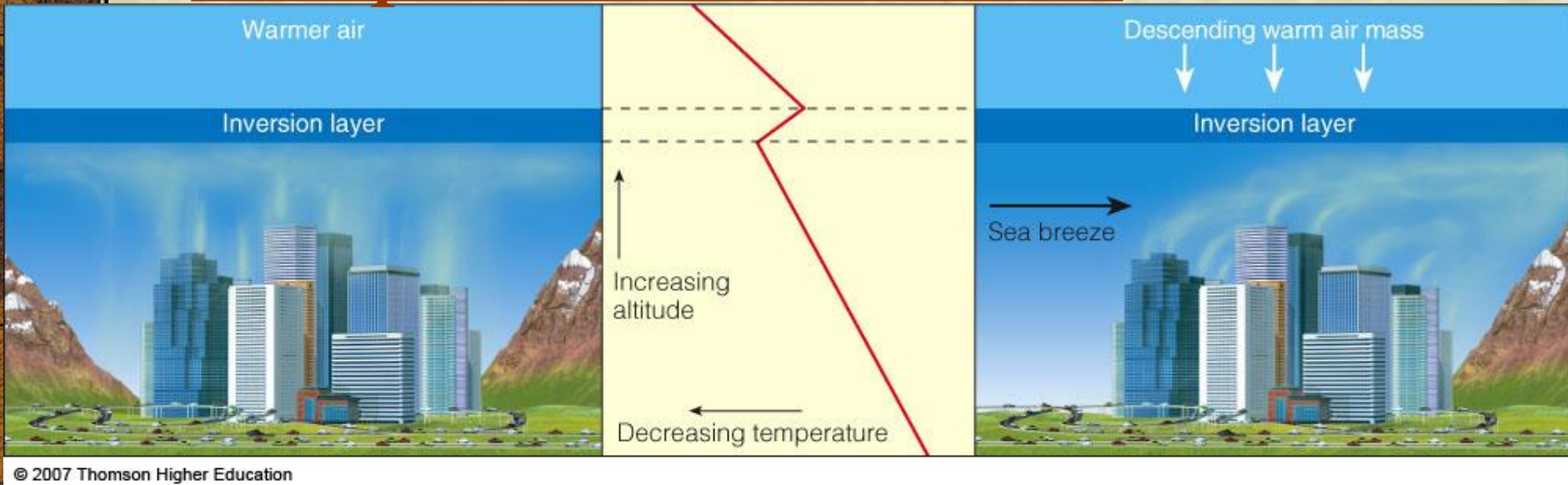


# Factors Influencing Levels of Outdoor Air Pollution

---

- Outdoor air pollution can be reduced by:
  - settling out, precipitation, sea spray, winds, and chemical reactions.
- Outdoor air pollution can be increased by:
  - urban buildings (slow wind dispersal of pollutants), mountains (promote temperature inversions), and high temperatures (promote photochemical reactions).

# Temperature Inversions



- Cold, cloudy weather in a valley surrounded by mountains can trap air pollutants (left).
- Areas with sunny climate, light winds, mountains on three sides and an ocean on the other (right) are susceptible to inversions. Especially a problem with high population (autos).

Figure 19-5

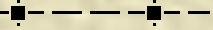




# ACID DEPOSITION

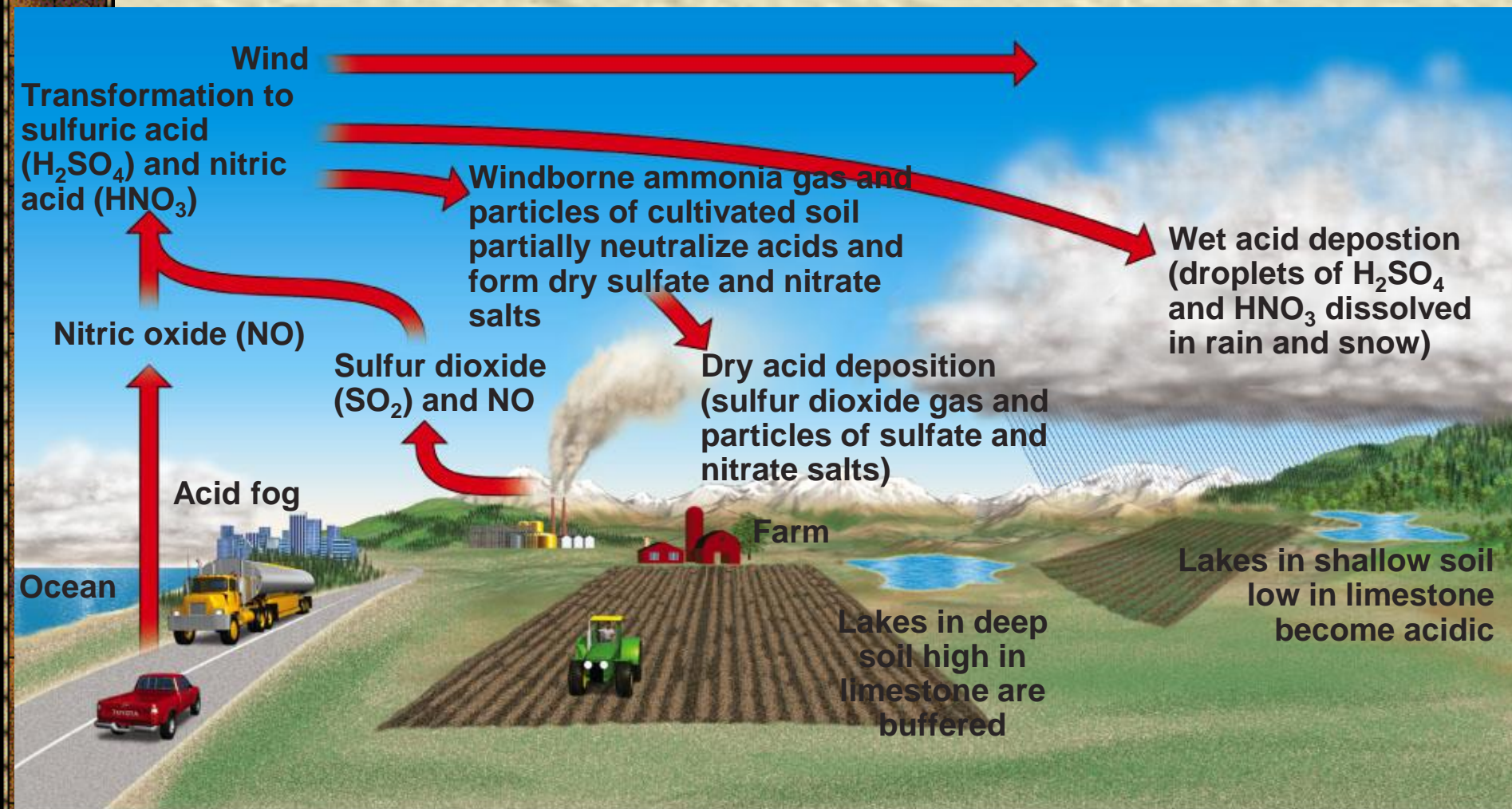
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- Sulfur dioxides (SO<sub>x</sub>), nitrogen oxides (NO<sub>x</sub>), and particulates can react in the atmosphere to produce acidic chemicals that can travel long distances before returning to the earth's surface.
  - Tall smokestacks reduce local air pollution but can increase regional air pollution.



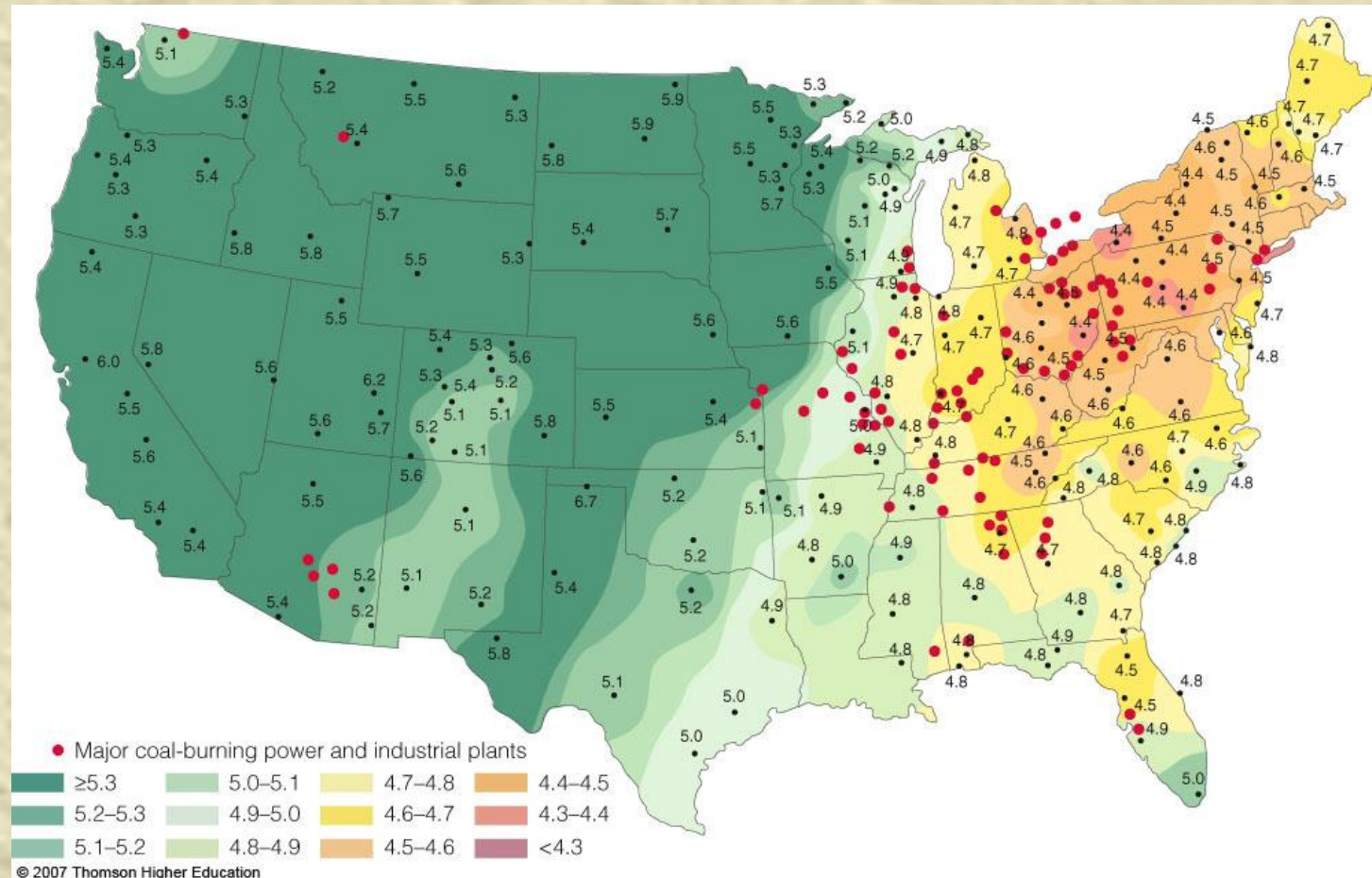
- Figure 19-6





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# ACID DEPOSITION



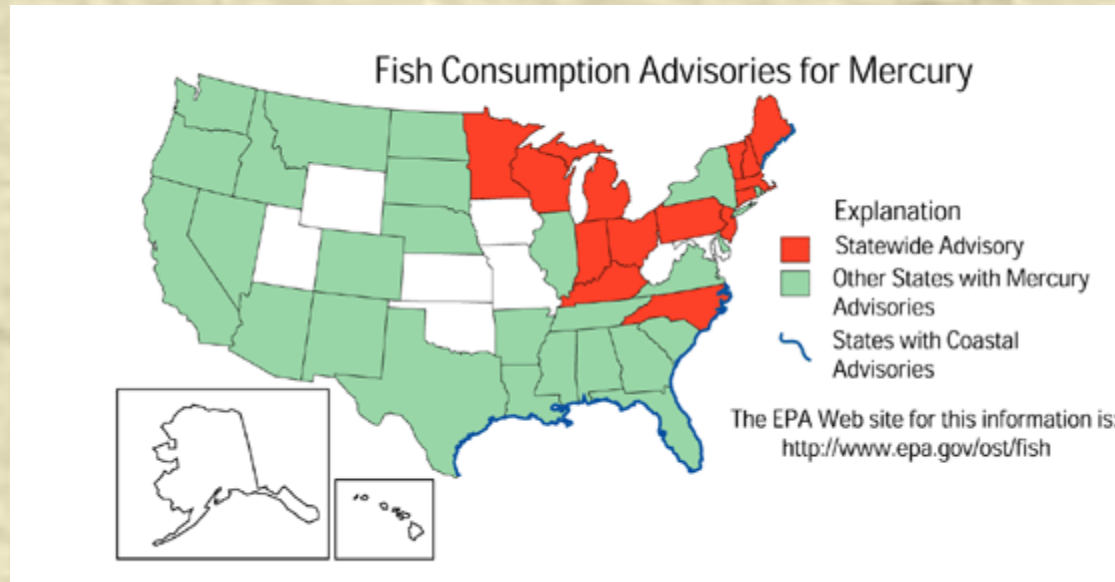
- pH measurements in relation to major coal-burning and industrial plants.

Figure 19-7

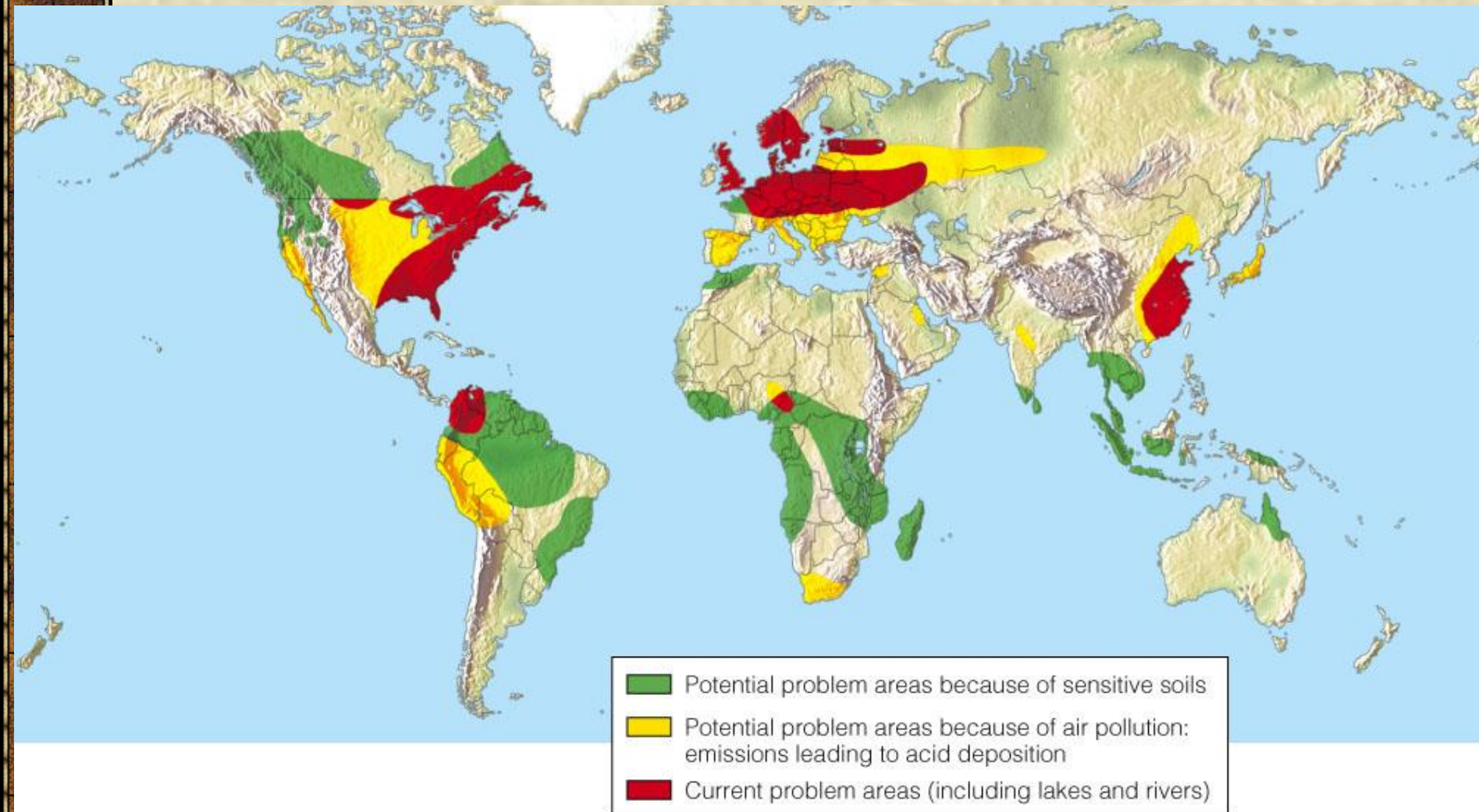


# ACID DEPOSITION

- Acid deposition contributes to chronic respiratory disease and can leach toxic metals (such as lead and mercury) from soils and rocks into acidic lakes used as sources for drinking water.



# ACID DEPOSITION

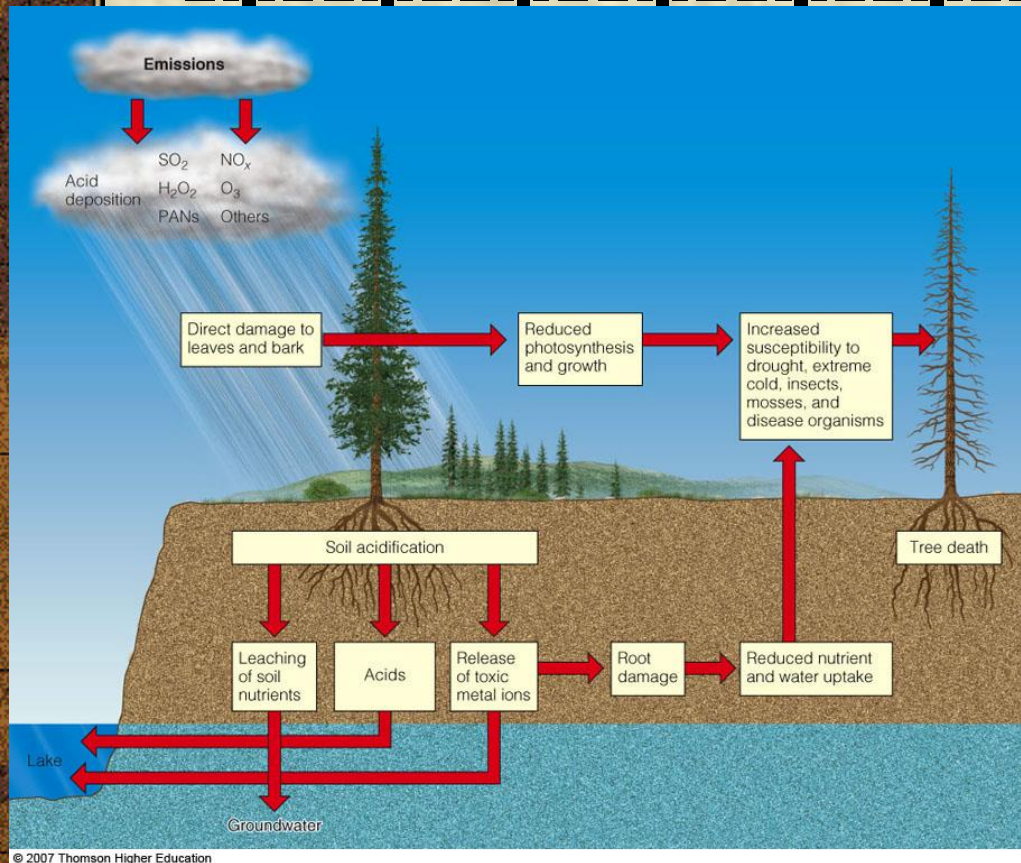


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Figure 19-8

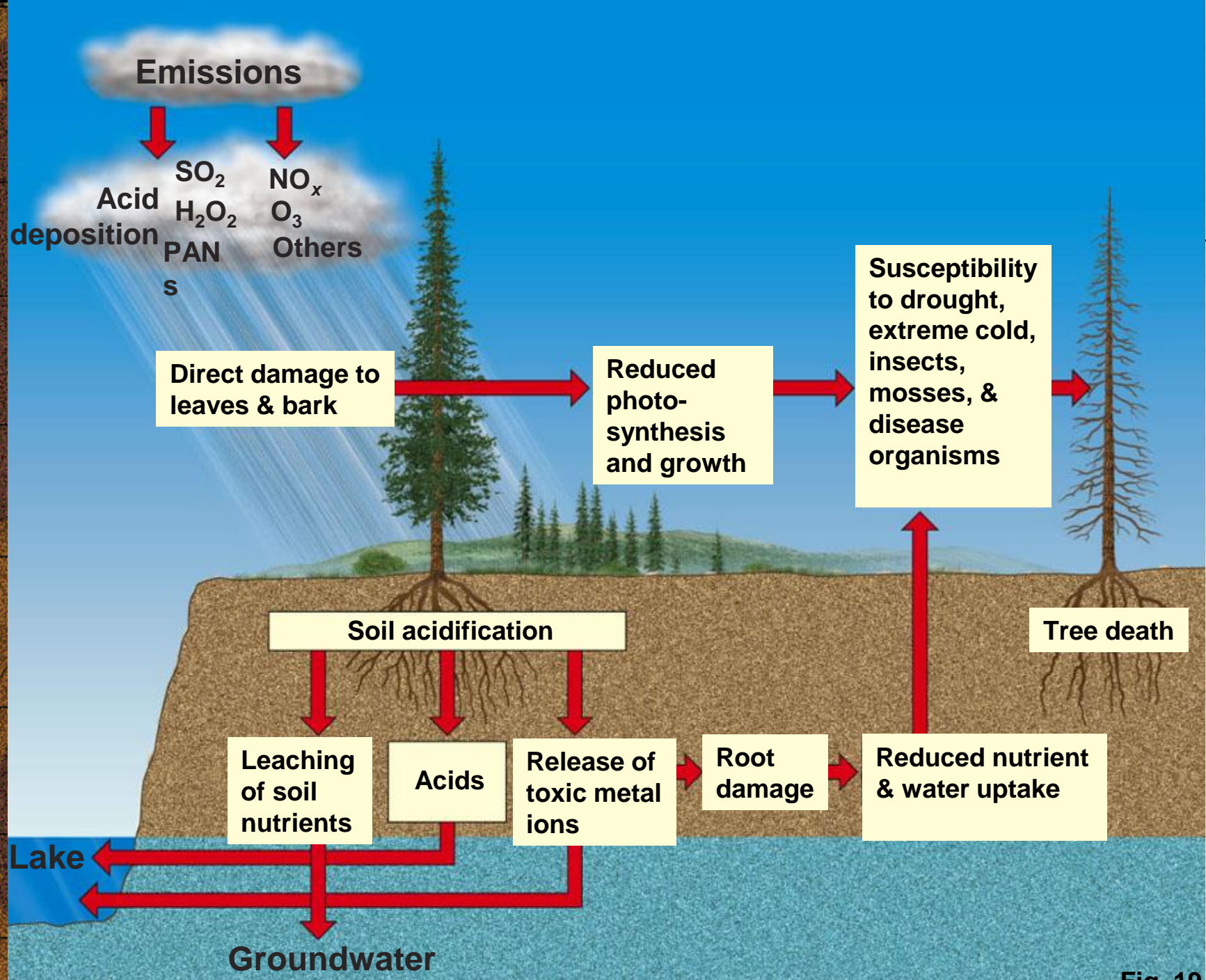


# ACID DEPOSITION



- Air pollution is one of several interacting stresses that can damage, weaken, or kill trees and pollute surface and groundwater.

Figure 19-9





## Solutions

### Acid Deposition

#### Prevention

Reduce air pollution  
by improving  
energy efficiency

Reduce coal use

Increase natural  
gas use

Increase use of  
renewable energy  
resources

Burn low-sulfur coal

Remove  $\text{SO}_2$   
particulates &  $\text{NO}_x$   
from smokestack  
gases

Remove  $\text{NO}_x$  from  
motor vehicular  
exhaust

Tax emissions of  $\text{SO}_2$



#### Cleanup

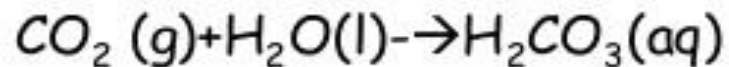
Add lime to  
neutralize  
acidified lakes

Add phosphate  
fertilizer to  
neutralize  
acidified lakes

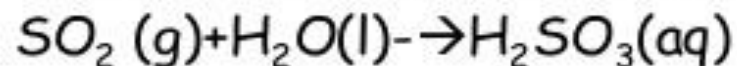
# MAKING ACID RAIN



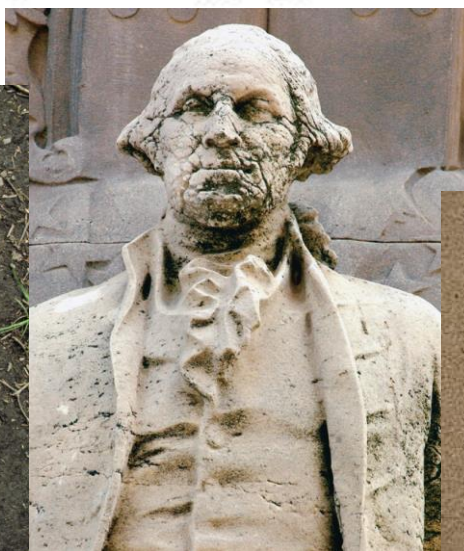
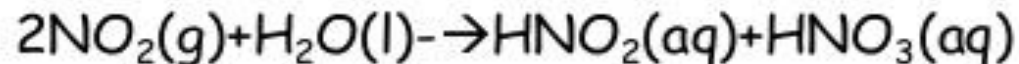
- When  $\text{CO}_2$  reacts with water, carbonic acid is formed.



- When  $\text{SO}_2$  reacts with water, sulfurous acid is formed.



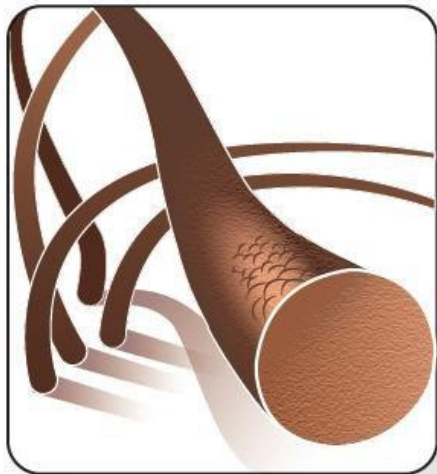
- When  $\text{NO}_2$  reacts with water, nitric acid is formed.



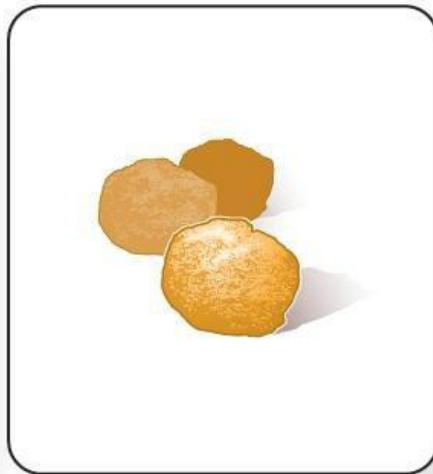


# Particulate Matter (PM)

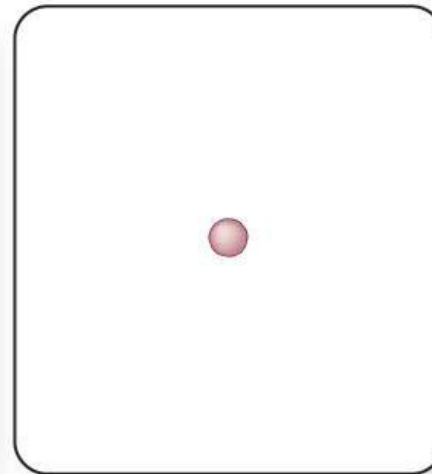
## Fine Particulate Matter Size Comparison



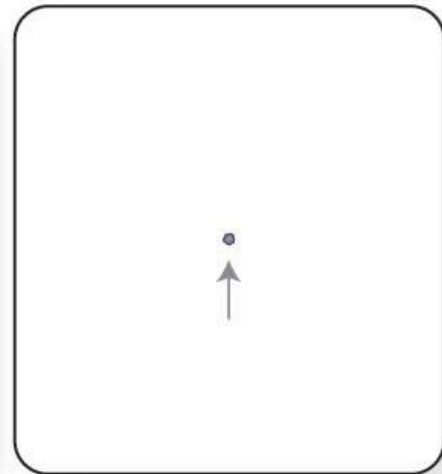
Human hair (about  $70\mu\text{m}$  wide)



Grain of sand (about  $50\mu\text{m}$  wide)



$\text{PM}_{10}$  (less than  $10\mu\text{m}$  wide)

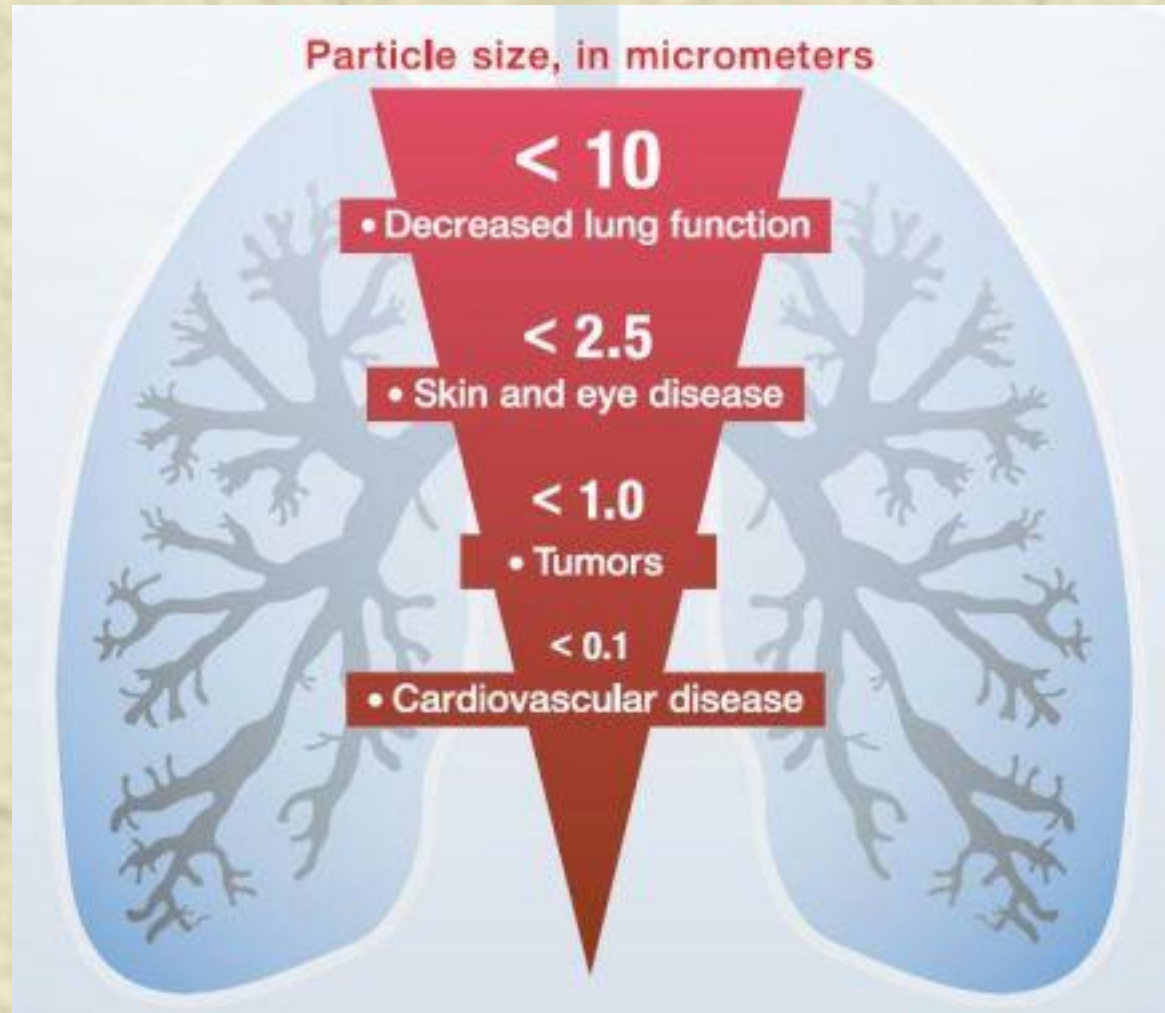


$\text{PM}_{2.5}$  (less than  $2.5\mu\text{m}$  wide)

$\mu\text{m}$  = micrometer

# Health Risks of Particulate Matter

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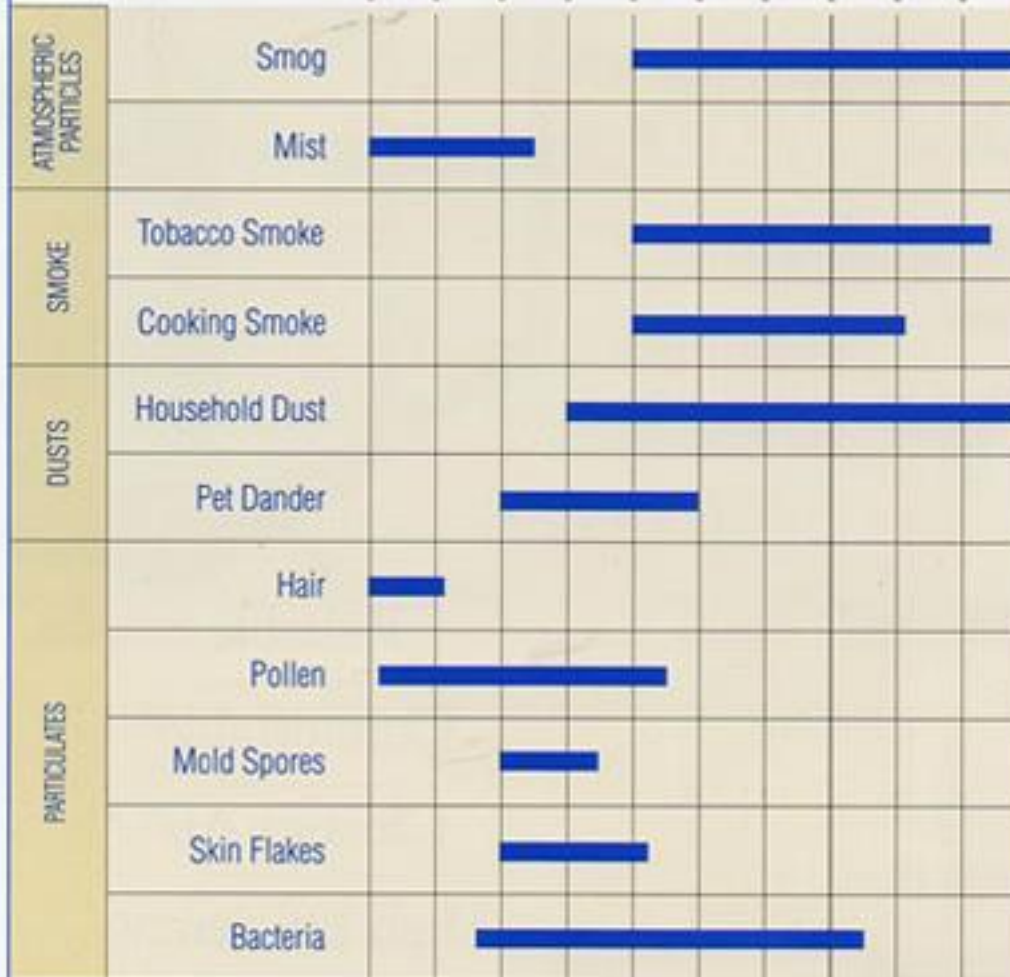




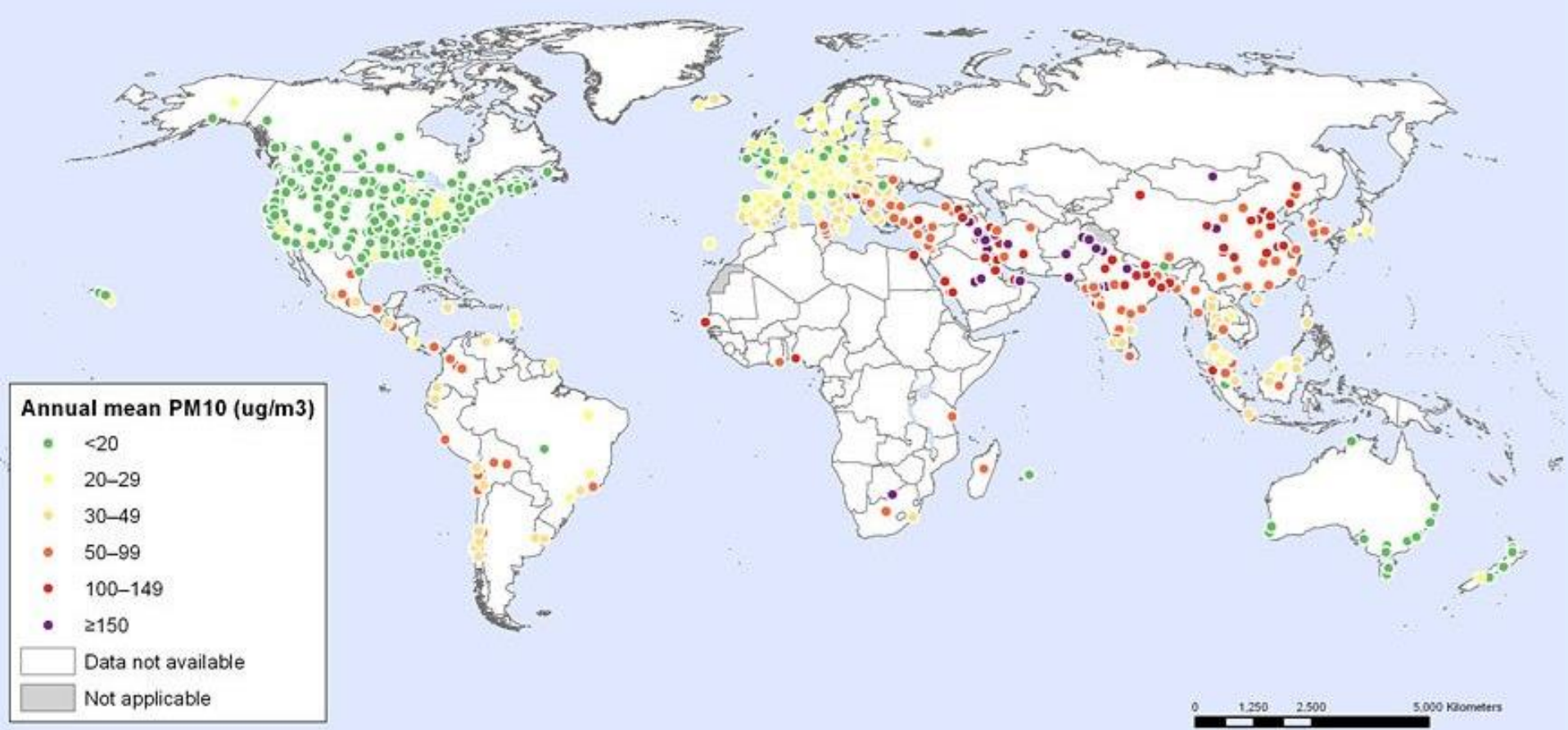
## Common Air Contaminant

Approximate particle size (microns)

Visible to Naked Eye	Visible Through Light Microscope					Visible Through Electron Microscope				
100	50	25	10	1	0.5	0.4	0.3	0.1	0.01	



AccuClean can filter up to 99.98% of all the airborne allergens listed on this chart — .1 microns and larger — allergens that might otherwise be inhaled and become trapped in your lungs.



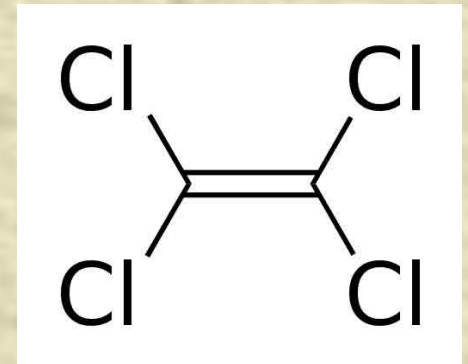
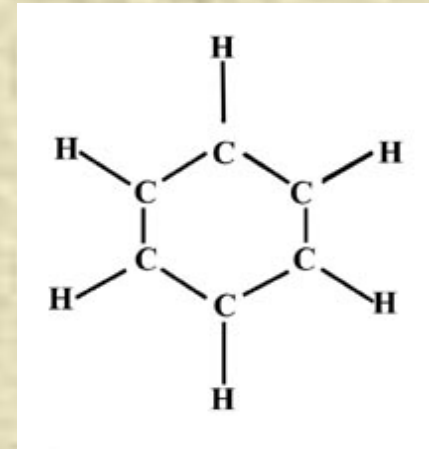


# Hazardous Air Pollutants

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HAPs:

- Pesticides
- Benzene in gasoline
- Glues
- Cleaners
- Perchloroethylene (dry cleaners)
- Toxic metals from smelters



# Air Quality is better in US; EPA estimates since 1970

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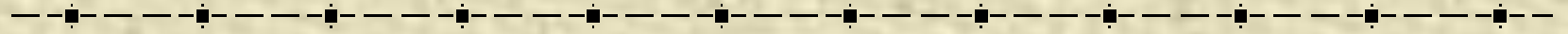
- Particulate Matter (PM)- down 78%
- Carbon Dioxide (CO<sub>2</sub>)- down 23%
- Nitrogen Dioxide (NO<sub>x</sub>)- **up 14%**
- Lead (Pb)- down 98%
- Sulfur Dioxide (SO<sub>2</sub>)- down 32%

Air quality is worse in developing countries:

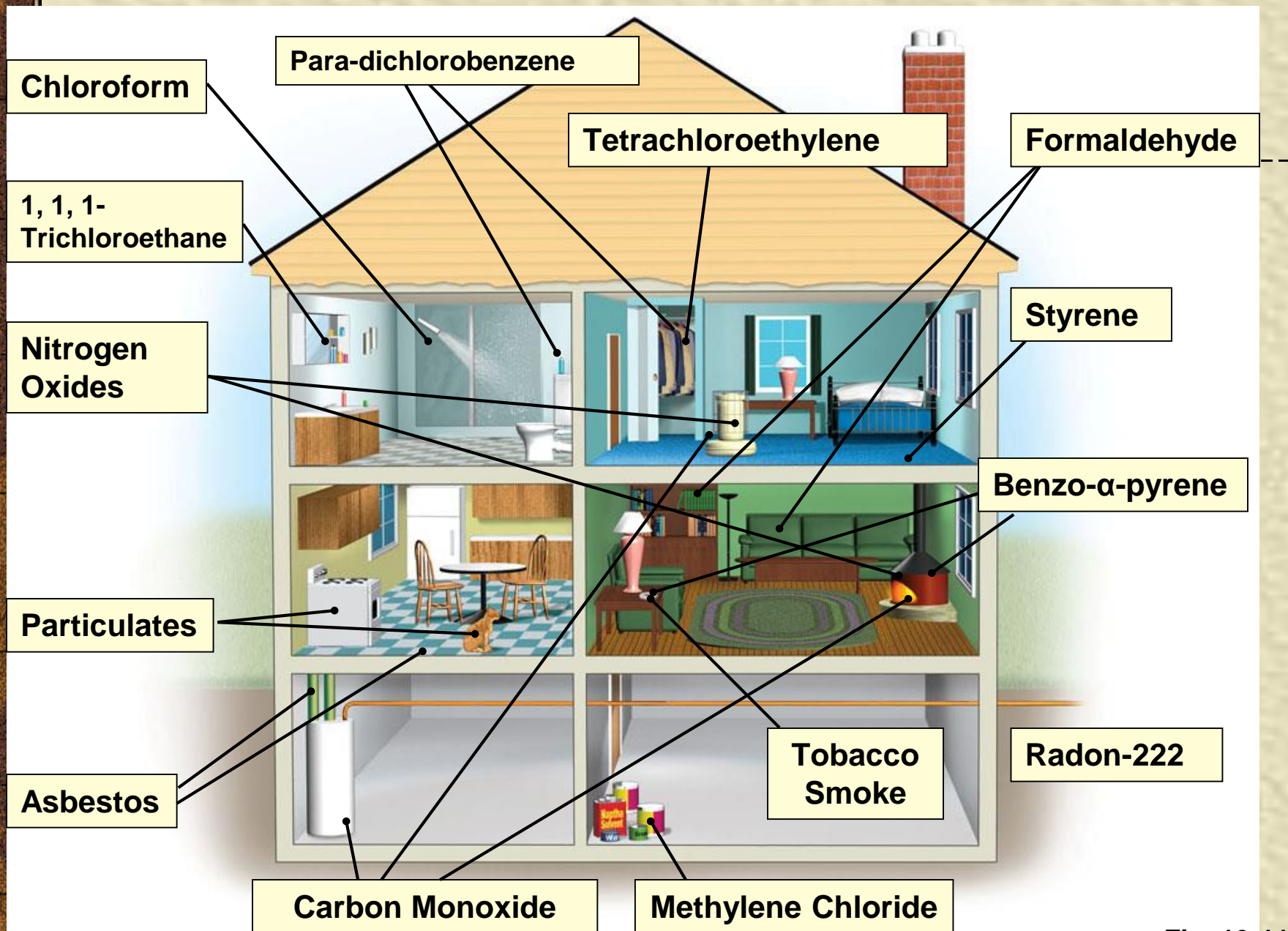
Mexico City & Beijing: air exceeds WHO standards 350 days/year



# INDOOR AIR POLLUTION



- Indoor air pollution usually is a greater threat to human health than outdoor air pollution.
- According to the EPA, the four most dangerous indoor air pollutants in developed countries are:
  - Tobacco smoke.
  - Formaldehyde.
  - Radioactive radon-222 gas.
  - Very small fine and ultrafine particles.





# INDOOR AIR POLLUTION

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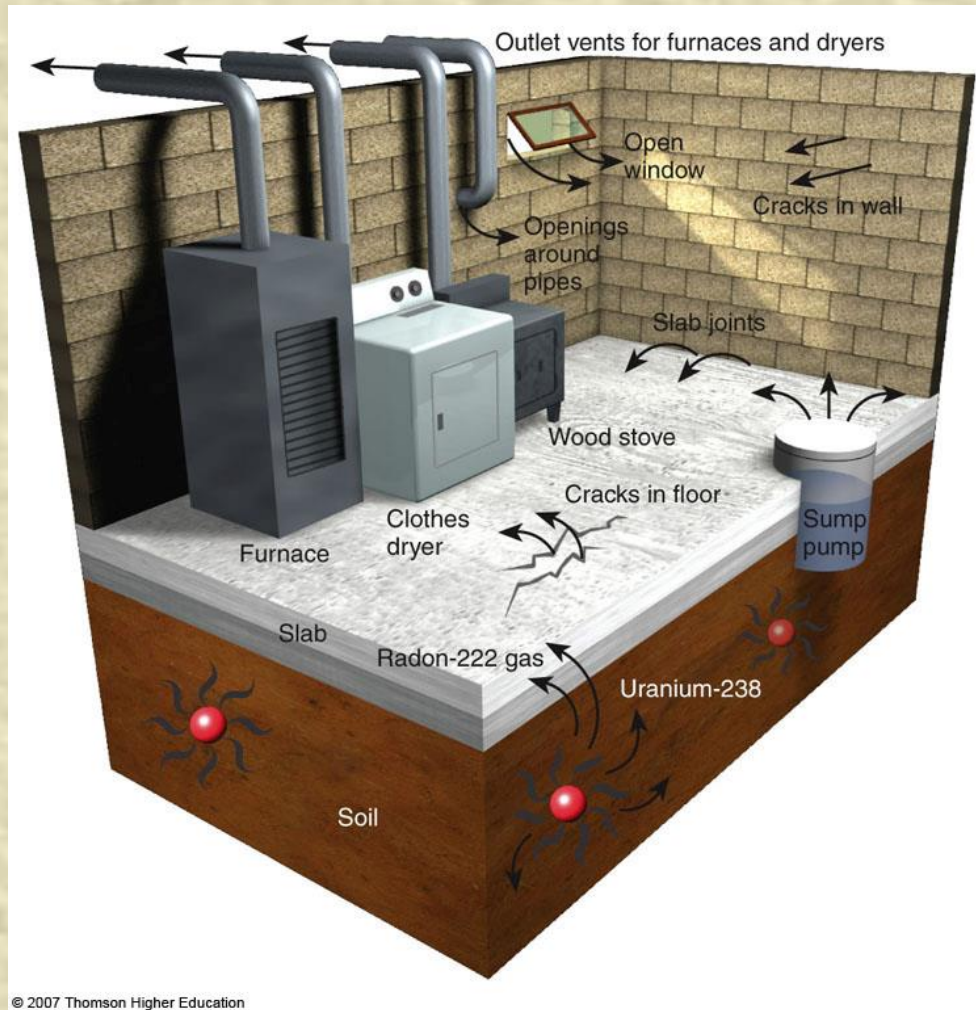


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- Household dust mites that feed on human skin and dust, live in materials such as bedding and furniture fabrics.
- Can cause asthma attacks and allergic reactions in some people.

Figure 19-12

# Case Study: Radioactive Radon



- Radon-222, a radioactive gas found in some soils and rocks, can seep into some houses and increase the risk of lung cancer.

Sources and paths of entry for indoor radon-222 gas.



# HEALTH EFFECTS OF AIR POLLUTION

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Normal human lungs (left) and the lungs of a person who died of emphysema (right).



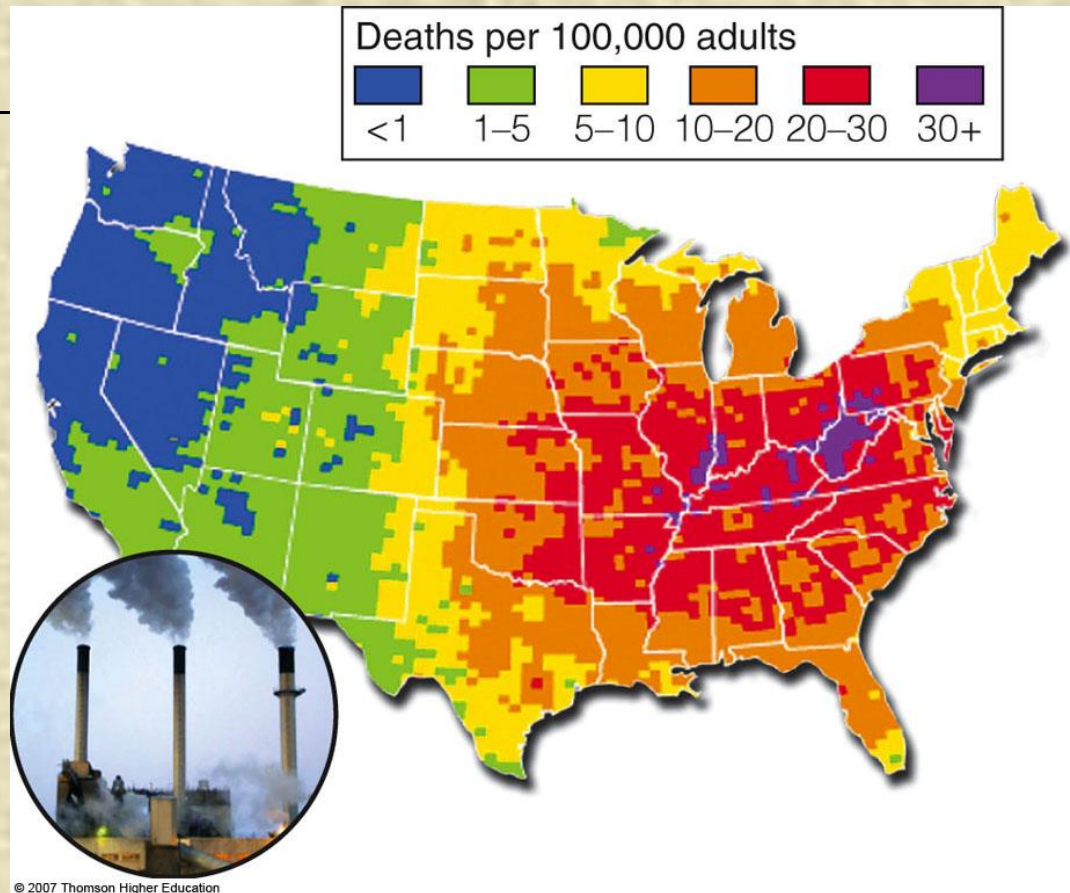
# Air Pollution is a Big Killer

---

- Each year, air pollution prematurely kills about 3 million people, mostly from indoor air pollution in developing countries.
  - In the U.S., the EPA estimates that annual deaths related to indoor and outdoor air pollution range from 150,000 to 350,000.
  - According to the EPA, each year more than 125,000 Americans get cancer from breathing diesel fumes.



# Air Pollution is a Big Killer



- Spatial distribution of premature deaths from air pollution in the United States.

# PREVENTING AND REDUCING AIR POLLUTION

---

- The Clean Air Acts in the United States have greatly reduced outdoor air pollution from six major pollutants:
  - Carbon monoxide
  - Nitrogen oxides
  - Sulfur dioxides
  - Suspended particulate matter (less than PM-10)



# Using the Marketplace to Reduce Outdoor Air Pollution

---

- To help reduce SO<sub>2</sub> emissions, the Clean Air Act authorized an emission trading (cap-and-trade) program.
  - Enables the 110 most polluting power plants to buy and sell SO<sub>2</sub> pollution rights.
  - Between 1990-2002, the emission trading system reduced emissions.
  - In 2002, the EPA reported the cap-and-trade system produced less emission reductions than were projected.



# Solutions:

## Reducing Outdoor Air Pollution

---

- There are a of ways to prevent and control air pollution from coal-burning facilities.
  - *Electrostatic precipitator*: are used to attract negatively charged particles in a smokestack into a collector.
  - *Wet scrubber*: fine mists of water vapor trap particulates and convert them to a sludge that is collected and disposed of usually in a landfill.





# Solutions:

## Reducing Outdoor Air Pollution

---

- There are a number of ways to prevent and control air pollution from motor vehicles.
  - Because of the Clean Air Act, a new car today in the U.S. emits 75% less pollution than did pre-1970 cars.
  - There is an increase in motor vehicle use in developing countries and many have no pollution control devices and burn leaded gasoline.

# Solutions

## Motor Vehicle Air Pollution

### Prevention

**Mass transit**

**Bicycles and walking**

**Less polluting engines**

**Less polluting fuels**

**Improve fuel efficiency**

**Get older, polluting cars off the road**

**Give buyers large tax write-offs or rebates for buying low-polluting, energy efficient vehicles**



### Cleanup

**Emission control devices**

**Car exhaust inspections twice a year**

**Stricter emission standards**





# Indoor Air Pollution

---

- Little effort has been devoted to reducing indoor air pollution even though it poses a much greater threat to human health than outdoor air pollution.
- Environmental and health scientists call for us to focus on preventing air pollution (especially indoor) in developing countries.

## Solutions

### Indoor Air Pollution

#### Prevention

#### Cleanup or Dilution

**Cover ceiling tiles & lining of AC ducts to prevent release of mineral fibers**

**Ban smoking or limit it to well ventilated areas**

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

**Prevent radon infiltration**

**Use office machines in well ventilated areas**

**Use less polluting substitutes for harmful cleaning agents, paints, and other products**



**Use adjustable fresh air vents for work spaces**

**Increase intake of outside air**

**Change air more frequently**

**Circulate a building's air through rooftop green houses**

**Use exhaust hoods for stoves and appliances burning natural gas**

**Install efficient chimneys for wood-burning stoves**



# 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  $0.5^{\circ}\text{C}$  over a 15 month period and then return to normal by 1995.

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# PAST CLIMATE AND THE GREENHOUSE EFFECT

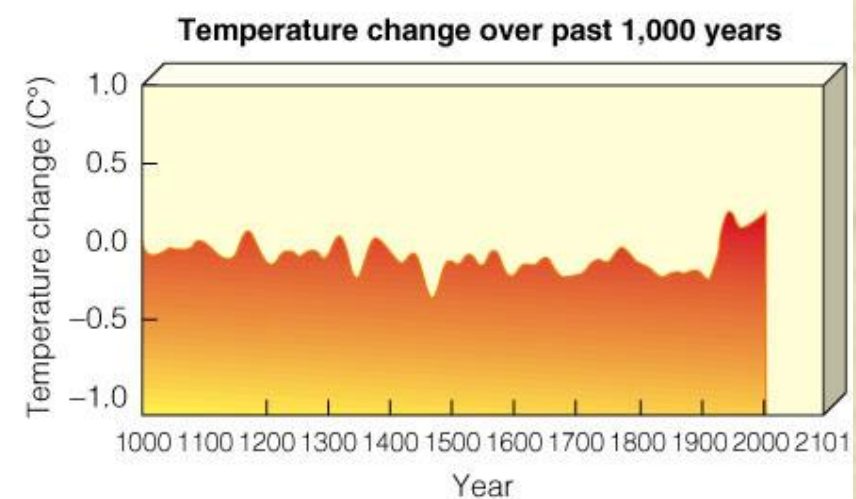
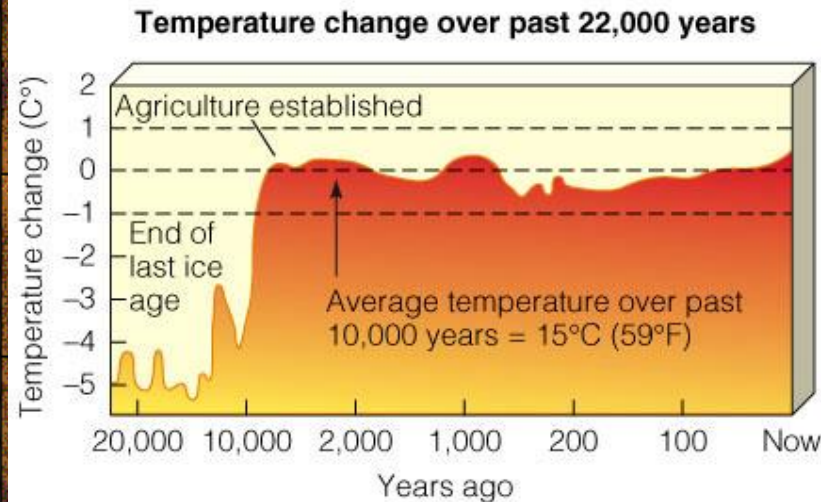
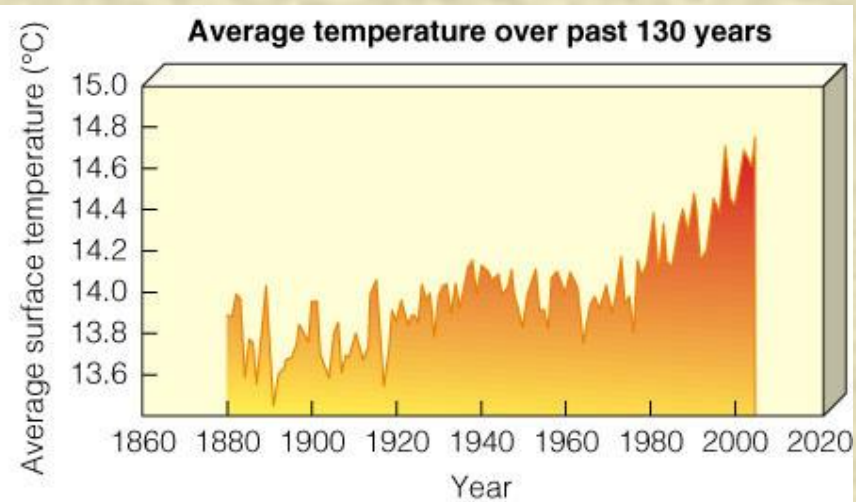
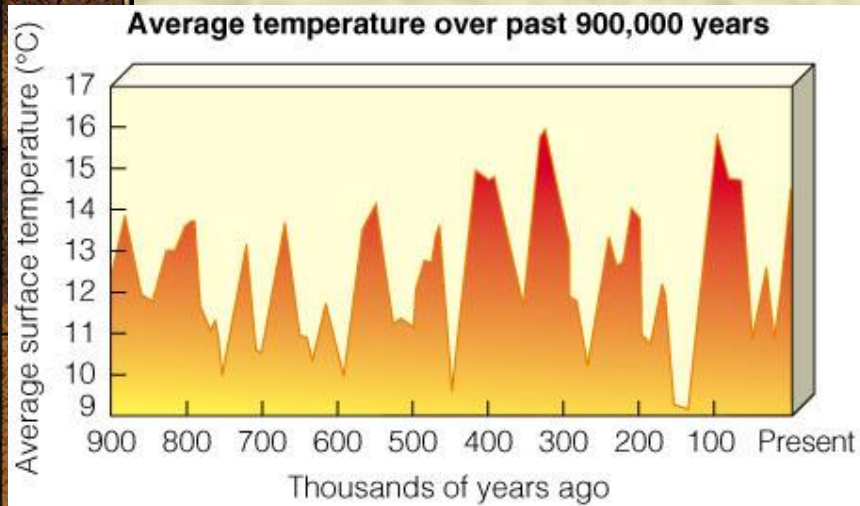


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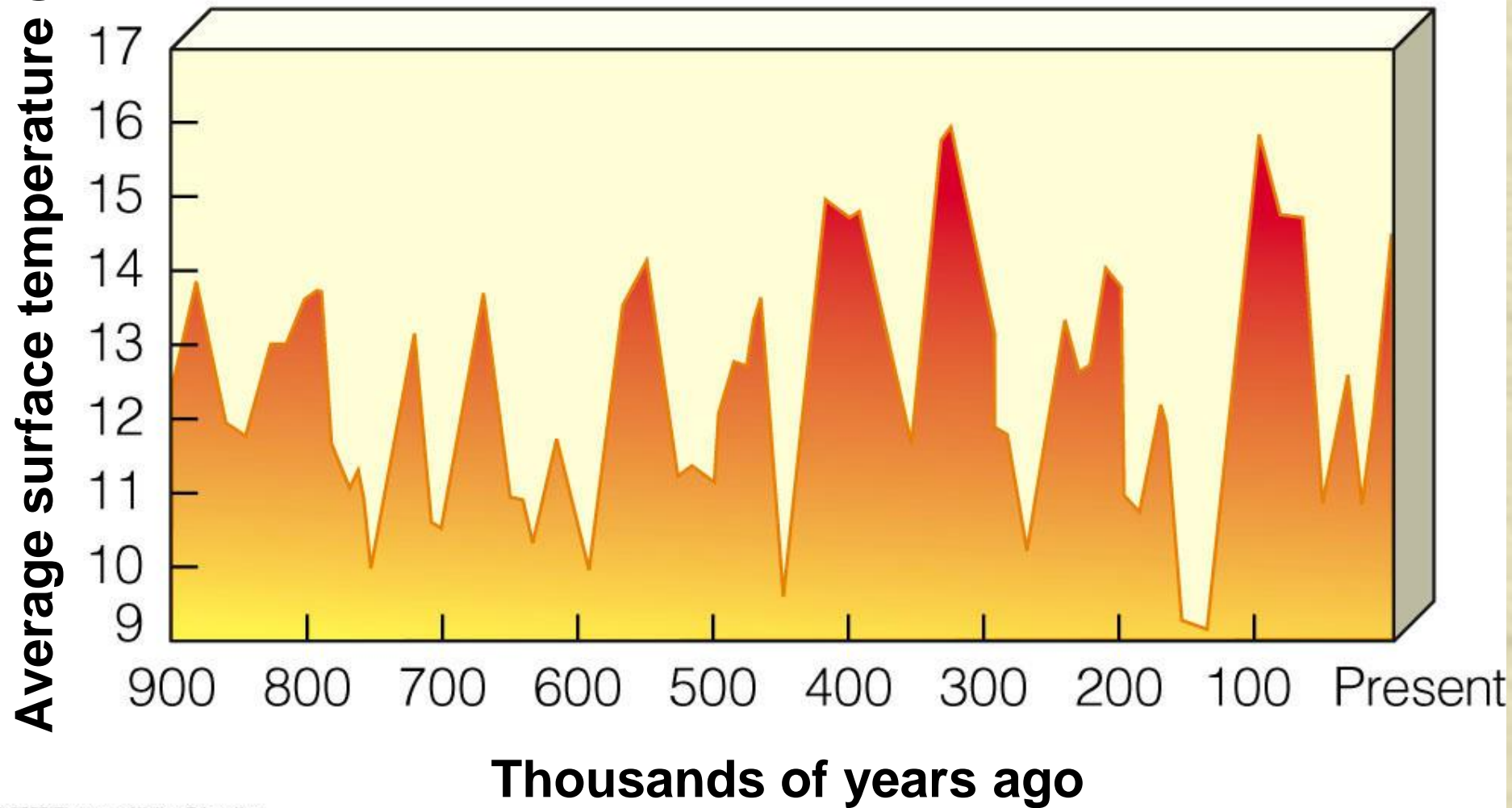
- Over the past 900,000 years, the troposphere has experienced prolonged periods of global cooling and global warming.
- For the past 1,000 years, temperatures have remained fairly stable but began to rise during the last century.



# PAST CLIMATE AND THE GREENHOUSE EFFECT



## Average temperature over past 900,000 years

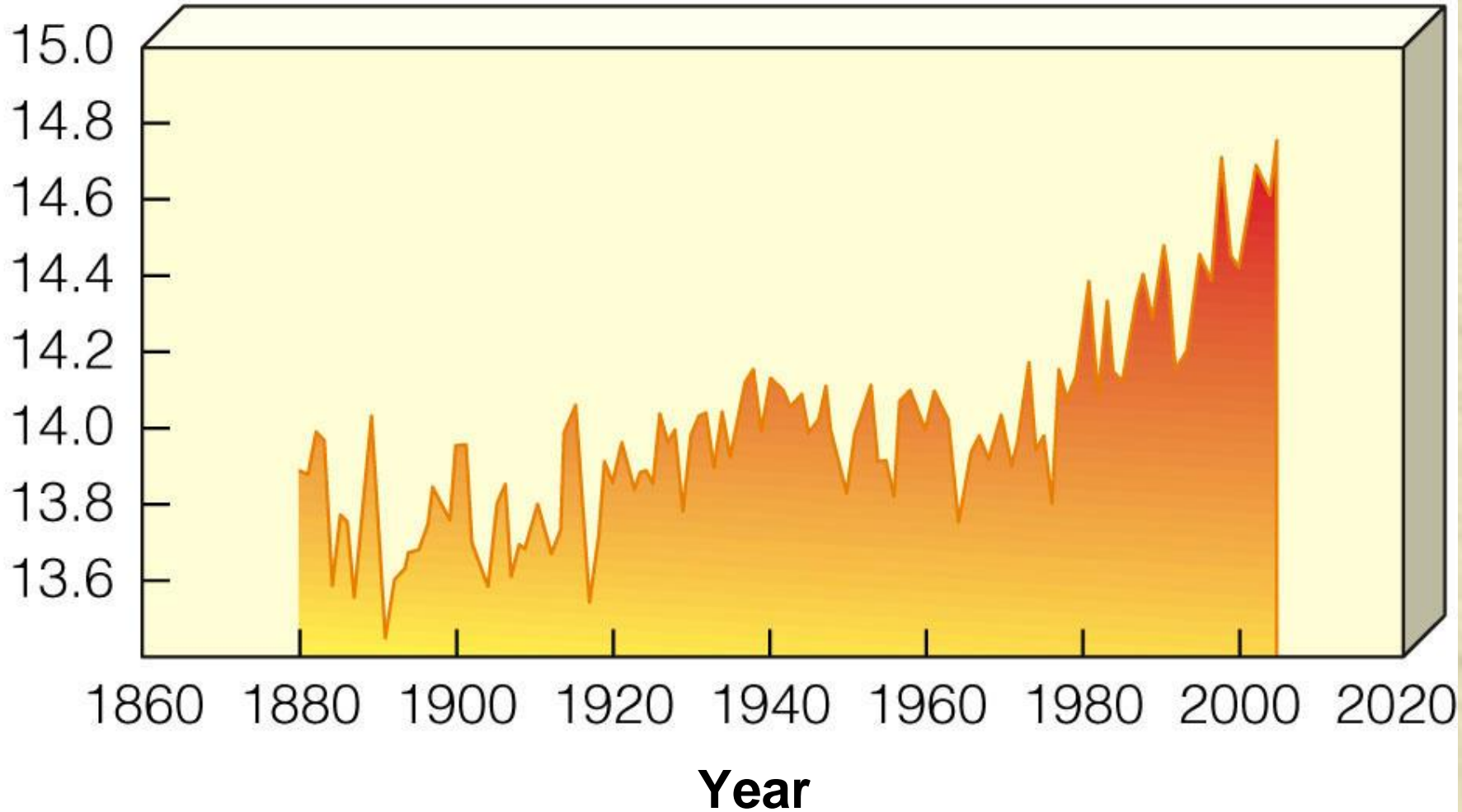


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Average surface temperature (°C)

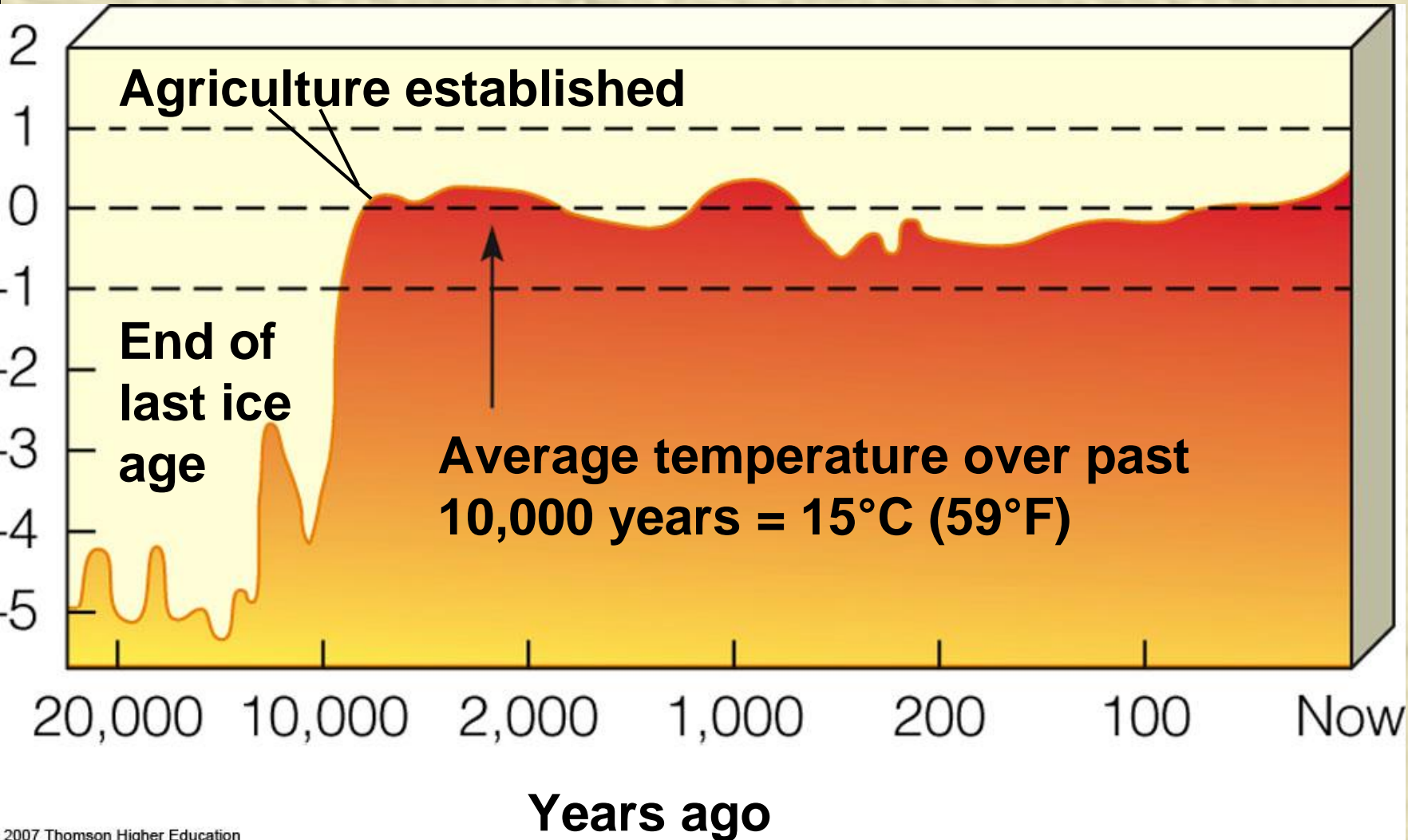
## Average temperature over past 130 years



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# Temperature change over past 22,000 years

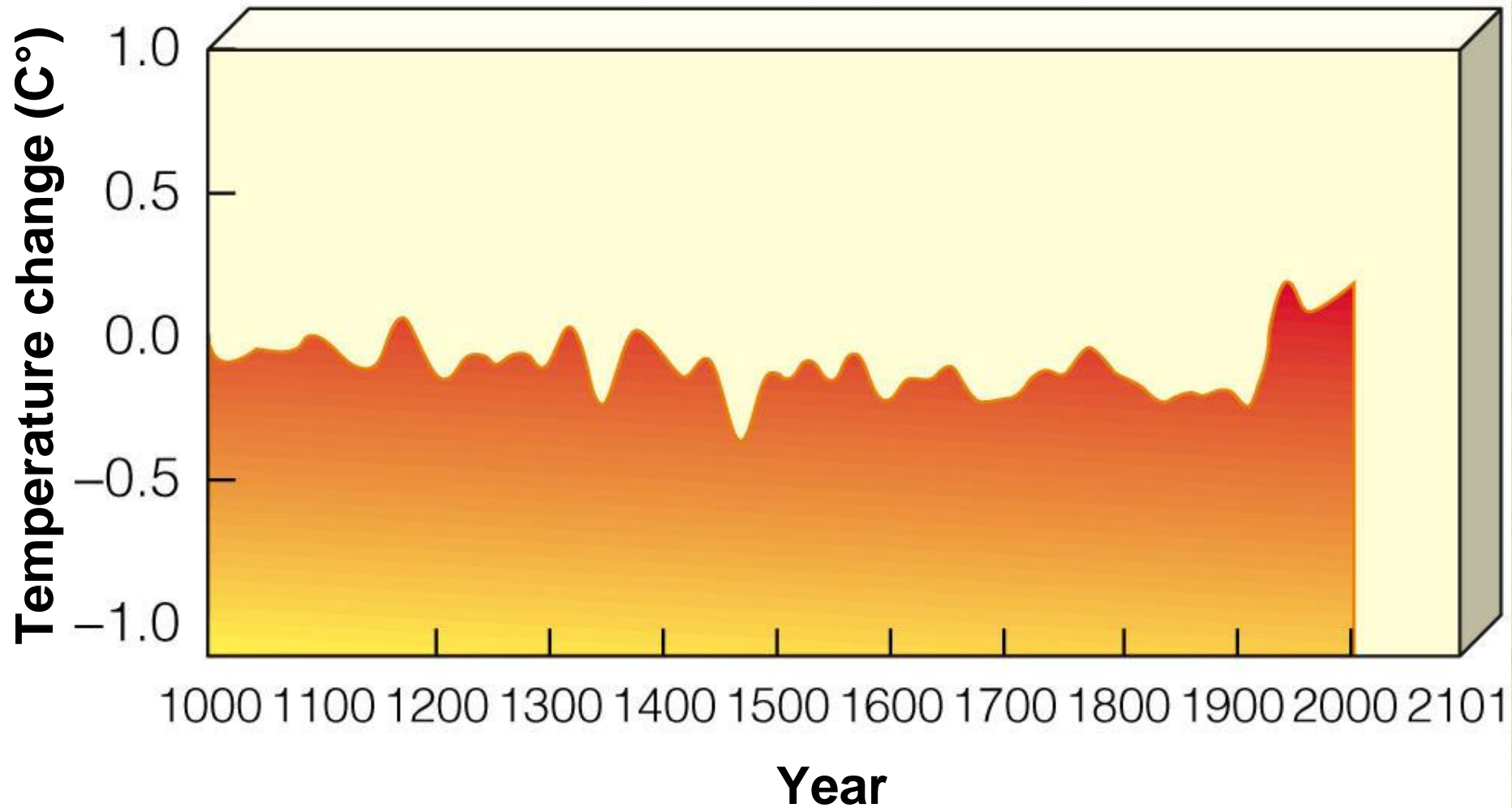
Temperature change (C°)



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## Temperature change over past 1,000 years



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

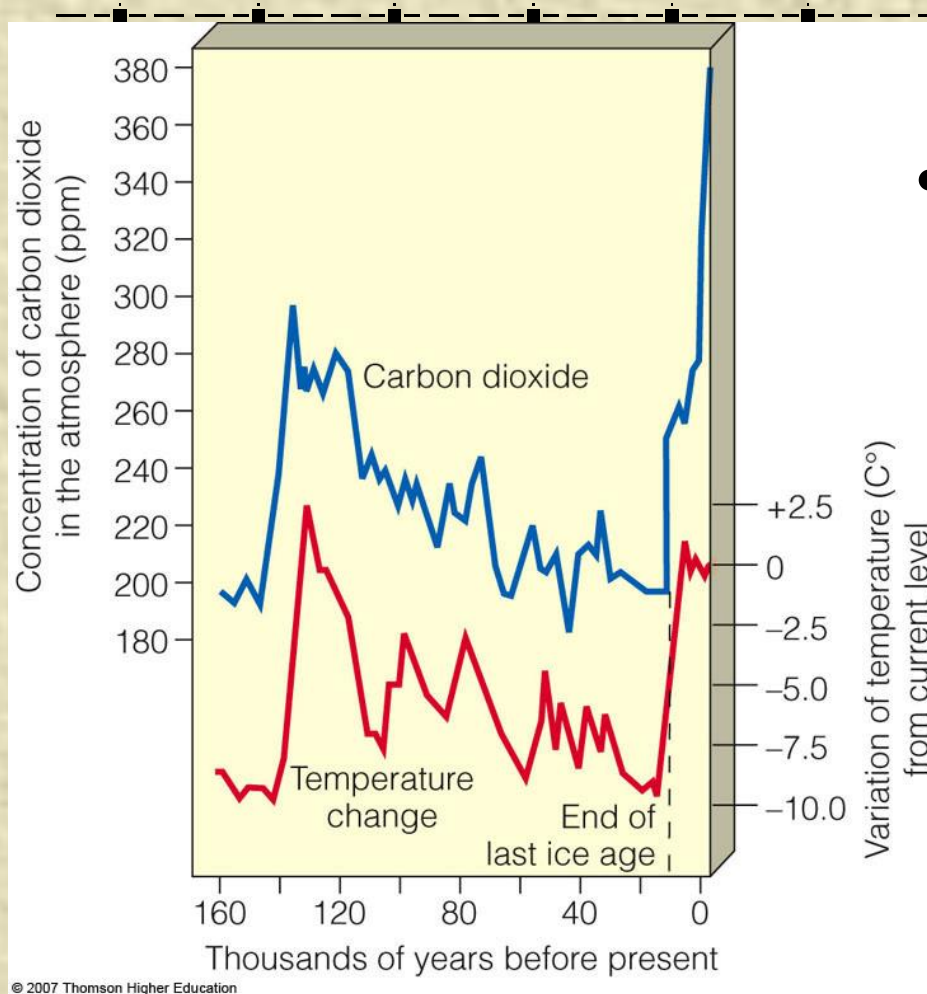


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- Scientists analyze tiny air bubbles trapped in ice cores learn about past:
  - *troposphere composition.*
  - *temperature trends.*
  - *greenhouse gas concentrations.*
  - *solar, snowfall, and forest fire activity.*



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

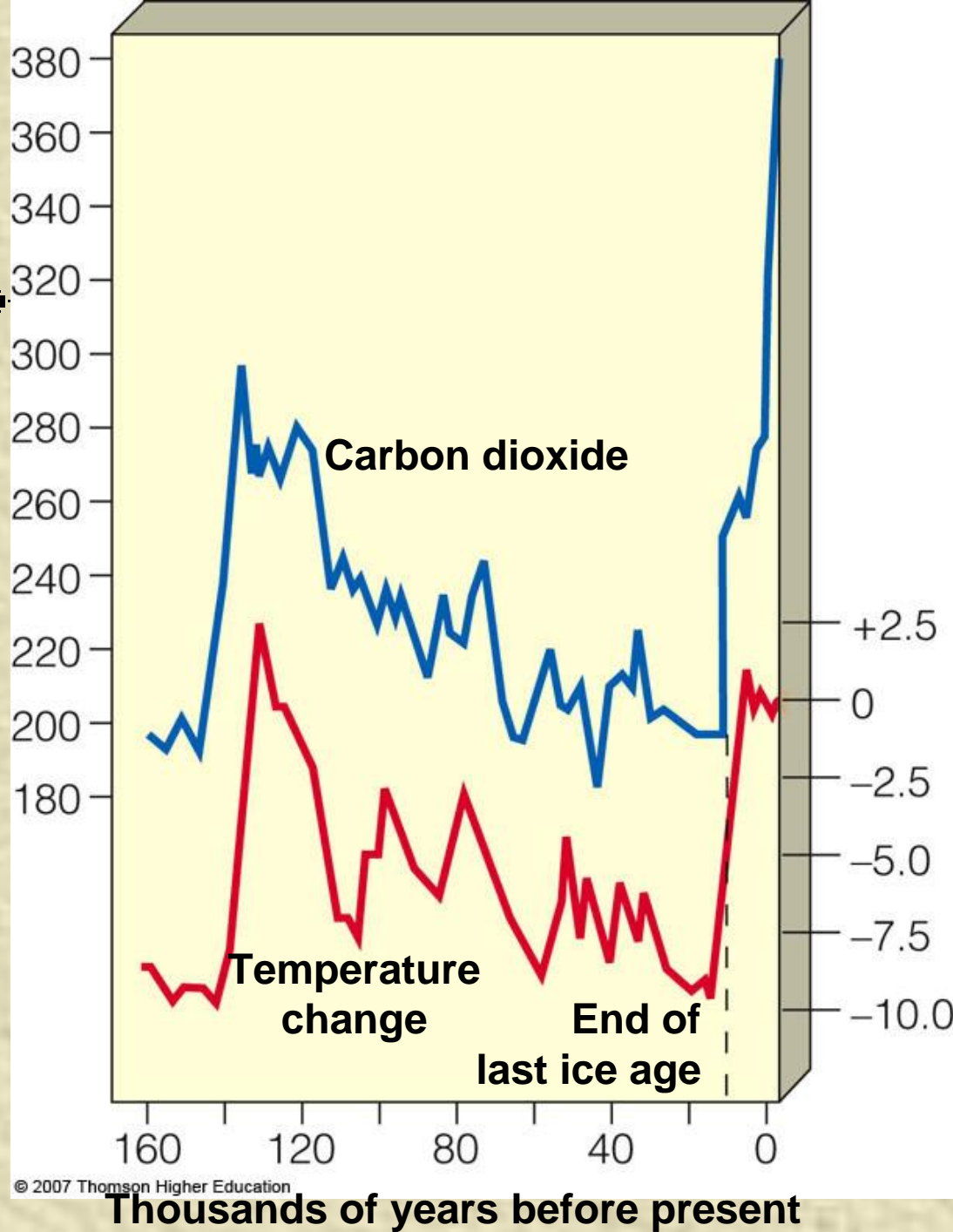


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- In 2005, an ice core showed that CO<sub>2</sub> levels in the troposphere are the highest they have been in 650,000 years.

Figure 20-4

Concentration of carbon dioxide  
in the atmosphere (ppm)



Variation of temperature (C°)  
from current level

Fig. 20-4, p.



# 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



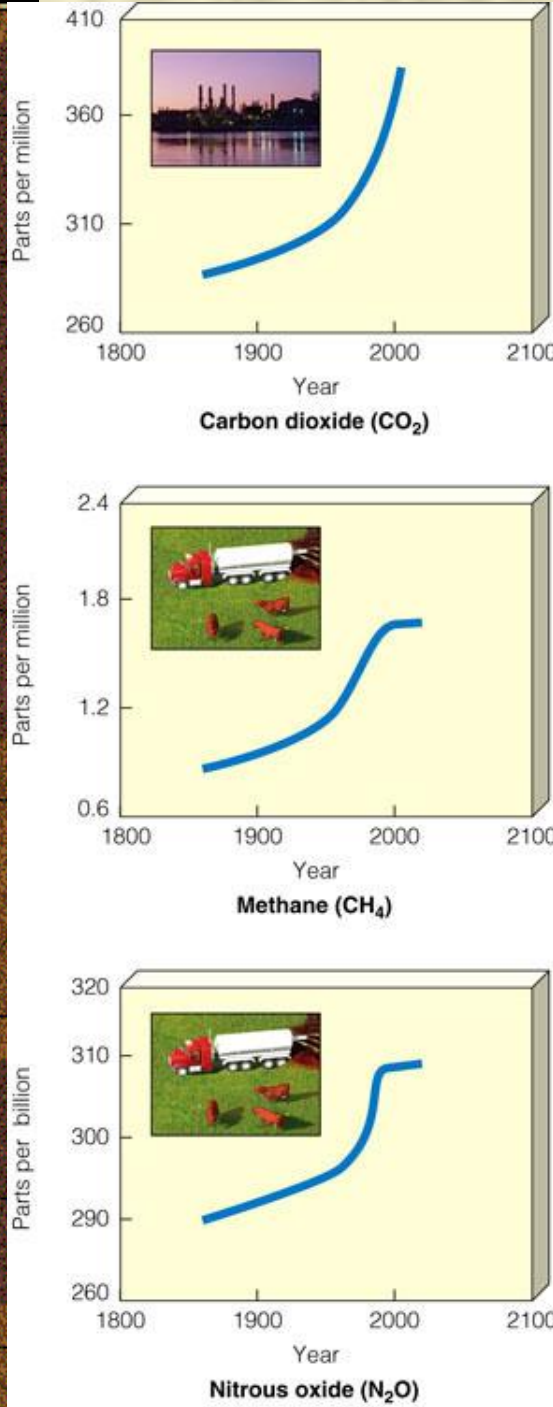
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- The major greenhouse gases in the lower atmosphere are water vapor, carbon dioxide, methane, and nitrous oxide.
  - These gases have always been present in the earth's troposphere in varying concentrations.
  - Fluctuations in these gases, plus changes 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.



# 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 C°.
  - 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.



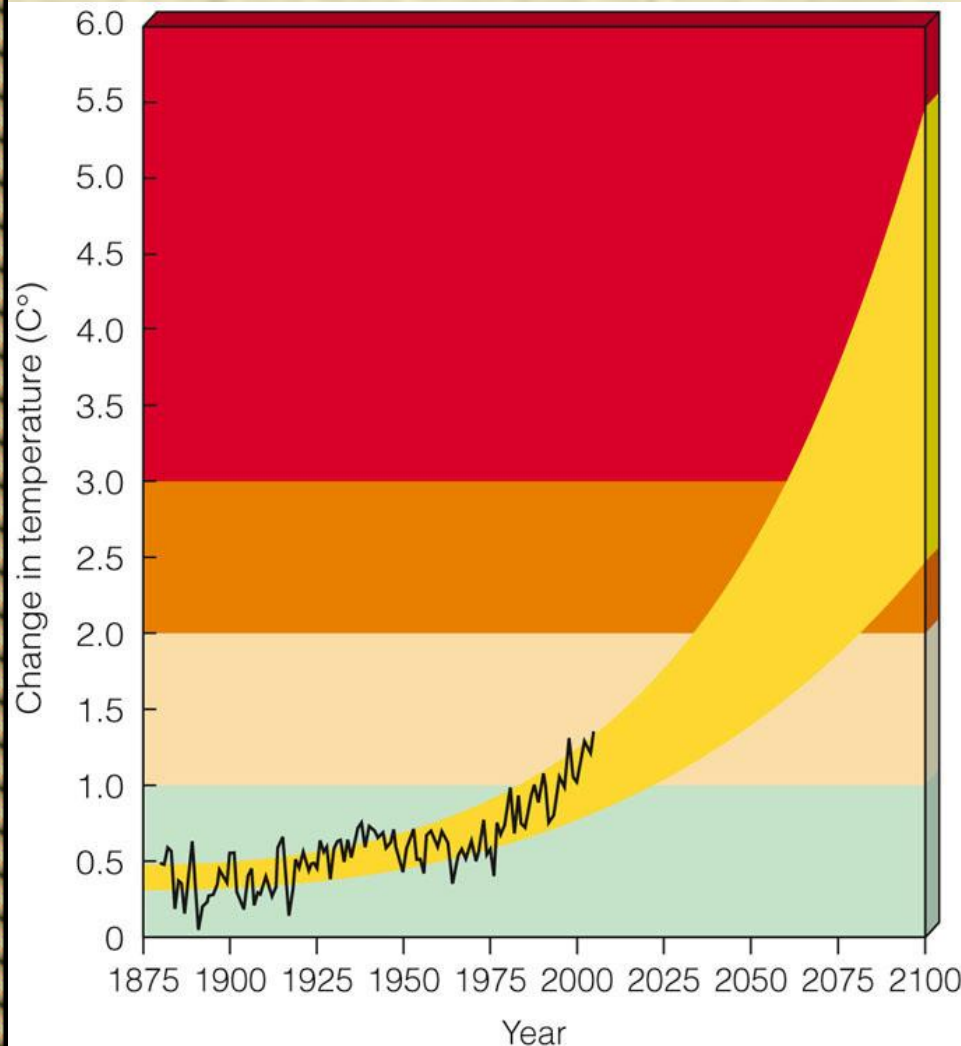
# CLIMATE CHANGE AND HUMAN ACTIVITIES



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- 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



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

Figure 20-7

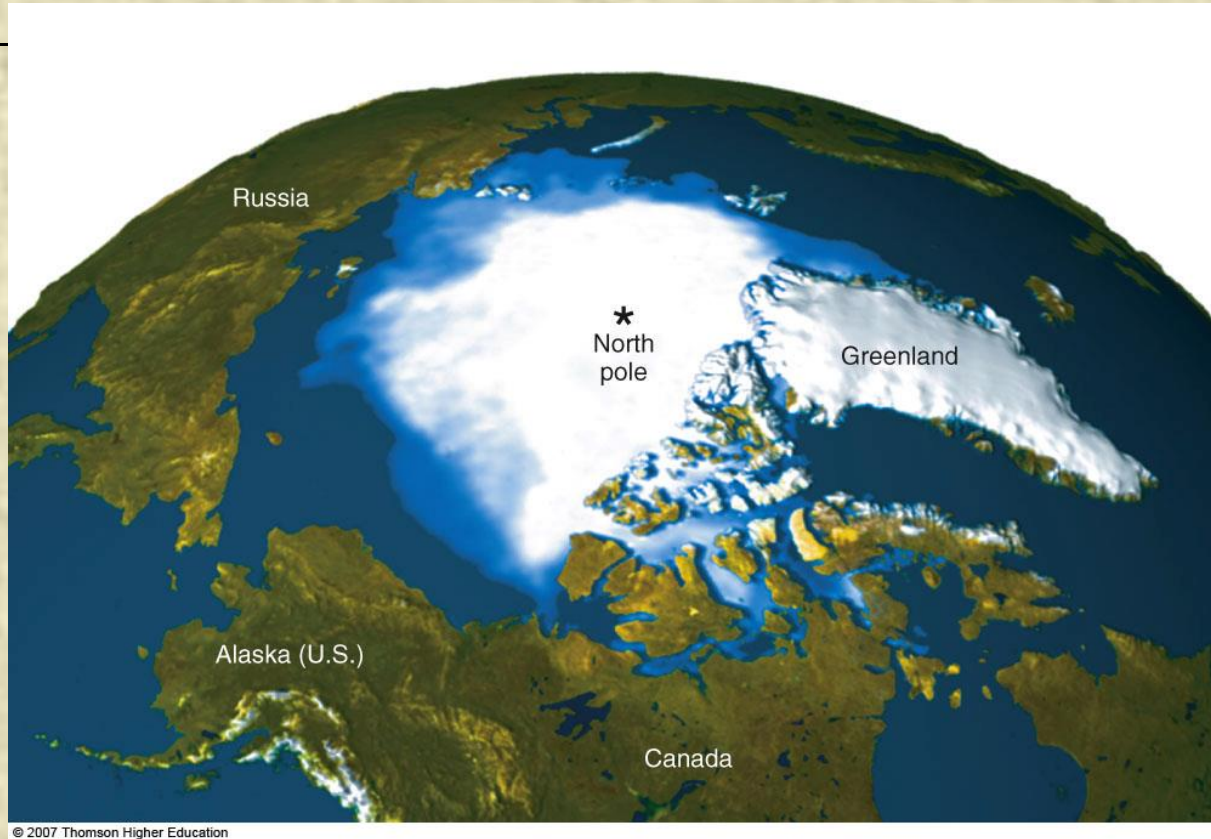


# FACTORS AFFECTING THE EARTH'S TEMPERATURE

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- 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 GLOBAL WARMING



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

Figure 20-8



# Heat Transfer

## Conduction

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- Warm air holds more moisture than cold air. During conduction, heat & moisture from the ocean or land moves into the atmosphere.
- Ex. cold air moving over warm water (like a lake), forming steam fog.

# Heat Transfer

## Convection

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- This causes rising air currents and leads to cloud formation.
- It takes heat from the lower atmosphere to the higher atmosphere where pressure is less, causing air to expand, which in turn cools the air.
- The air cannot hold as much moisture because it is cooler, so clouds form (condensation).





# Heat Transfer

## Radiation

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- Radiation drives weather. Heat from the sun warms the earth, which radiates the heat back into the atmosphere.

# Solar Scattering Radiation

- As the sun hits the earth, molecules are scattered into the air. This changes the direction of the heat coming in. Some are scattered back to space, but others are absorbed.
- Scattering is what makes the sky blue.





# Solar Radiation

## Albedo

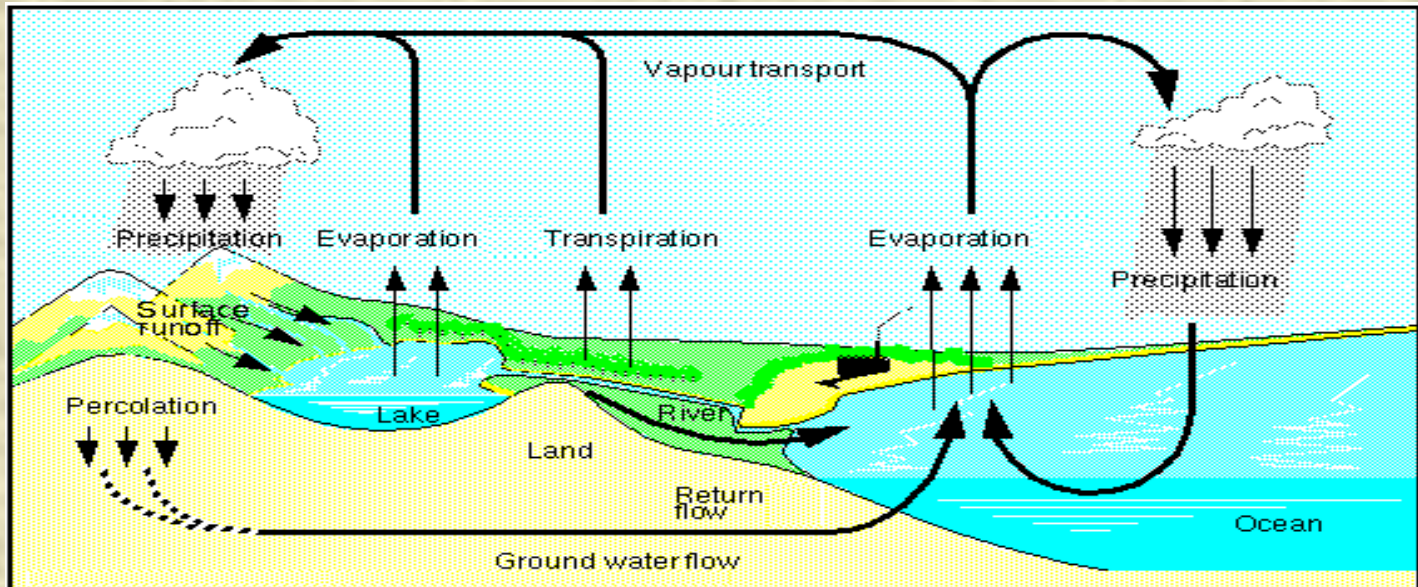
- The proportional reflectance of the Earth's surface.
- Ex, glaciers and ice sheets have a high albedo and reflect 80-90% of the sunlight hitting them, but asphalt and buildings have low albedos and reflect 10-15%, and oceans and forests reflect only about 5%.



# Solar Radiation

## Absorption

- 70% of the solar radiation that falls on Earth is absorbed and runs the water cycle, drives winds and ocean currents, powers photosynthesis, and warms the planet.



Courtesy Erich Roeckner, Max Planck Institute for Meteorology

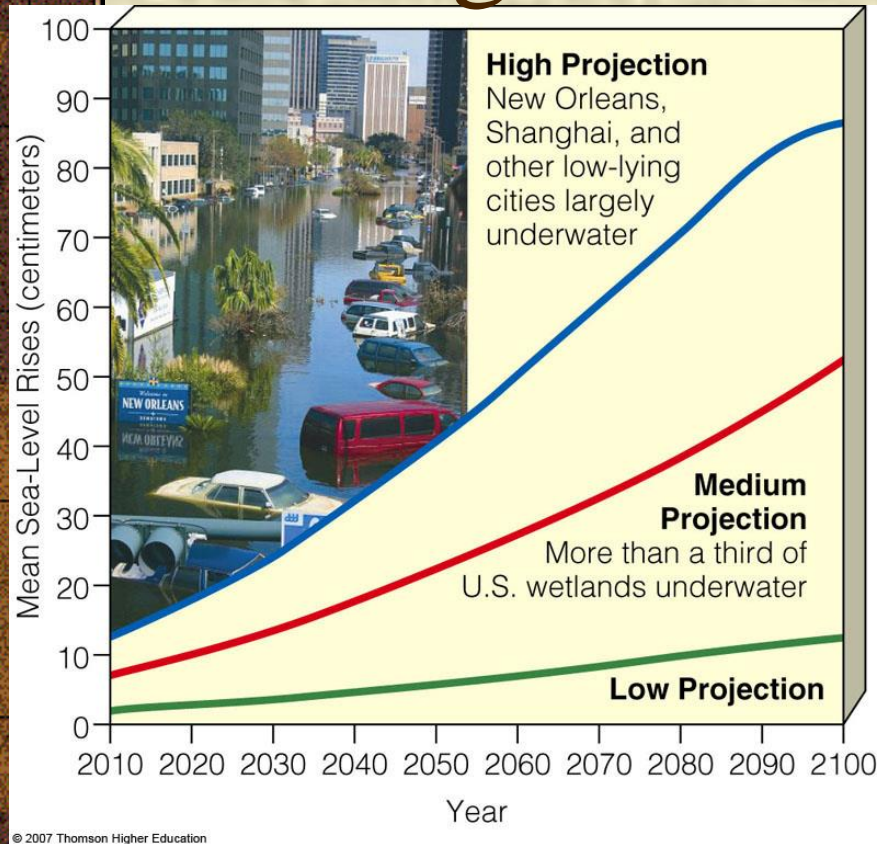


# Solar Radiation

## Control of Temperature

- When there isn't a lot of moisture in the atmosphere & it's a clear night, we have a large temperature drop (like in the desert), but when there is a blanket of clouds, the temperature stays uniform.

# 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.

Figure 20-10



# Rising Sea Levels

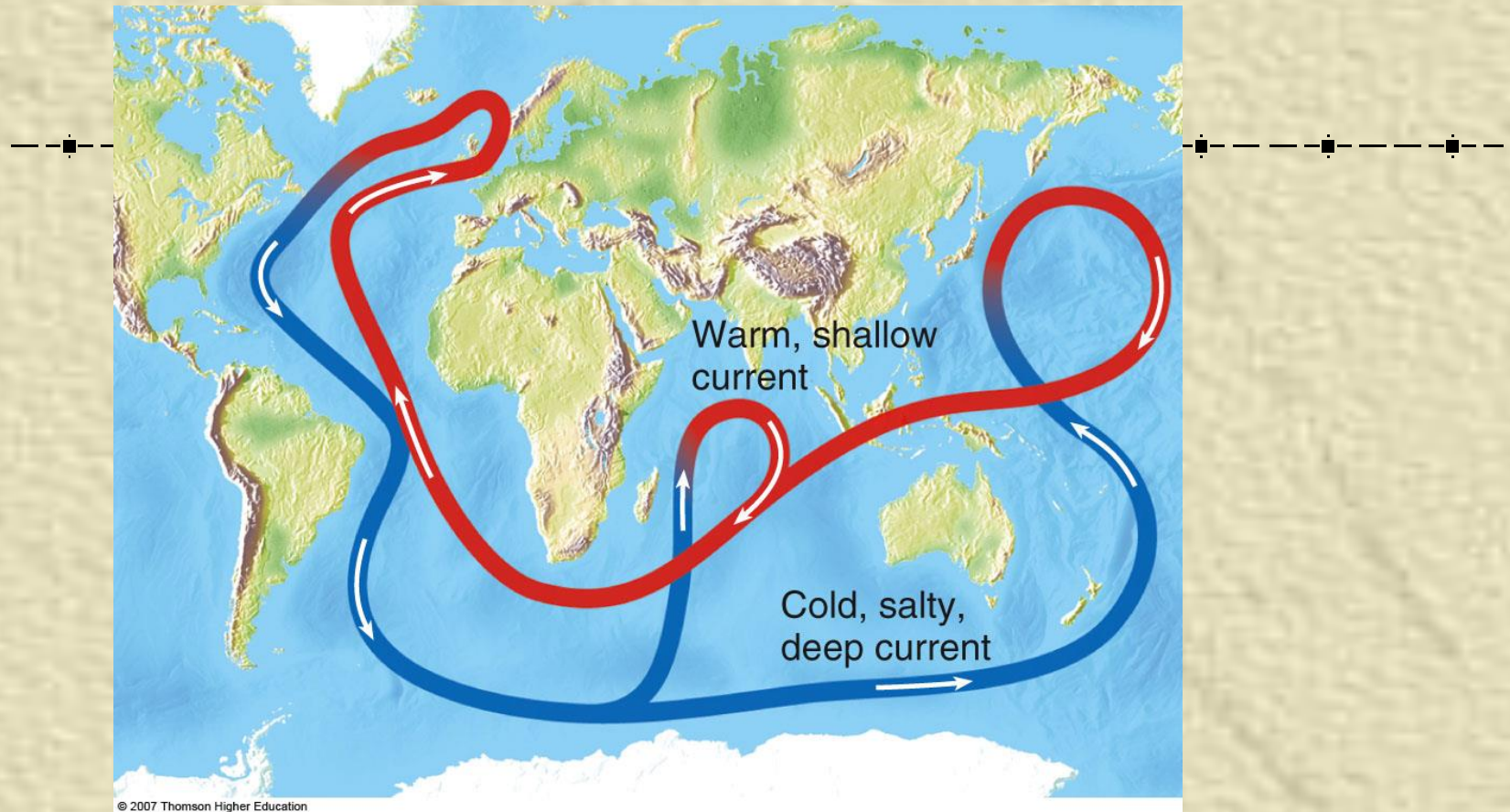


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- If seas levels rise by 9-88cm during this century, most of the Maldives islands and their coral reefs will be flooded.



# Changing Ocean Currents



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

Figure 20-12





# Thunderstorm

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## Characteristics

- Thunderstorms have high, cumulonimbus clouds that can reach 50,000 feet. An updraft of warm air causes cold air to rush downwards. This is why you feel a sudden cold breeze right before a thunderstorm. Lightening causes the ozone smell.

## Problems

- Problems include rain, flooding, hail, lightening, high winds, and loss of life can occur.



# Tornadoes

## Characteristics

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- Tornadoes are a powerful, rotating funnel of air associated with severe thunderstorms. Tornadoes form when a mass of cool, dry air collides with warm, humid air, producing a strong updraft of spinning air on the underside of a cloud. It is a tornado if the spinning air descends and touches the ground.



# Tornadoes

## Problems

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- They can destroy buildings, bridges, and freight trains, and even blow the water out of a river or small lake, leaving it empty. Tornadoes also kill people; more than 10,000 people in the U.S. died in tornadoes in the 20<sup>th</sup> century. They are most common in the Great Plains and Midwestern states (especially Texas, Oklahoma, and Kansas), as well as states along the Gulf of Mexico.


# Hurricanes

## Characteristics

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- Hurricanes are giant, rotating tropical storms with winds of at least 74 miles per hour, with some reaching 155 miles per hour. They form as strong winds pick up moisture over warm surface waters of the tropical ocean and start to spin as a result of the rotation of the Earth. The spinning causes an upward spiral of massive clouds as air is pulled upward.





# Hurricanes

## Problems

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- These are destructive when they hit land, not so much from strong winds as from resultant storm surges, but waves that rise as much as 25 feet above the ocean surface. These can damage property and result in loss of life.

# EFFECTS OF GLOBAL WARMING

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- 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 OF GLOBAL WARMING

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- 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.

## **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 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 belching cows**





# Solutions: Reducing the Threat

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- 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.

# WHAT IS BEING DONE TO REDUCE GREENHOUSE GAS EMISSIONS?

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- 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

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- 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.

# Moving Beyond the Kyoto Protocol



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- 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.

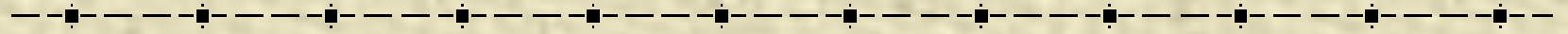


# Actions by Some Countries, States, and Businesses

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- 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.

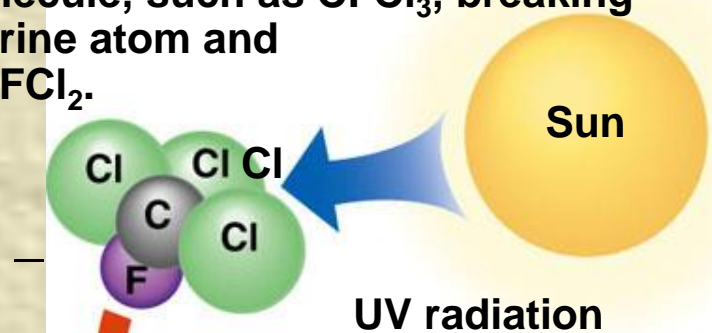
# OZONE DEPLETION IN THE STRATOSPHERE



- 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.

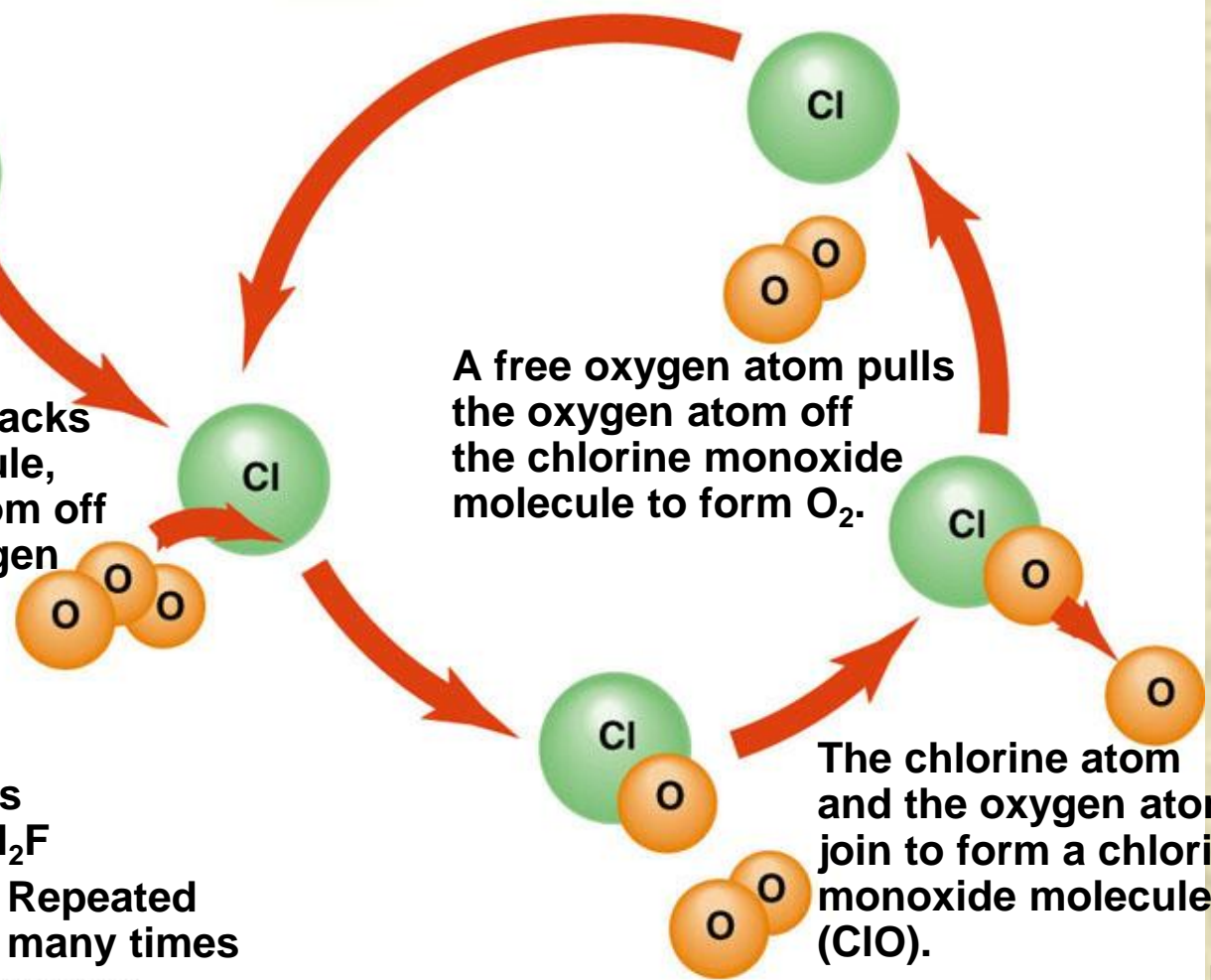


Ultraviolet light hits a chlorofluorocarbon (CFC) molecule, such as  $\text{CFCl}_3$ , breaking off a chlorine atom and leaving  $\text{CFCl}_2$ .



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 ( $\text{O}_2$ ).

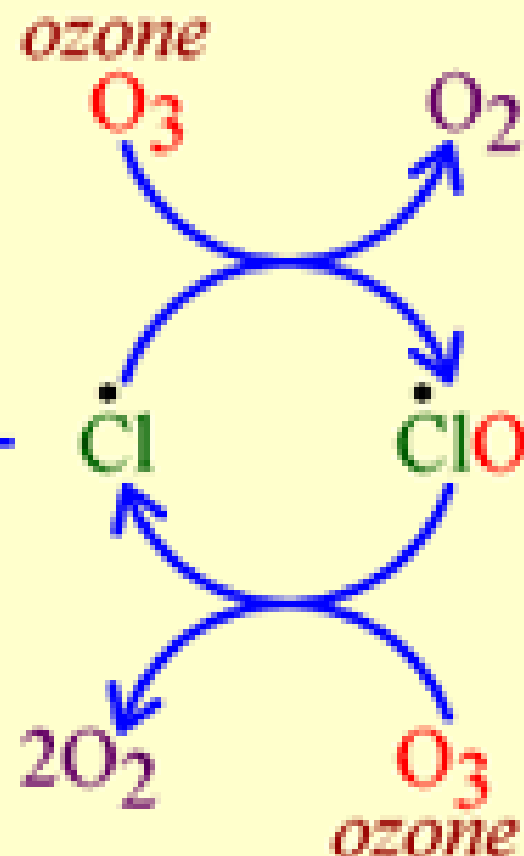
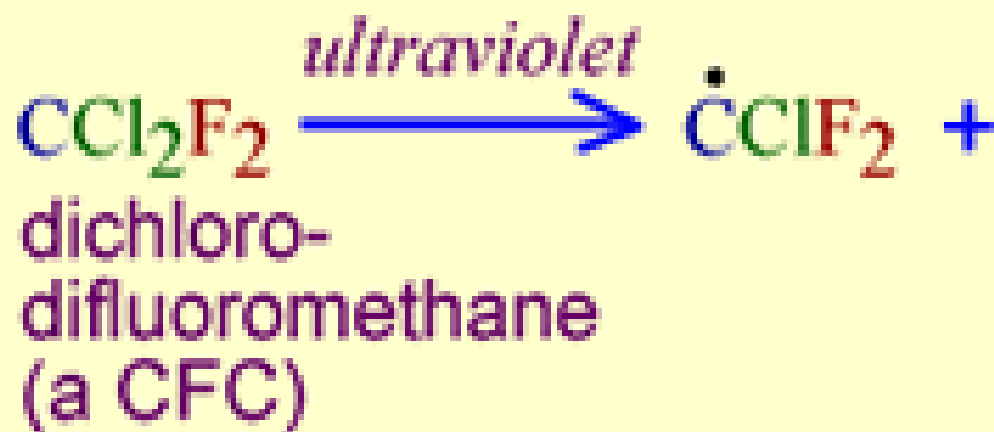


A free oxygen atom pulls the oxygen atom off the chlorine monoxide molecule to form  $\text{O}_2$ .

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

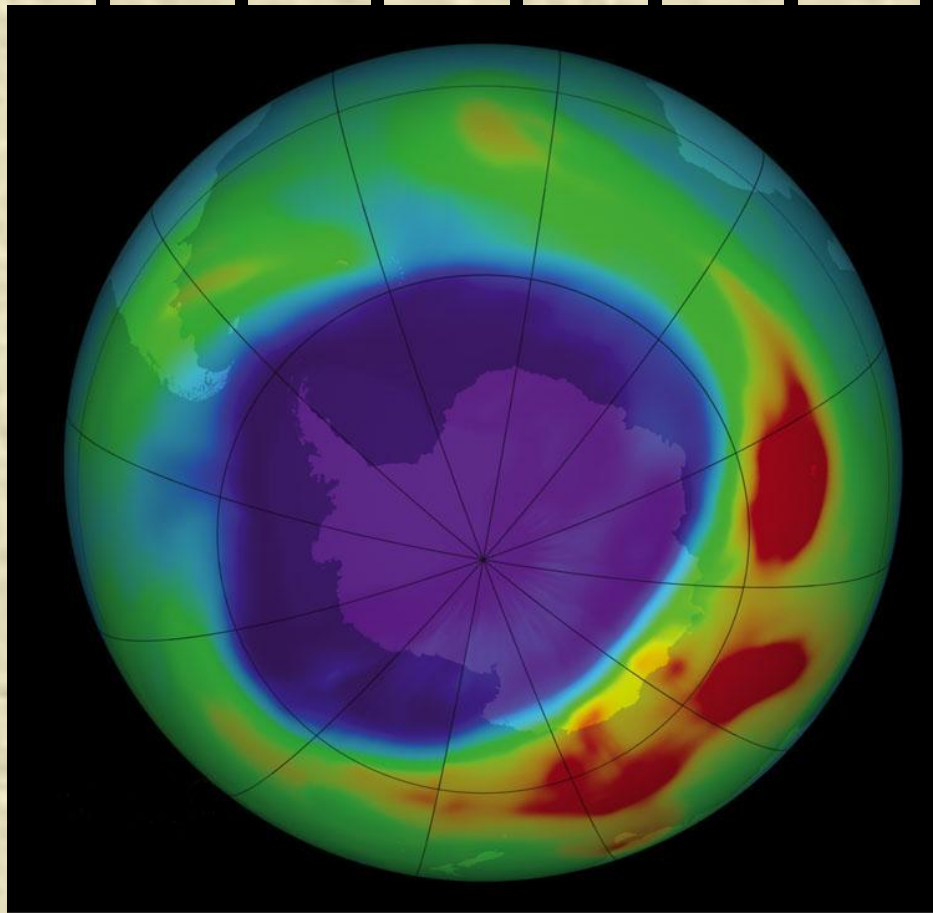
**Summary of Reactions**  
 $\text{CCl}_3\text{F} + \text{UV} \rightarrow \text{Cl} + \text{CCl}_2\text{F}$   
 $\text{Cl} + \text{O}_3 \rightarrow \text{ClO} + \text{O}_2$   
 $\text{Cl} + \text{O} \rightarrow \text{Cl} + \text{O}_2$  } Repeated many times

## An ozone depleting reaction with a CFC





# OZONE DEPLETION IN THE STRATOSPHERE

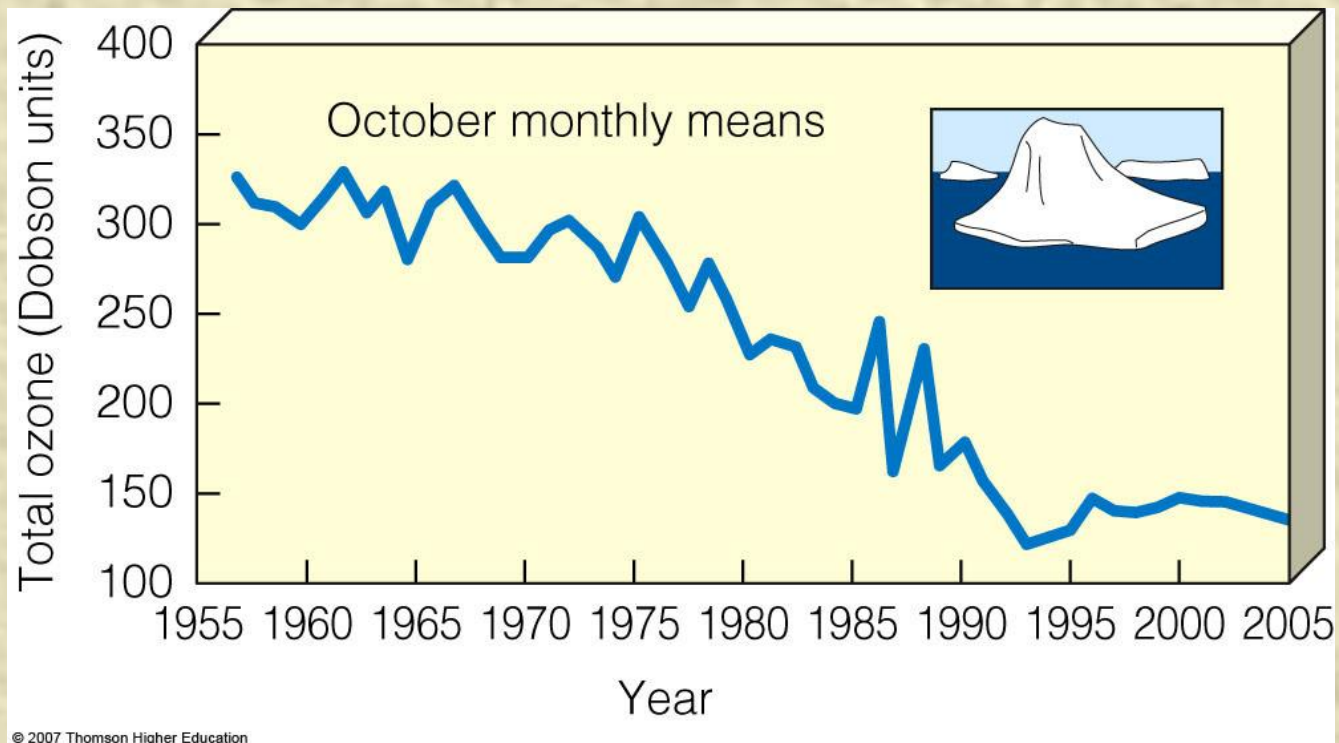


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- During four months of each year up to half of the ozone in the stratosphere over Antarctica and a smaller amount over the Arctic is depleted.

Figure 20-19

# OZONE DEPLETION IN THE STRATOSPHERE



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

Figure 20-20



# OZONE DEPLETION IN THE STRATOSPHERE

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- *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**

### **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.

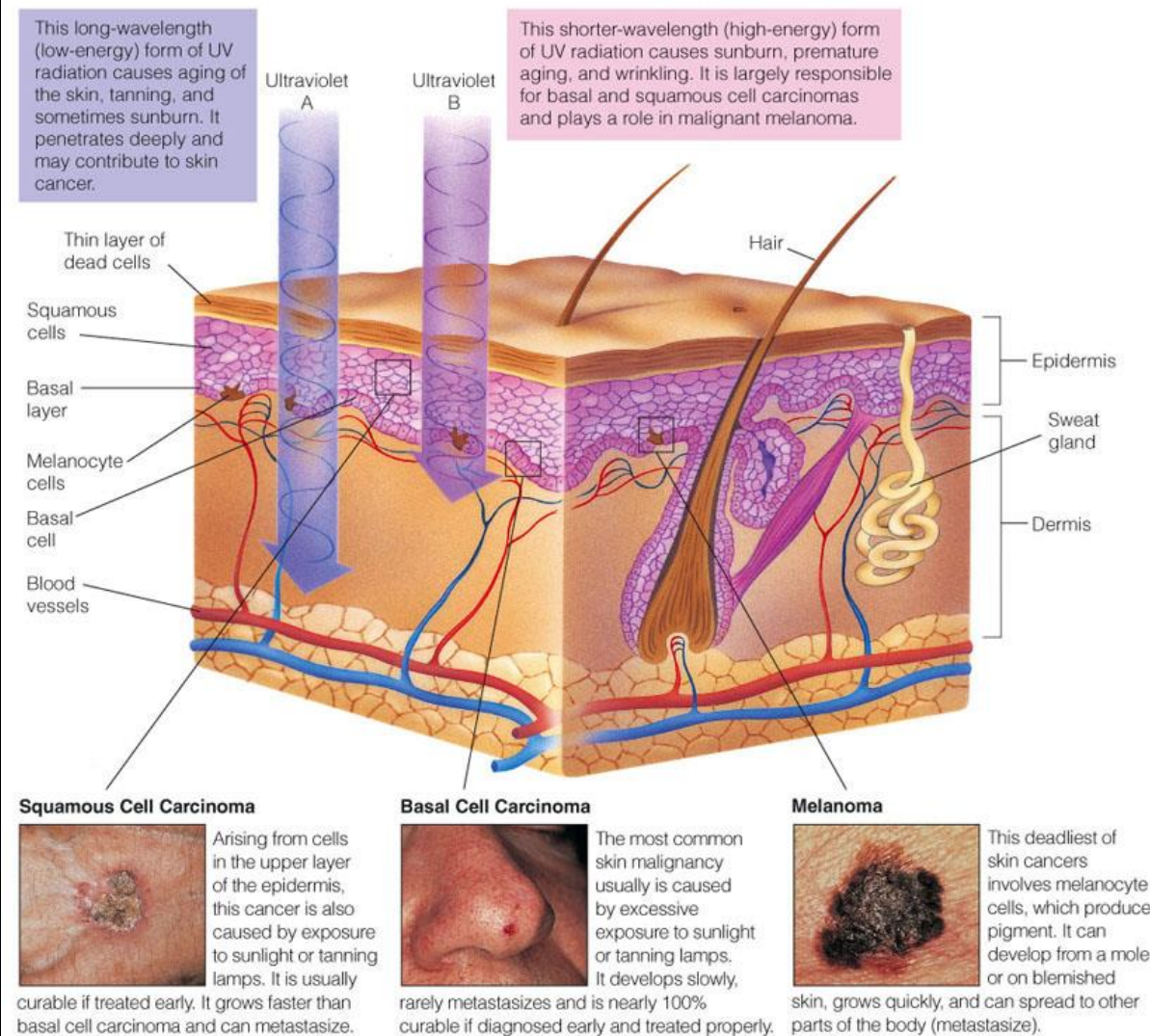


Figure 20-22

# Human Impact (Positive)

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## Pollution Control Devices

- Emission Control Devices – filter particles
- Scrubbers – use water to filter particles and gases
- Catalytic Converters – on cars; finish burning wastes to decrease carbon monoxide levels
- 1-800-453-SMOG



# Law – Clean Air Act

- 1963 - first passage
- 1970, 1977 and 1990 - amended
- Involves EPA
- Sets standards for acceptable levels of sulfur oxides, nitrogen oxides, ozone, carbon monoxide, hydrocarbons, lead, & more
- Provides pollution credits for industries that utilize pollution-control devices+
- Bush administration has relaxed rules
- It established NAAQS and AQI

# National Ambient Air Quality Standards (NAAQS)

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- Sets acceptable concentrations for 6 “criteria” pollutants that:
  - Threaten public health/the environment over broad areas (non-point)
  - Are emitted in large quantities
  - CO, Pb, Nitrogen Oxides, Ozone, Particulate Matter and Sulfur Dioxides





# Air Quality Index (AQI)

- 
- Measures levels of 5 criteria pollutants
  - Forecast of daily air pollution levels
  - Purpose to educate and protect public-focuses on health effects
  - Categories: green= good, yellow= moderate, orange= unhealthy for sensitive groups, red= unhealthy, purple= very unhealthy

# National Emissions Standards for Hazardous Air Pollutants

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- Regulates emissions (from point sources)
- For specific substances (air toxics w/ known or suspected serious health effects (mutagens, carcinogens, neurotoxins))
- Tend to be localized, from point sources
- Examples: Ammonia, chlorine, asbestos, arsenic, mercury, benzene