

Air Pollution

**G. Tyler Miller's
Living in the Environment
14th Edition**

Chapter 20

Key Concepts of Chapter 20

- **Structure and composition of the atmosphere**
- **Types and sources of outdoor air pollution**
- **Types, formation, and effects of smog**
- **Sources and effects of acid deposition**
- **Effects of air pollution**
- **Prevention and control of air pollution**

Section 1 Key Concepts

- What are the key characteristics of the atmosphere?
- What is the troposphere, stratosphere and other layers of the atmosphere? Why are they important?

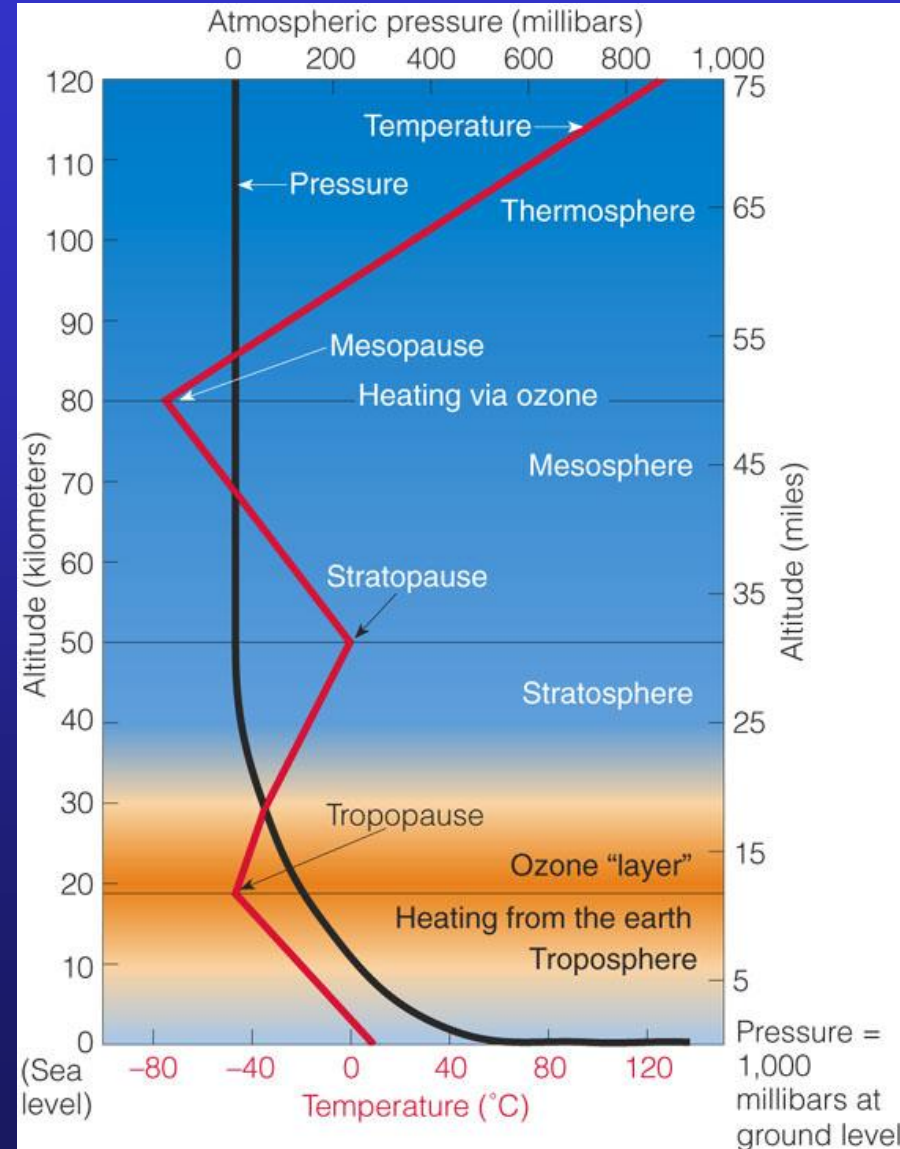


Structure of Atmosphere

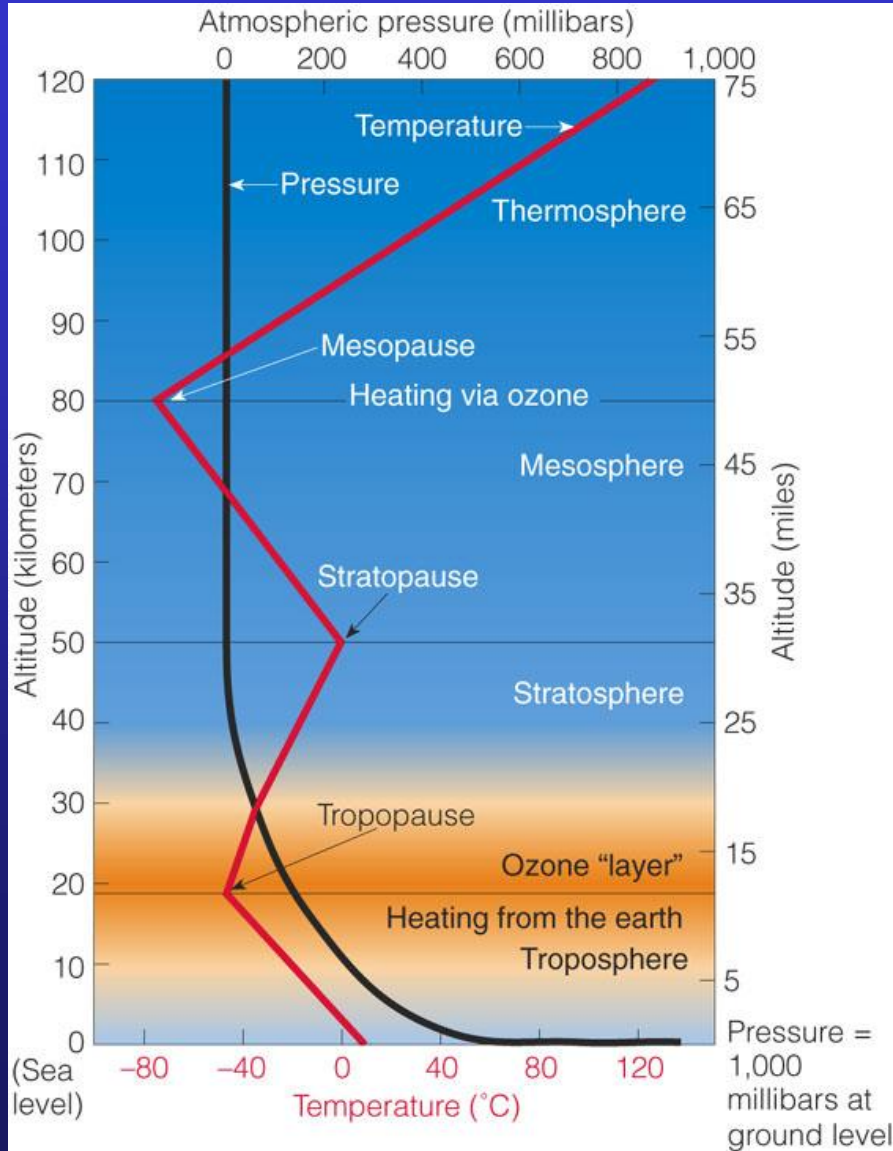
The atmosphere (mainly nitrogen and oxygen) consists of several layers with differing temperatures, pressure and composition.

- Why doesn't atmosphere float into space?
- What is "air pressure?"

Abdul R Khan



Structure of Atmosphere

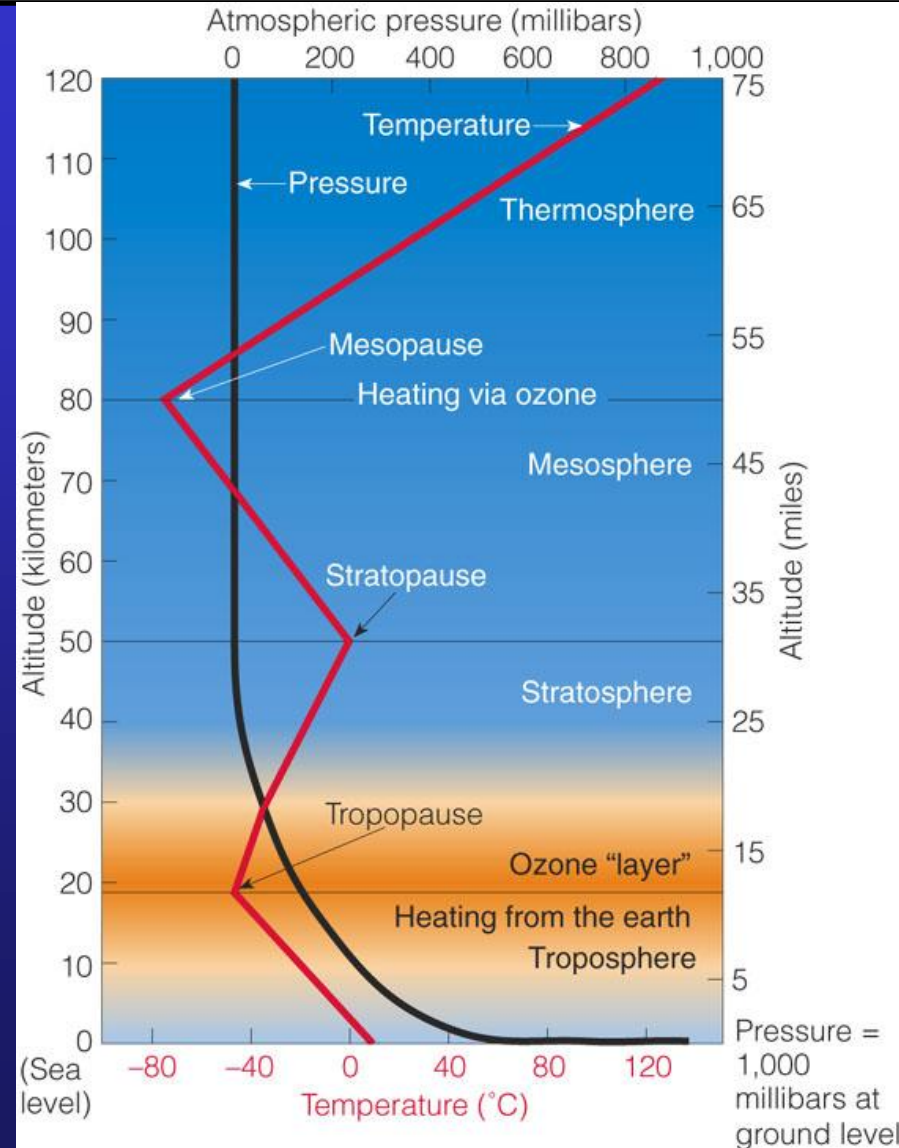


Troposphere:

- Innermost layer
- 75-80% of air mass
- 11-5 miles thick
- Earth Apple, Skin Troposphere
- All weather found here
- 78% N₂, 21% O₂, others H₂O vapor, CO₂, Ar

The Atmosphere

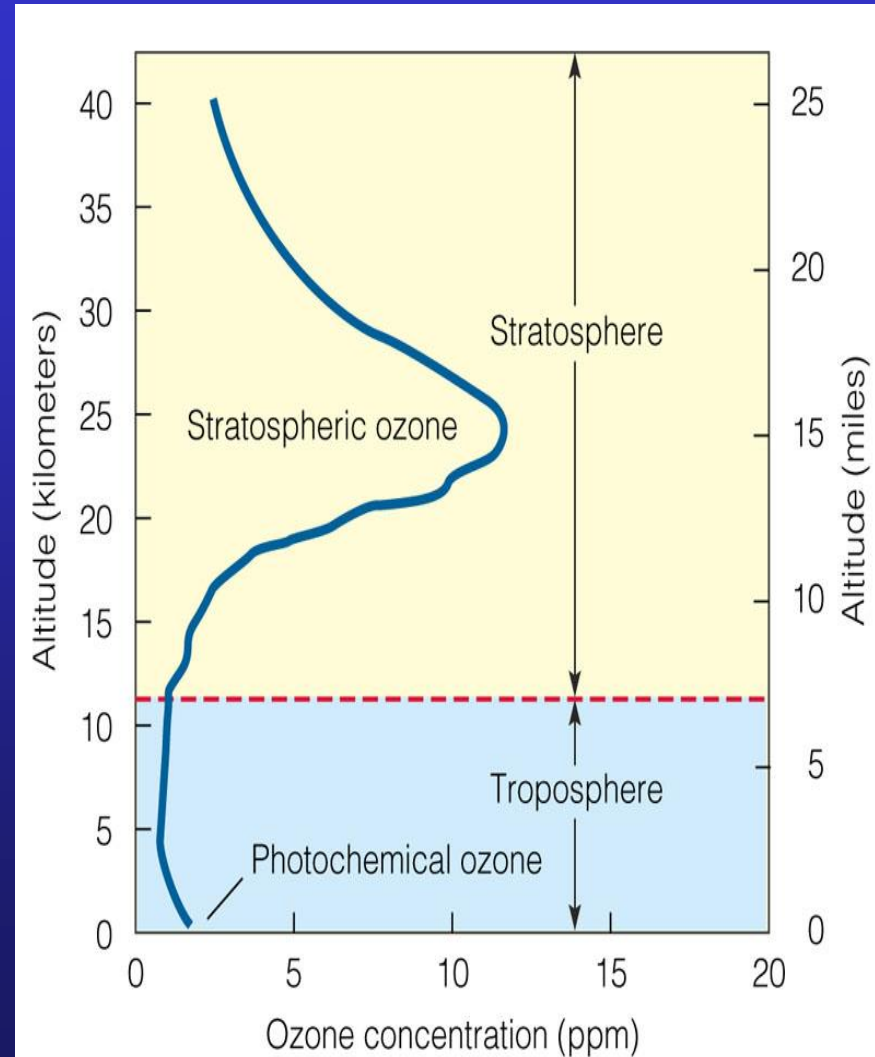
- Troposphere
- 78% N₂, 21% O₂
- Stratosphere
- Ozone layer



Structure of Atmosphere

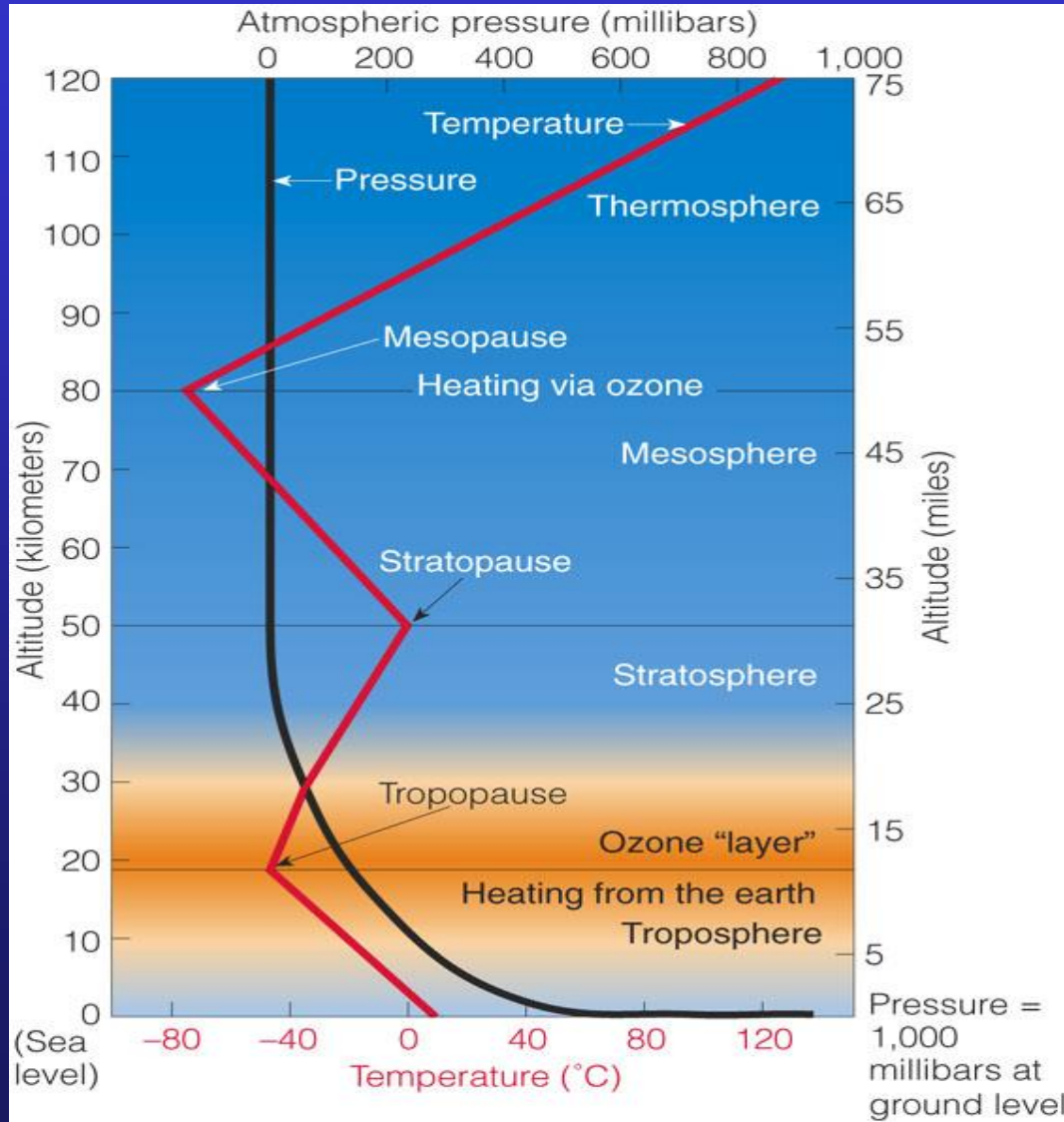
Stratosphere

- Second layer
- Filters UV rays
- Much less air mass and water vapor, much more O₃ than troposphere.
- Blocks 95% UV radiation
- “Good Ozone vs. Bad Ozone”



Structure of Atmosphere

“Other Layers”



Section 2 Key Ideas

- What are the major types and sources of air pollution?
- What are primary and secondary pollutants?
Mobile and Stationary sources?
- What is the history of air pollution?
- Should carbon dioxide be classified as an air pollutant?

Air Pollution: What is it?

The presence of chemicals in the atmosphere high enough to affect climate and harm organisms and materials.



Natural vs. Human Made

Outdoor Air Pollution

Sources:

Mobile or Stationary

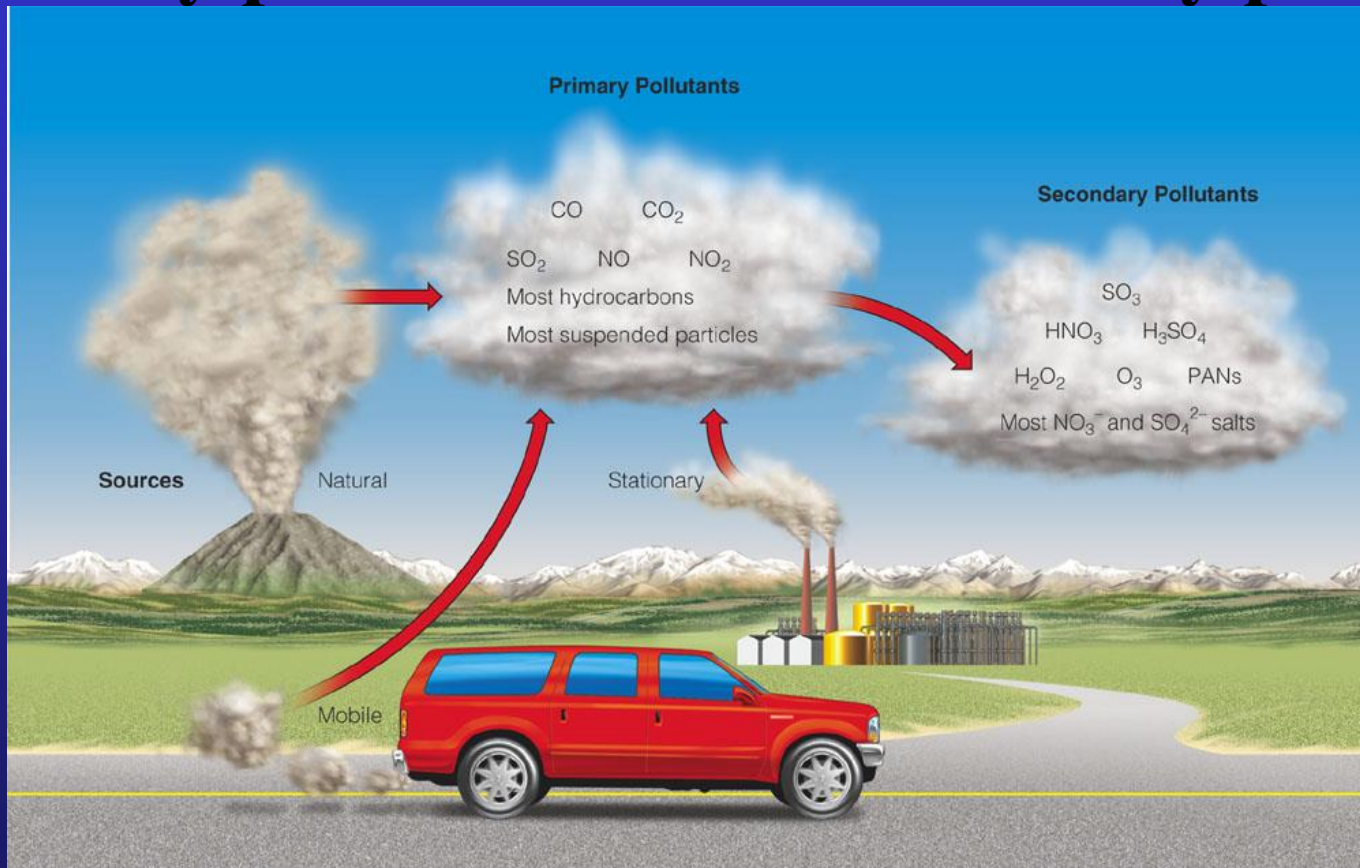
Most urban area pollution source is burning fossil fuels.



Outdoor Air Pollution

➤ **Primary pollutants**

➤ **Secondary pollutants**



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Fig. 20-4 p. 436

Also refer to Tables 20-1 p. 436 and 20-2 p. 438

Outdoor Air Pollution

Major Classes of Air Pollution Table 20-1

- Carbon Oxides (CO and CO₂)
- Sulfur Oxides (SO₂)
- Nitrogen Oxides (NO and NO₂)
- Volatile Organic Compounds (VOCs – CFCs)
- Suspended Particulate Matter (soot, dust, asbestos, lead etc.)
- Photochemical Oxidants (ozone O₃)
- Radioactive Substances (Radon)
- Hazardous Air Pollutants (carcinogens, etc.)

Outdoor Air Pollution: History

- Not a “new” problem, but scale has changed during industrial revol.
- London “smog” killed 2,000 in 1880, 1,000 in 1911 and between 4,000 and 12,000 in 1952
- 1948 Donora PA 6,000 sick
- 1963 NYC 300 killed
- 1970, '77, '90 CAA



Outdoor Air Pollution

U.S. EPA Regulate 6 “Criteria” Air Pollutants

- **Carbon Monoxide**: colorless, odorless, deadly gas

Sources: motor vehicles, cigarettes

Impacts: reduces ability of blood to carry oxygen

- **Nitrogen Dioxide**: reddish-brown chemical found in smog

Sources: burning fossil fuels and industrial processes

Impacts: lung irritation, aggravates asthma, reduces visibility,

Outdoor Air Pollution

Sulfur Dioxide: colorless gas, major source of acid deposition

Sources: coal burning power plants

Impacts: acid deposition, breathing problems, property damage, soil, aquatic life damage

Particulate Matter: particles in the air, range from small to large

Sources: burning fossil fuels (diesel), agriculture, fires, unpaved roads

Impacts: lung damage, asthma, reduced life

Outdoor Air Pollution

Ozone: highly reactive gas with an unpleasant odor, commonly known as smog in troposphere “Bad Ozone”

Sources: chemical reaction with VOCs and NO_x from cars.

Impacts: breathing problems, eyes, nose, mouth irritation, lung disease, crop damage, visibility.

Lead: solid metal and compounds emitted as PM

Sources: paint, smelters, battery storage, leaded gas

Impacts: neurological problems, carcinogen

Should CO2 be 7th Criteria Pollutant?

In 2003, 12 states
(including NJ) sued EPA
for its failure to regulate
CO₂ as a pollutant under
CAA.

What are the arguments for
or against this listing?



Current and Historical Air Quality

- <http://airnow.gov/>

U.S. Government Web Site With Up To Minute Air Quality Data From Monitors Across the country

- <http://www.epa.gov/air/data/geosel.html>

U.S. EPA Air Quality Data: Tons of data regarding air quality across the U.S.

- <http://www.epa.gov/airtrends/>

EPA report on air trends in U.S.

Section 2 Review

- What are the major types and sources of air pollution?
- What are primary and secondary pollutants? Mobile and Stationary sources?
- What is the history of air pollution?
- Should carbon dioxide be classified as an air pollutant?



Section 3 Smog Key Ideas

- What is photochemical smog?
- How does smog form? How big of a problem is it?
- How are smog problems different in developing and developed countries?
- What factors influence the formation of smog? What are temperature inversions?

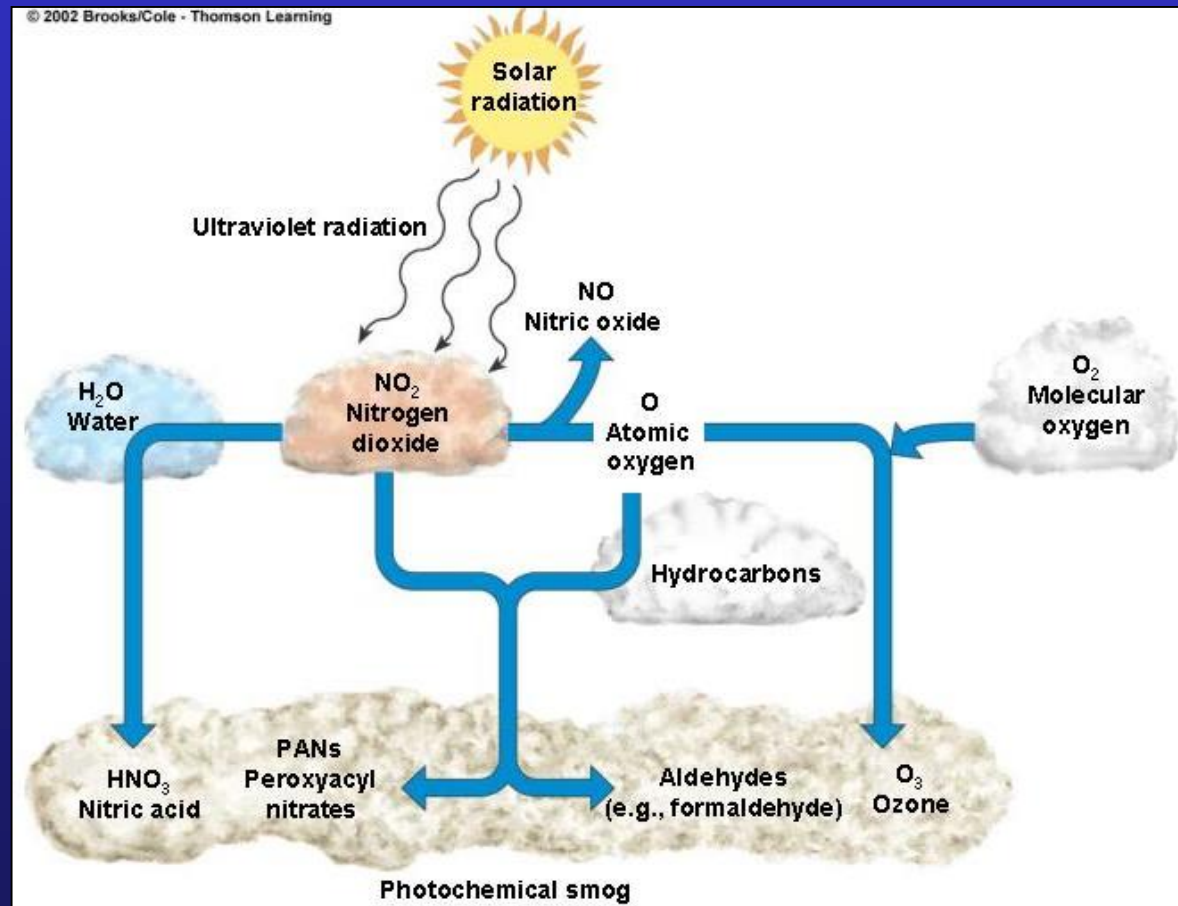
Photochemical Smog

➤ **Brown-air smog**

➤ **Photochemical reaction**

➤ **Photochemical oxidants**

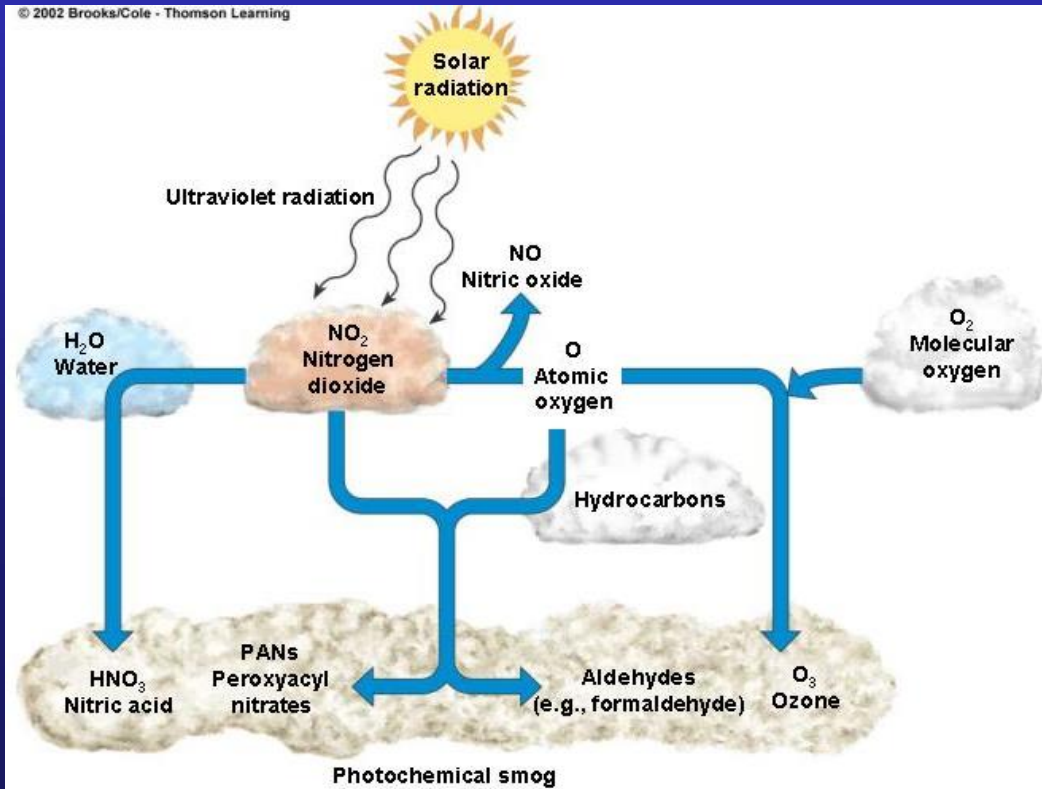
Fig. 20-5 p. 440



What is photochemical smog?

Secondary Pollutant

VOCs + NO_x + heat + Sunlight = Ground Level
Ozone (O₃)



Complex series of
chemical reactions

SMOG (smoke + fog)

What is photochemical smog?

All modern cities have smog,
but it is more common in
hot, sunny, warm climates
with a lot of motor vehicle
traffic.

*What time of year do you think
it is most common?*

- Los Angeles
- Denver
- Mexico City
- Houston
- Beijing China



Mexico City

*Exceeded ozone levels
300 days a year often by
400%*



Los Angeles

What is photochemical smog?



Industrial Smog: a mixture of SO_2 , droplets of sulfuric acid and suspended PM from burning coal and oil.

More of a problem today in developing countries.

Coal burning HUGE issue.

Health Impacts of Smog

Smog Impacts:

- Breathing Problems
- Coughing, Eye Irritation
- Aggravates asthma, heart problems
- Speeds up aging of lung tissue
- Damage plants
- Reduce Visibility



Factors Influencing Smog Formation



Smog Levels Are Influenced By:

- Local climate
- Topography
- Population Density
- Amount of industry
- Transportation

Factors Influencing Smog Formation

3 Natural Factors Can Reduce Smog:

- 1) Rain or snow can “wash” air**
- 2) Salty Sea Spray can also “wash” air**
- 3) Winds can push pollutants elsewhere**



Factors Influencing Smog Formation

4 Natural Factors Can Increase Smog:

- 1) Tall urban buildings slow air exchange**
- 2) Hills or Mountains do the same**
- 3) High temperatures**
- 4) Atmospheric Circulation towards poles**



Temperature Inversions



Naturally occurring layer of warm air sitting atop of a layer of cool air near the ground can trap pollutants near the ground.

Common in:

Large cities surrounded completely or almost completely by mountains (LA, Denver, Mexico City)

Inversion

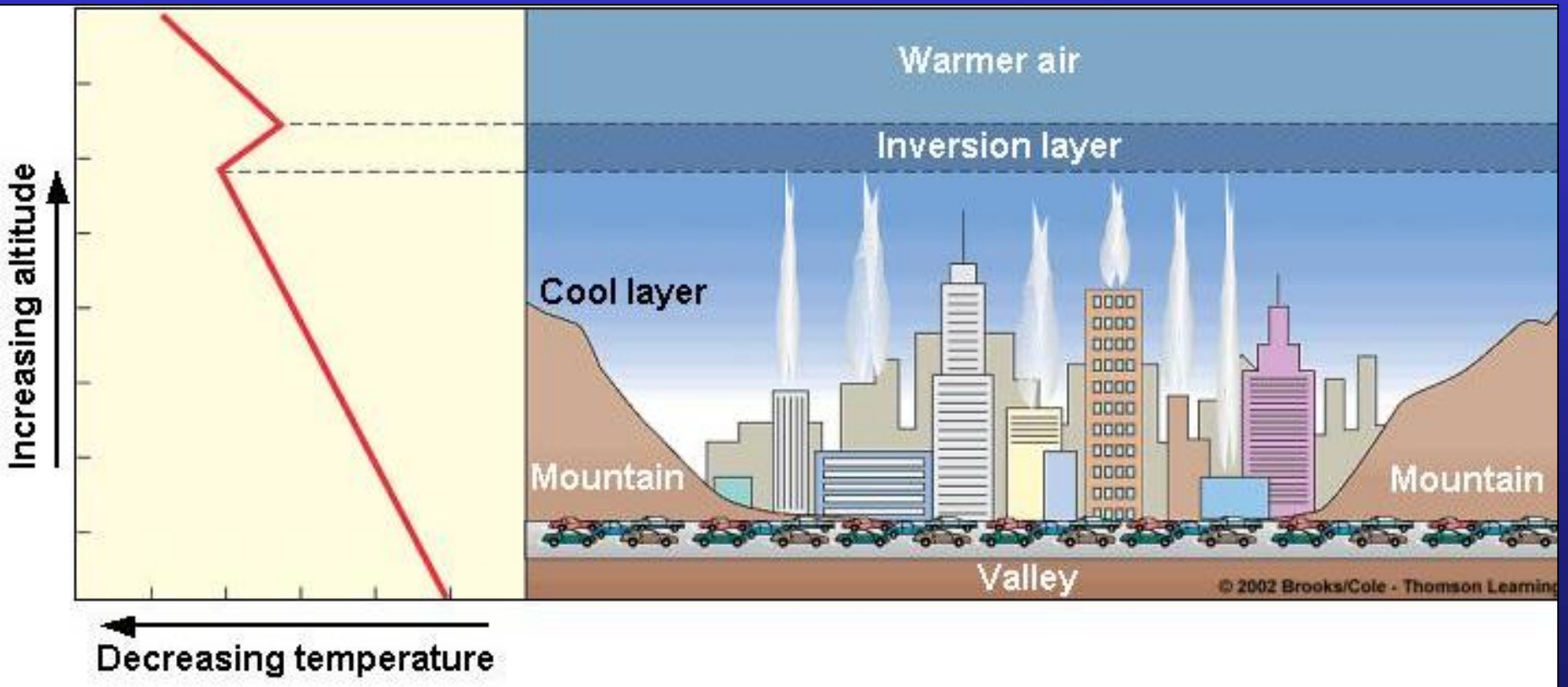


No Inversion



Helena
Montana

Temperature Inversions



Case Study Homework

Read page 442: “Case Study: South Asia’s Massive Brown Cloud-Choking in China and India.”

Question:

Describe what the problem is and what are possible solutions.

Industrial Smog

- Industrial smog
- Particulates
- Sulfur dioxide
- Sulfuric acid
- Gray-air smog

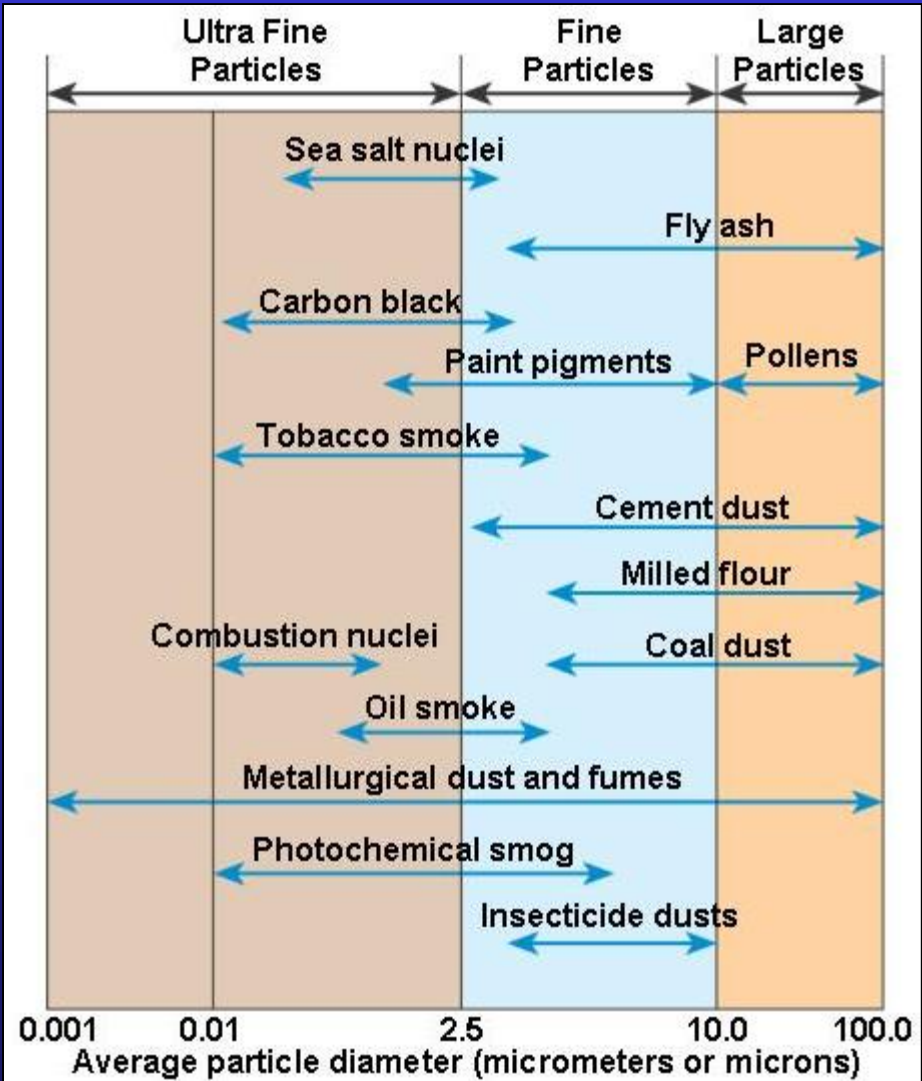
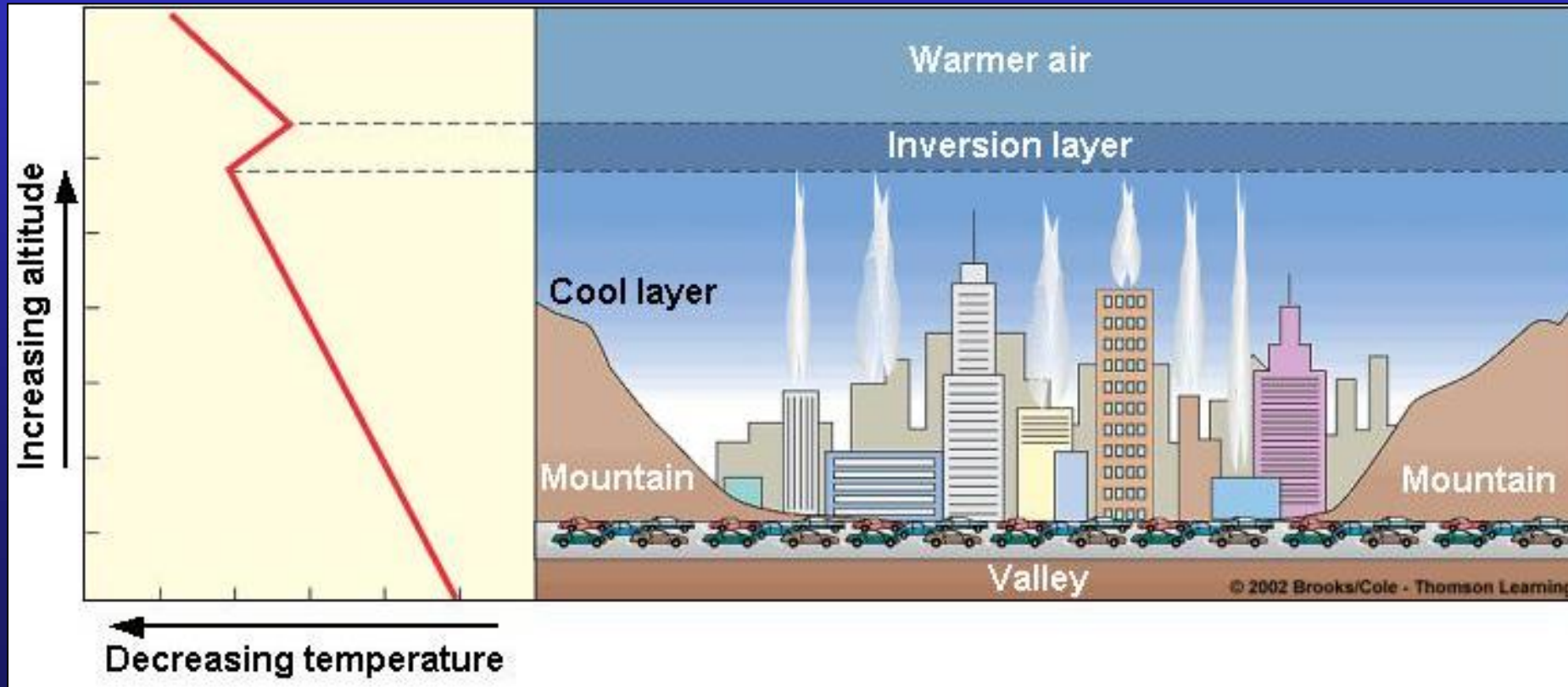


Fig. 20-6 p. 441

Temperature Inversions

➤ Subsidence inversion



Section 3: Smog Review

- What is photochemical smog?
- How does smog form? How big of a problem is it?
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Section 4 Key Ideas: Acid Deposition

- What is acid deposition? Where does it occur?
- What are harmful impacts of acid deposition?
- How serious of a problem is it in the United States?
- What can be done to reduce acid deposition?

What is acid deposition?

Often called acid rain

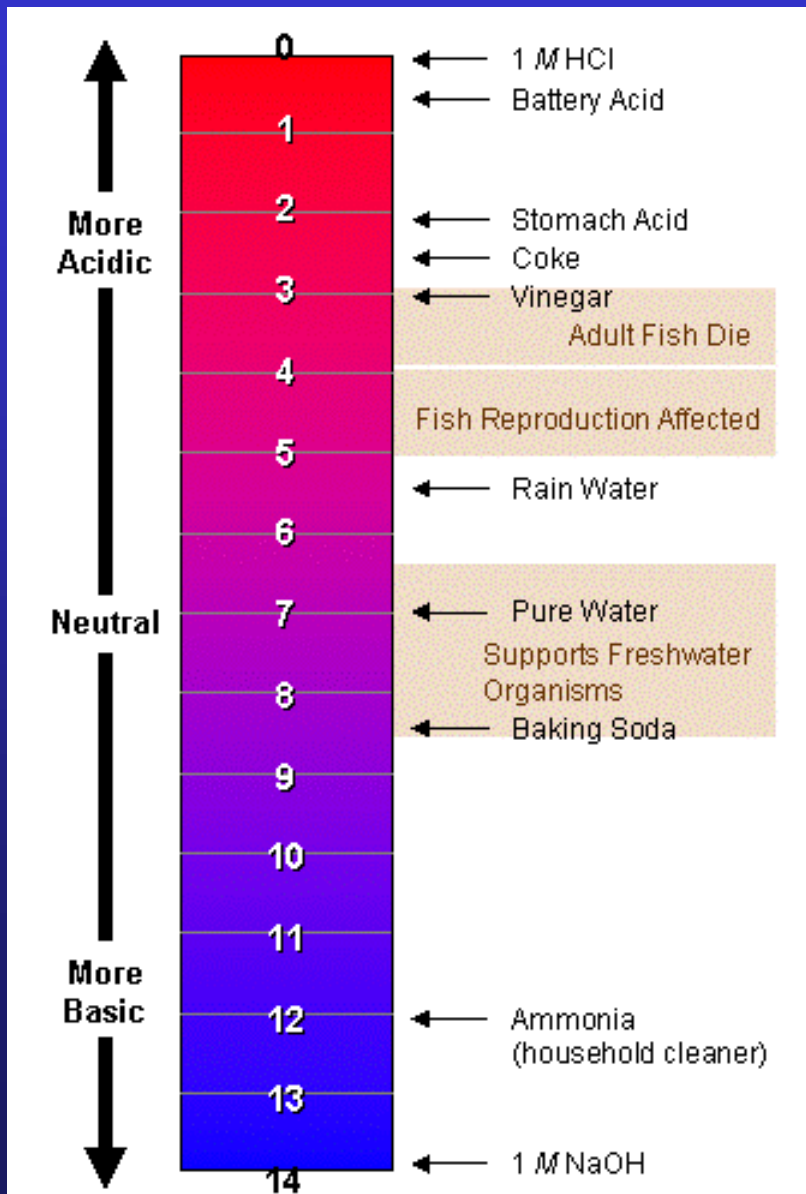
SO₂ and NO_x in the atmosphere interacts to produce acidic chemicals that can travel long distances before falling to earth.

Coal power plants are huge source.

Secondary Pollutant

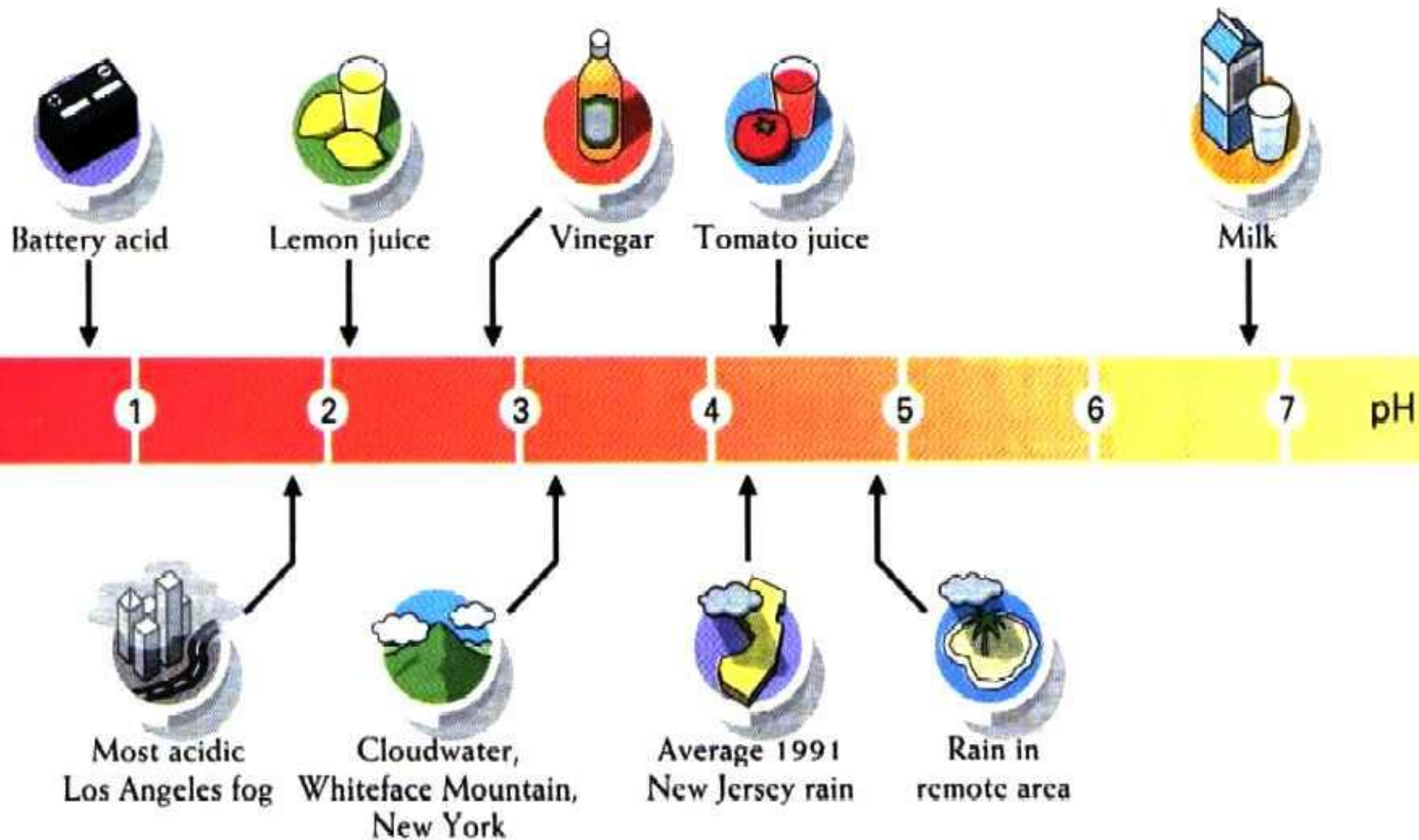


Acidic Review



**“Normal”
precipitation is
slightly acidic.**

Acidity Review



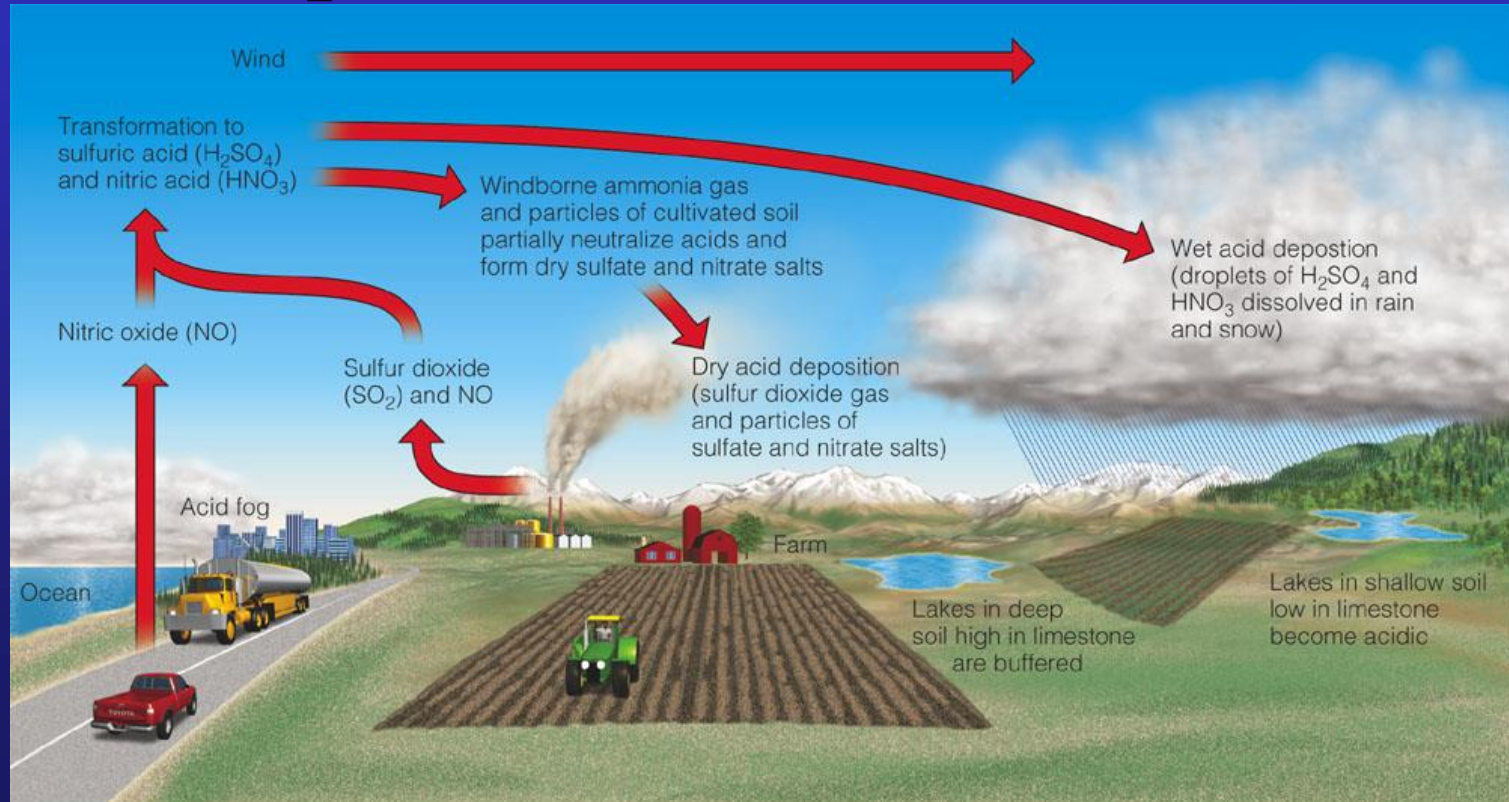
The pH values in atmospheric water of various types, compared with the pH values for several common liquids.

Regional Outdoor Air Pollution from Acid Deposition

➤ Acid deposition

➤ Wet deposition

➤ Dry deposition



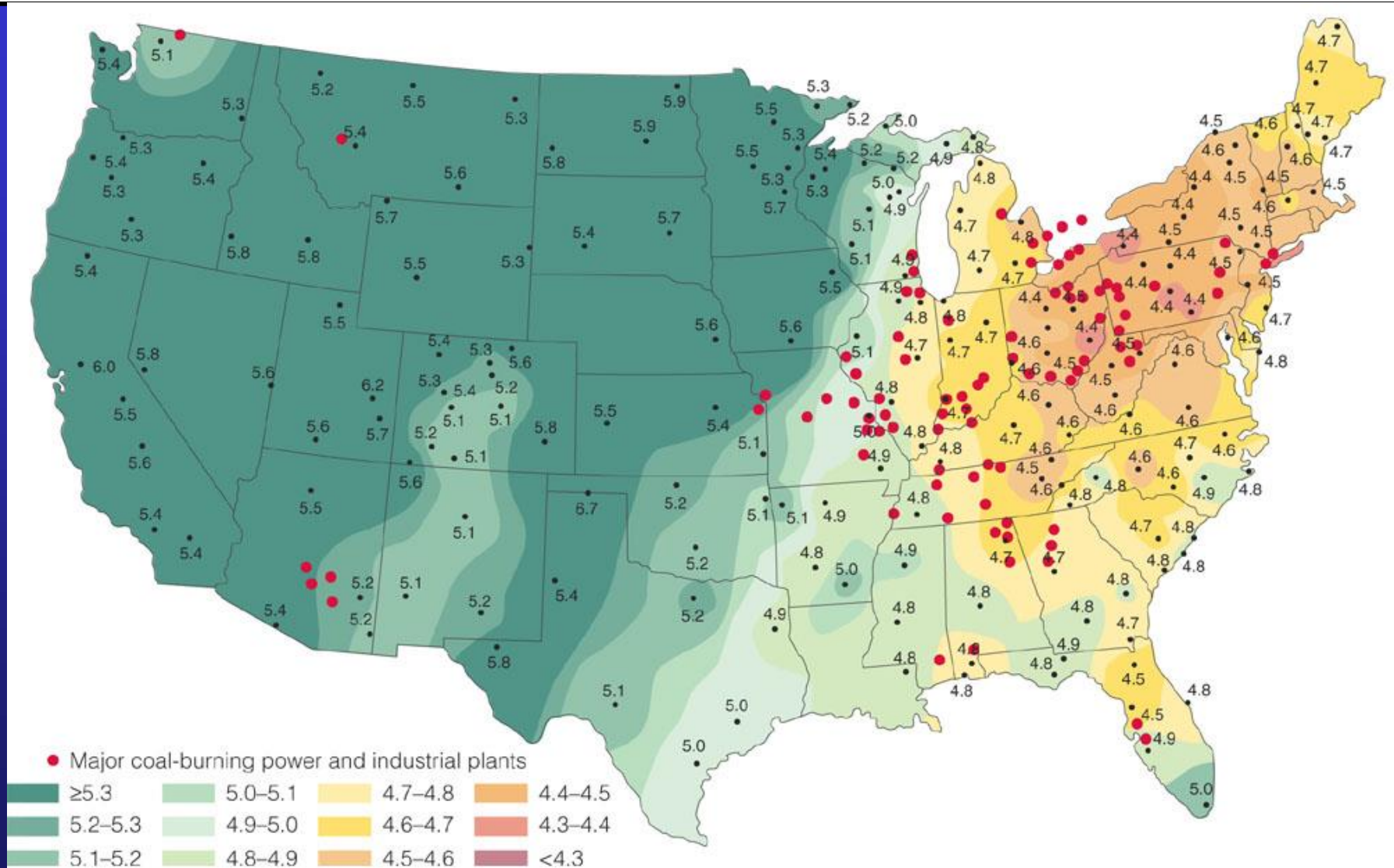
Where is acid rain a problem

Coal power plants in the midwest lead to very acidic precipitation in the northeastern U.S.

Land with limestone buffers acid where granite soils are very vulnerable



Acid Deposition in the US

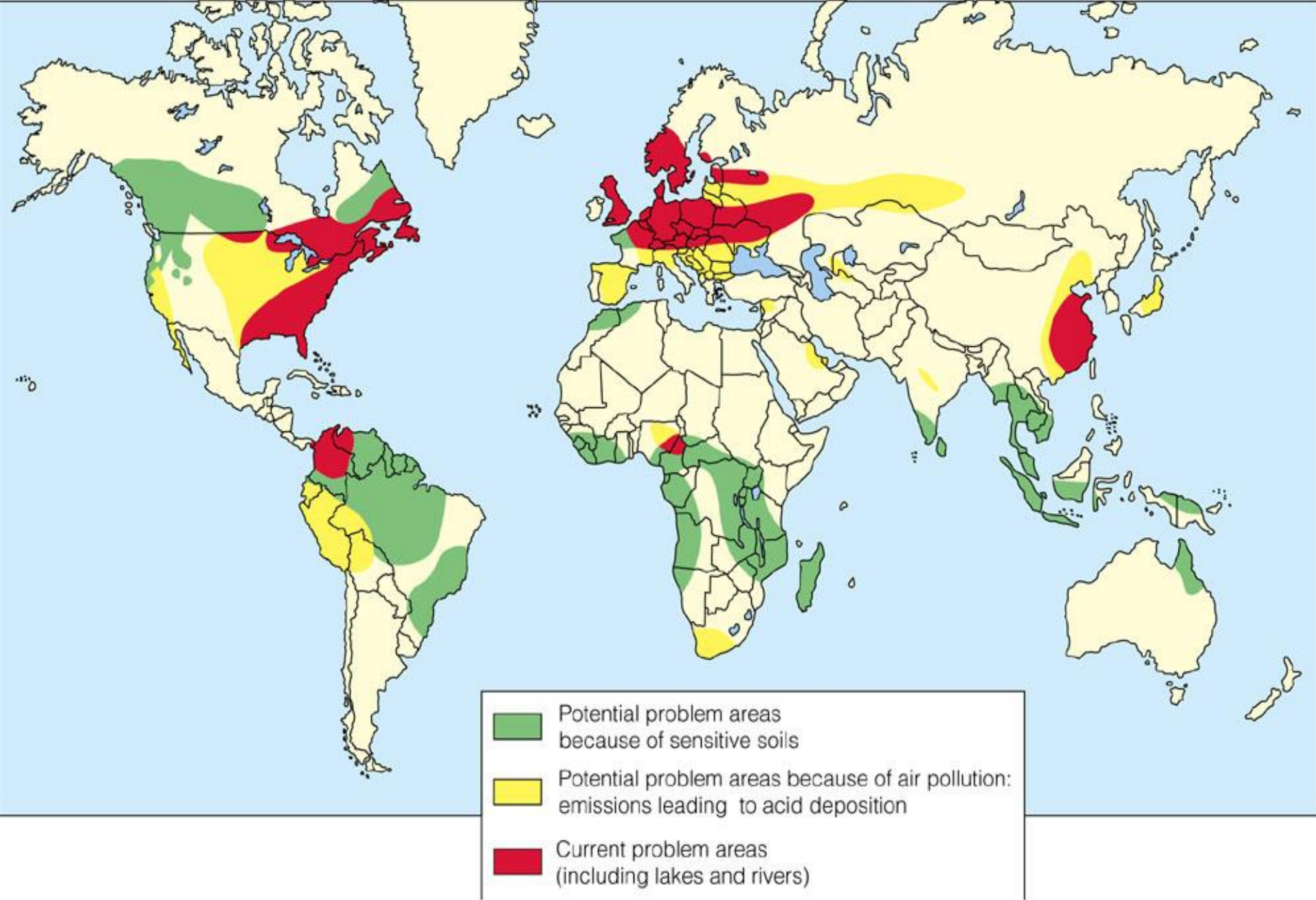


Worst Acid Deposition Problem

China gets 59% of its energy from coal burning.

Parts of European forest have long been in decline from acid deposition.





Acid Deposition and Humans

- **Respiratory diseases**
- **Toxic metal leaching**
- **Damage to structures, especially containing calcium carbonate**
- **Decreased visibility**
- **Decreased productivity and profitability of fisheries, forests, and farms**

Acid Deposition Impacts



Damage to lakes, forests, statues and buildings and rivers.



Acid rain withers trees in a coniferous forest in Europe.
Photo by The Ministry of Foreign Affairs of Japan

Acid Deposition and Aquatic Systems

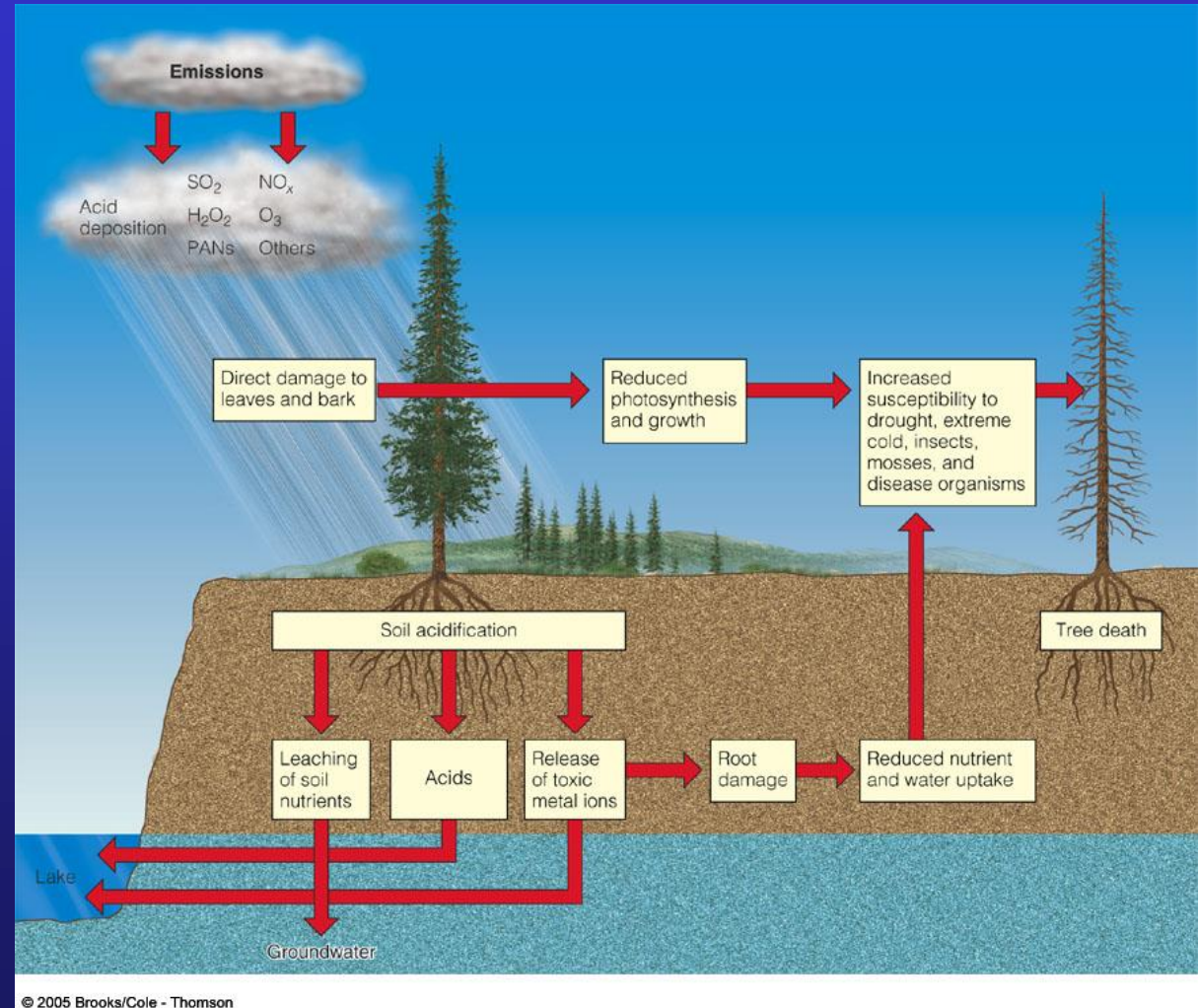
- **Fish declines**
- **Aluminum toxicity**
- **Acid shock**



In Canada 1,200 lakes contain little or no fish due to acid levels.

Acid Deposition, Plants, and Soil

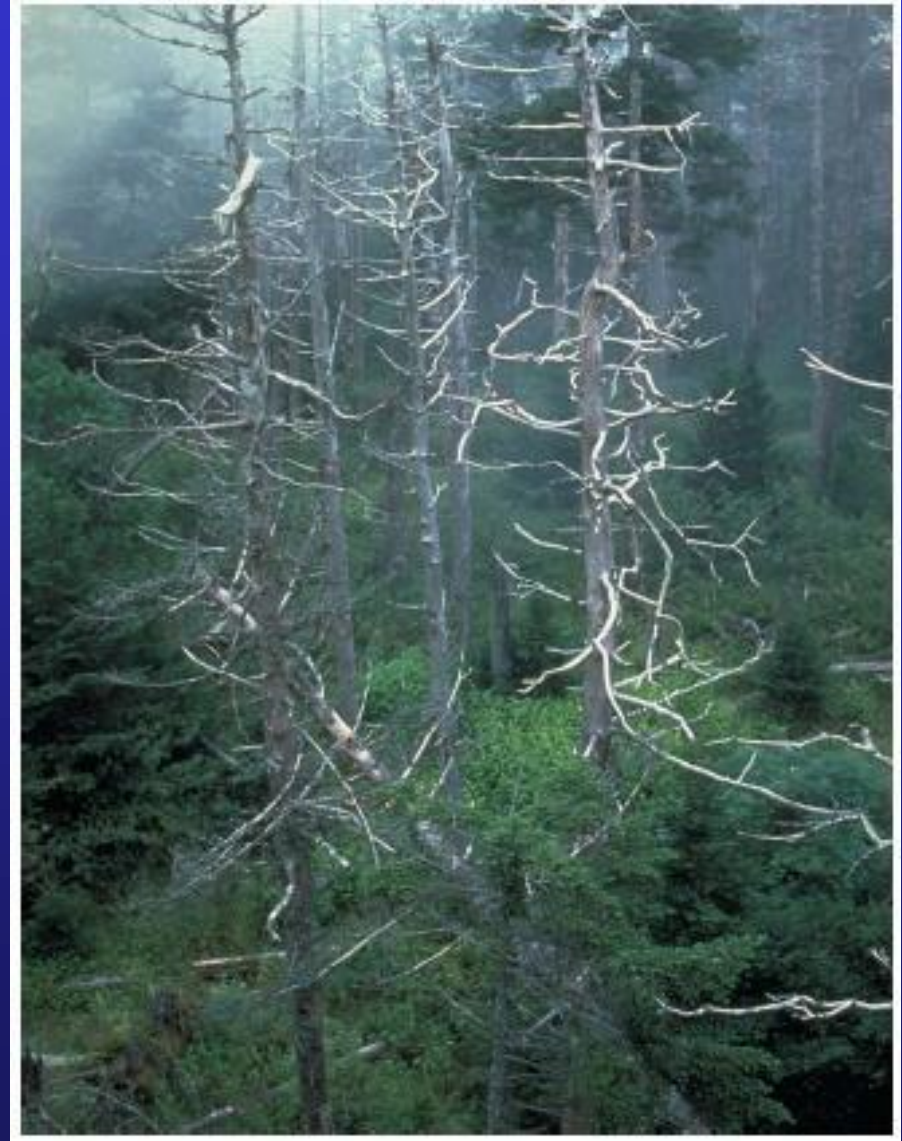
- Nutrient leaching
- Heavy metal release
- Weakens trees



Good News, Bad News

Good News: Acid depositions has not caused widespread decline in tree growth in U.S.

1990 Clean Air Act has led to decline in SO₂ and NO_x emissions



Good News, Bad News



*Bad News: acid
deposition continues.*

*Plants, lakes and forests
continue to struggle.*

*Estimated 80%
reeducation from coal
power plants is needed.*

Solutions to Acid Deposition



Section 4 Acid Rain Review

- What is acid deposition? Where does it occur?
- What are harmful impacts of acid deposition?
- How serious of a problem is it in the United States?
- What can be done to reduce acid deposition?



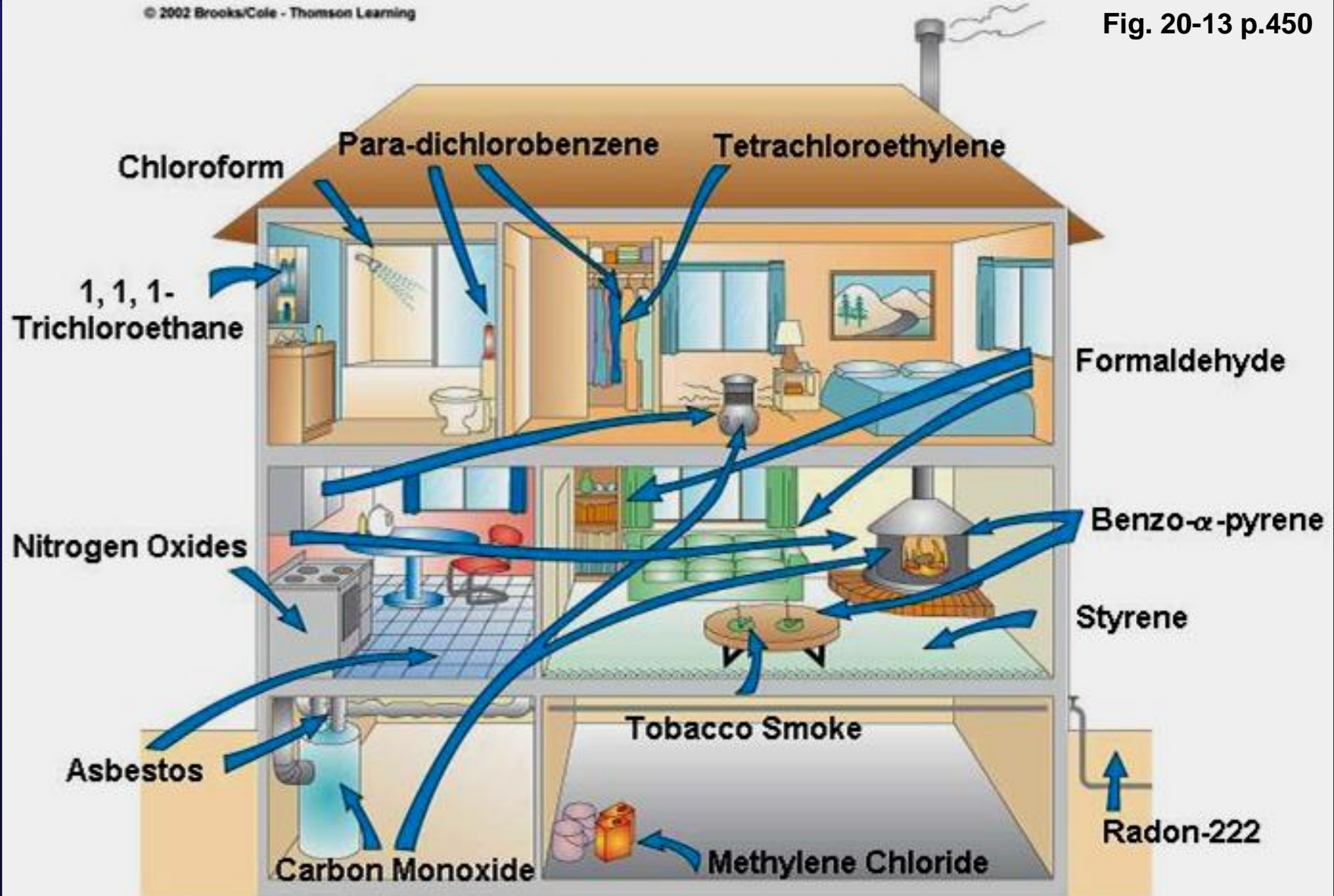
Section 5 Indoor Air Pollution

- How serious is indoor air pollution?
- Are you being exposed to radon gas?

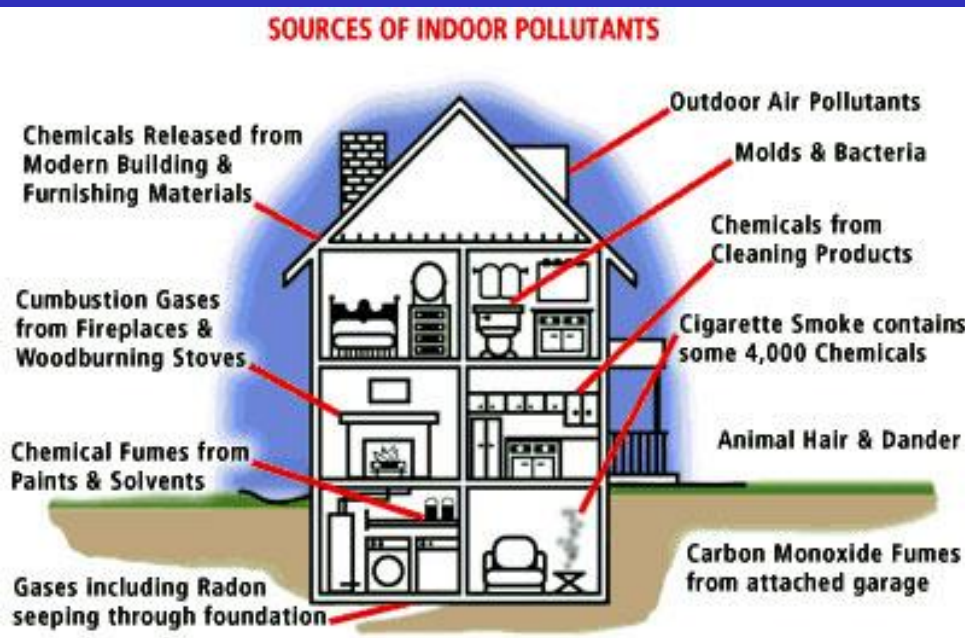
Indoor Air Pollution

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Fig. 20-13 p.450



Indoor Air Pollution



Indoor air pollution is usually a much greater threat to human health than outdoor pollution, however solutions may be harder to regulate.

EPA Study:

- 1) 11 major pollutants are 2 to 5 higher indoors

Indoor Air Pollution

2) Pollution levels inside car in traffic up to 18 times greater than outdoors.

3) People spend 70-98% of time indoors.

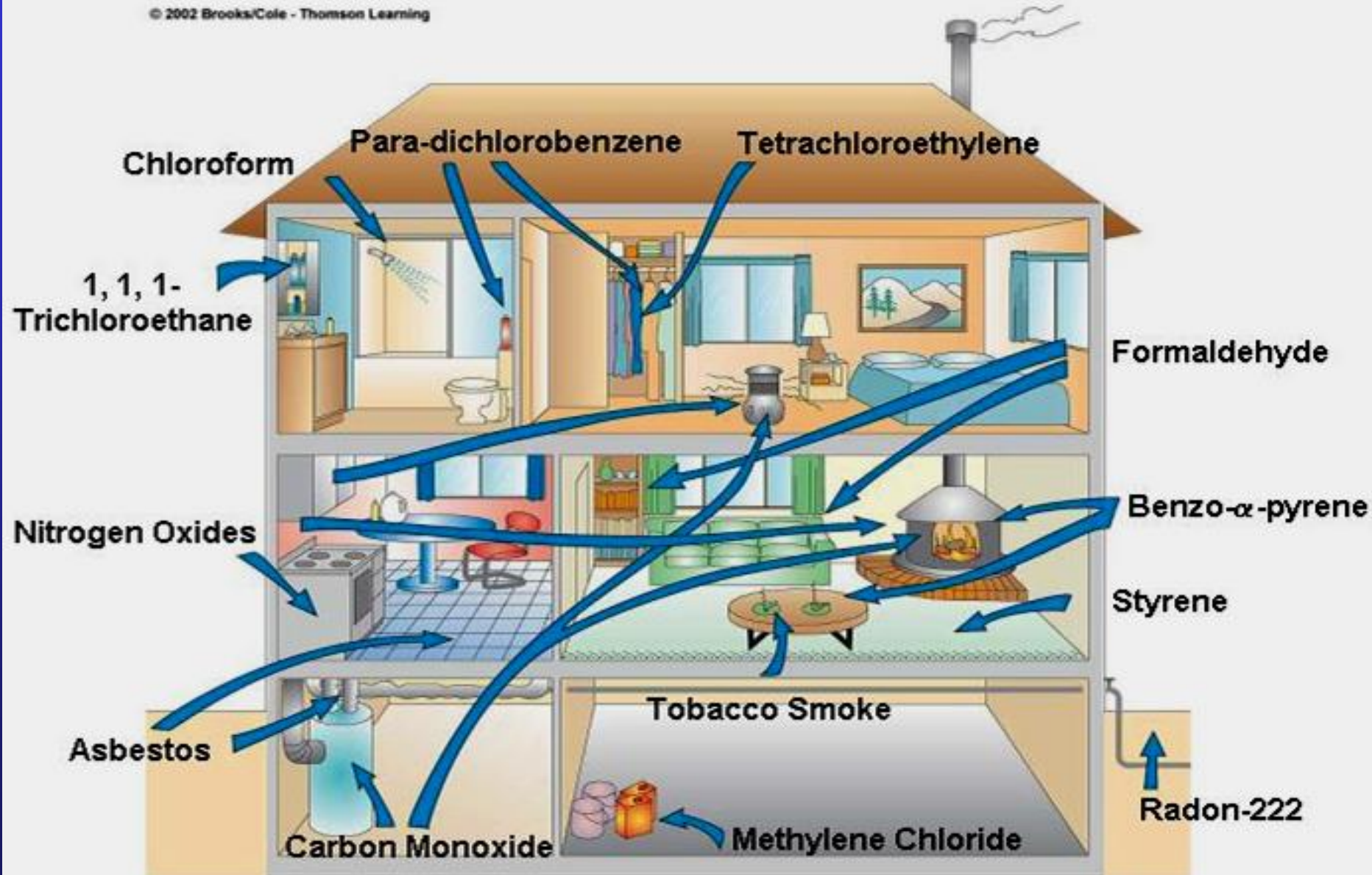
“Sick Building Syndrome”



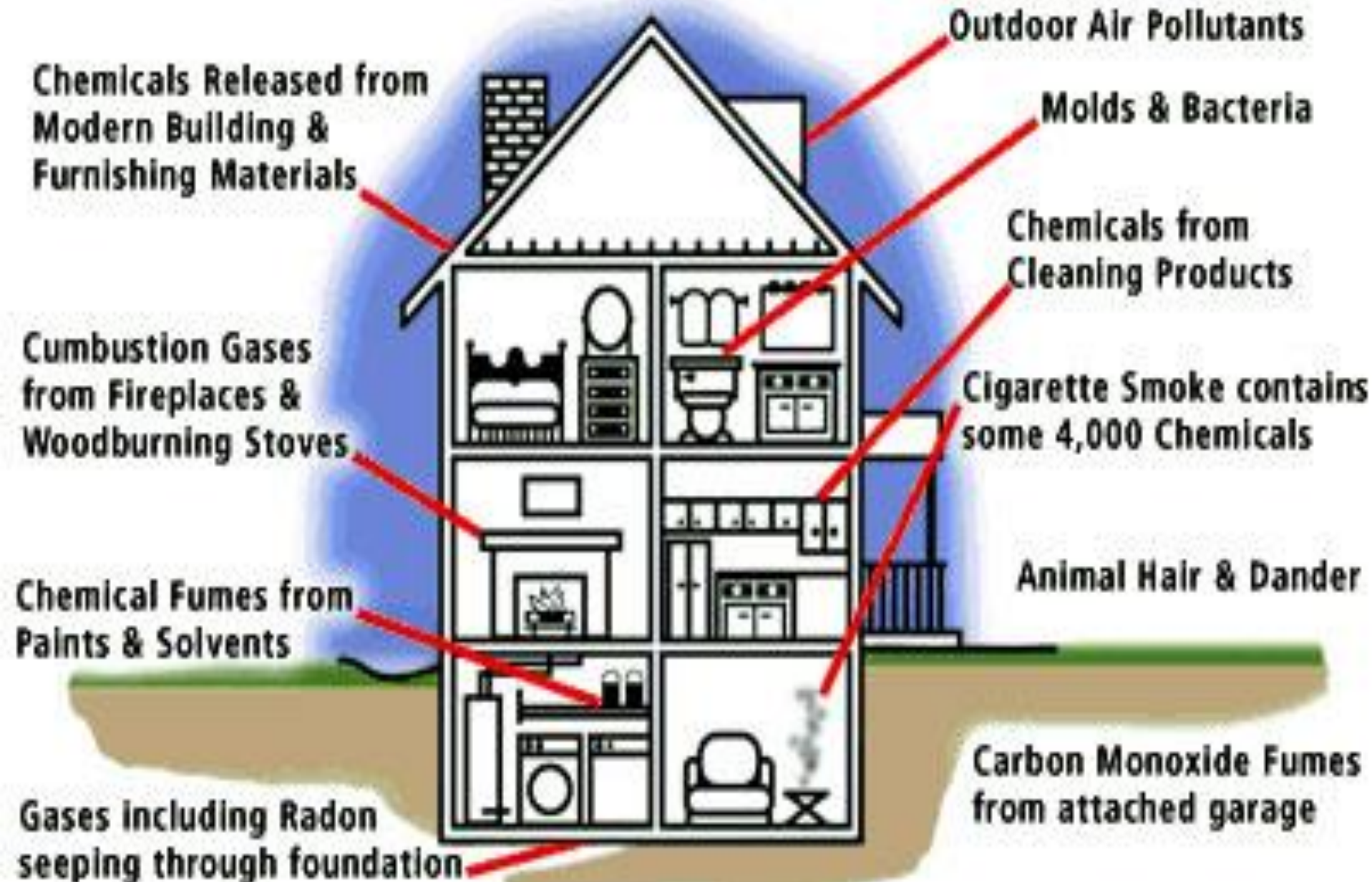
Developing Countries even more a problem

Indoor Air Pollution

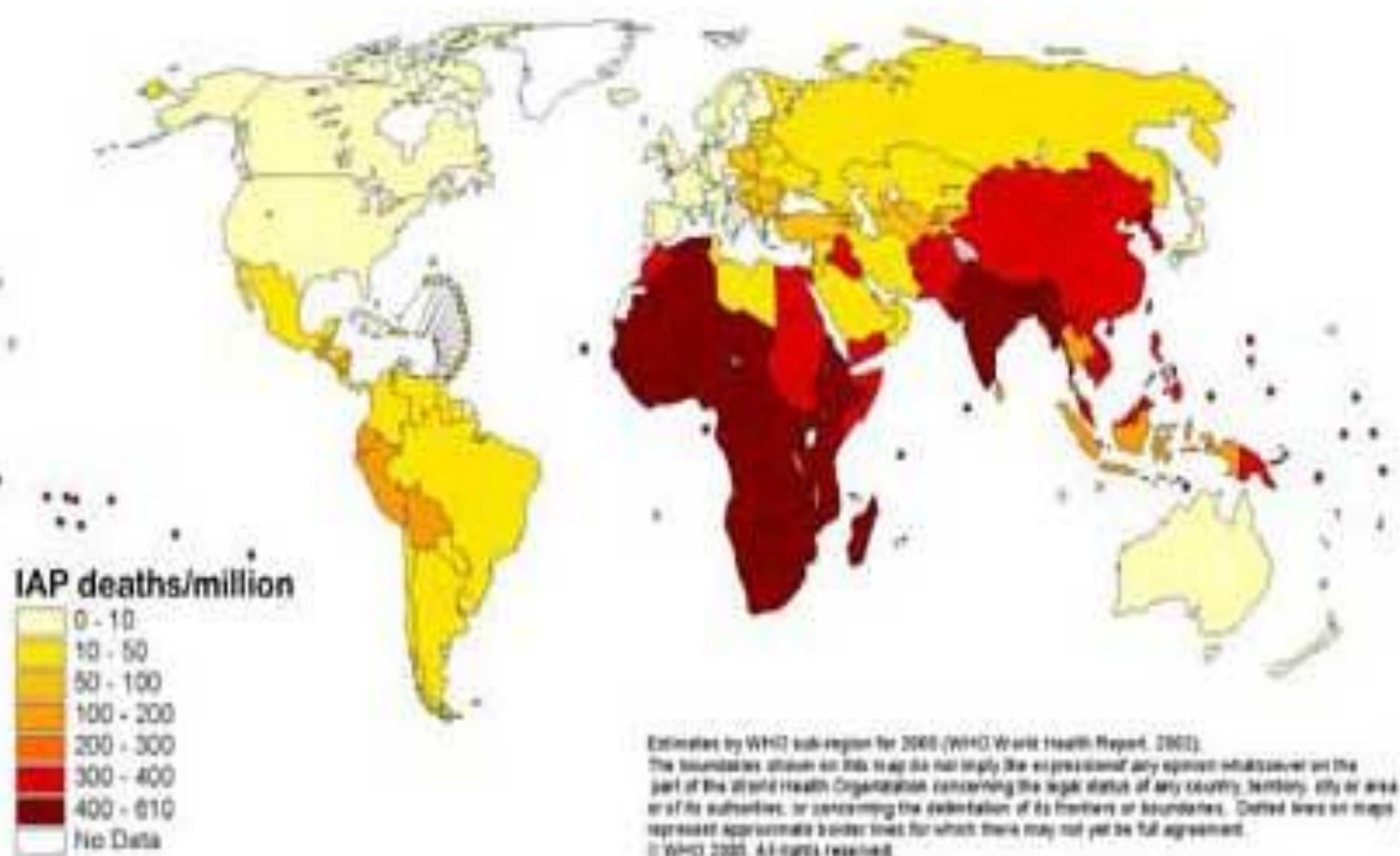
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SOURCES OF INDOOR POLLUTANTS

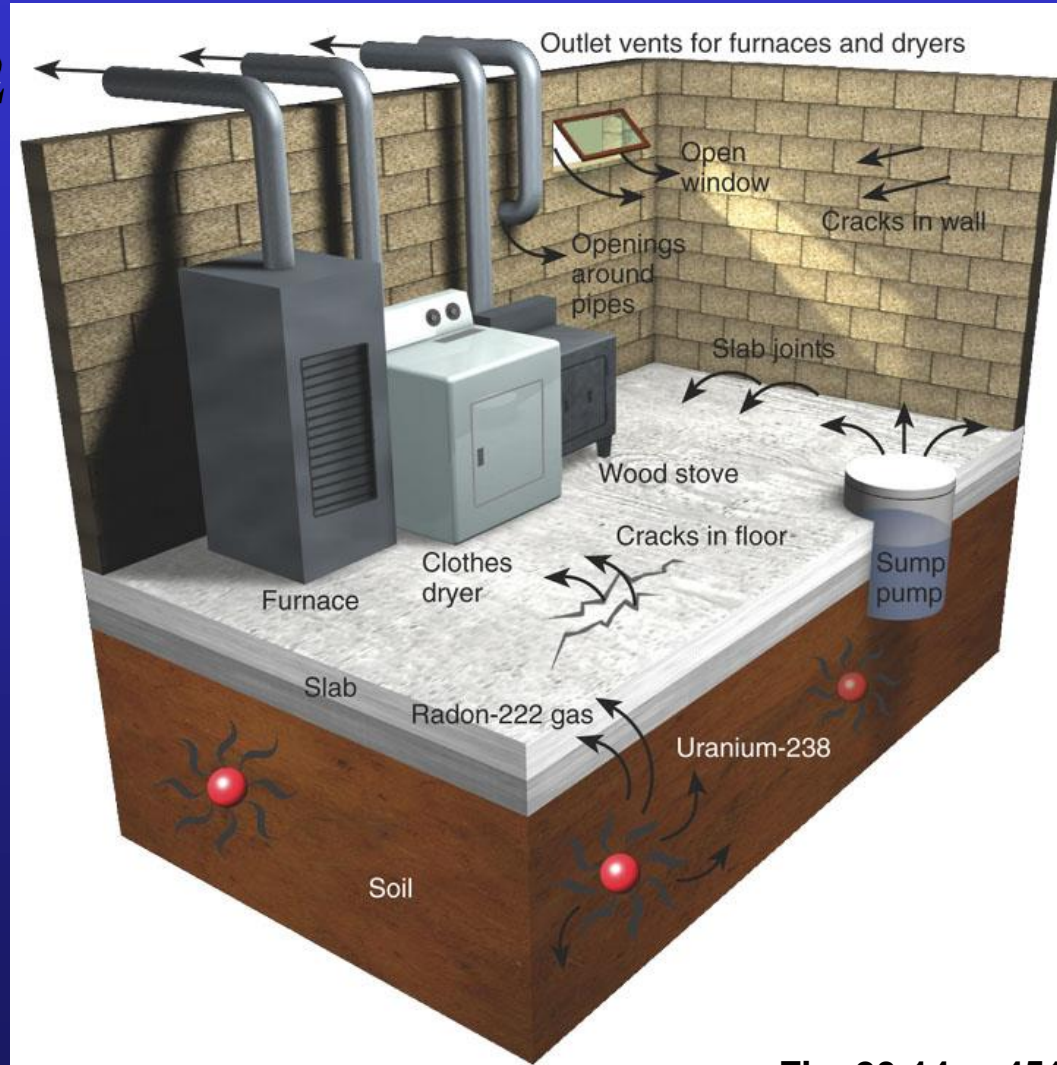


Deaths from indoor smoke from solid fuels



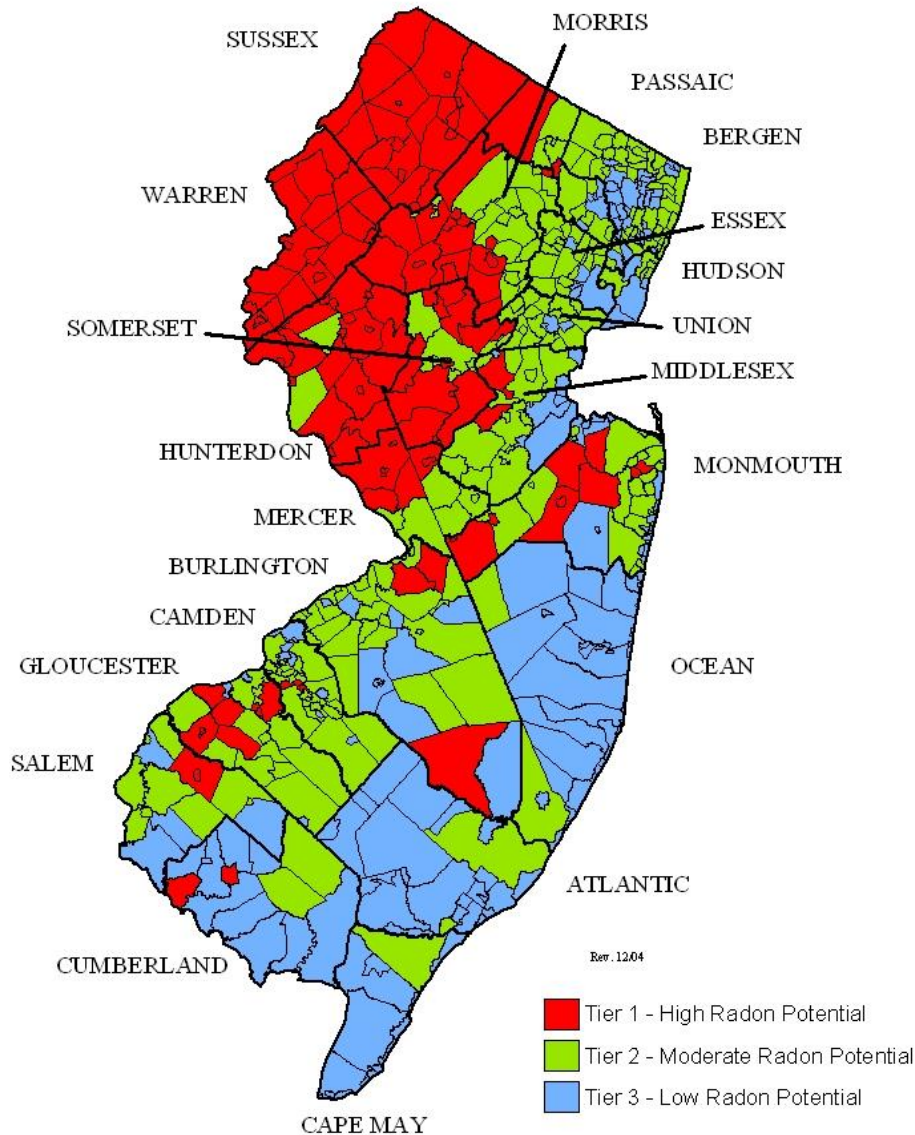
Radon

- **Radioactive radon-222**
- **Lung cancer threat**
- **Occurs in certain areas based on geology**
- **Associated with uranium and organic material in rock**





NJDEP RADON POTENTIAL MAP



FOR INFORMATION IN NEW JERSEY CALL (800) 648-0394

<http://www.njradon.org/>

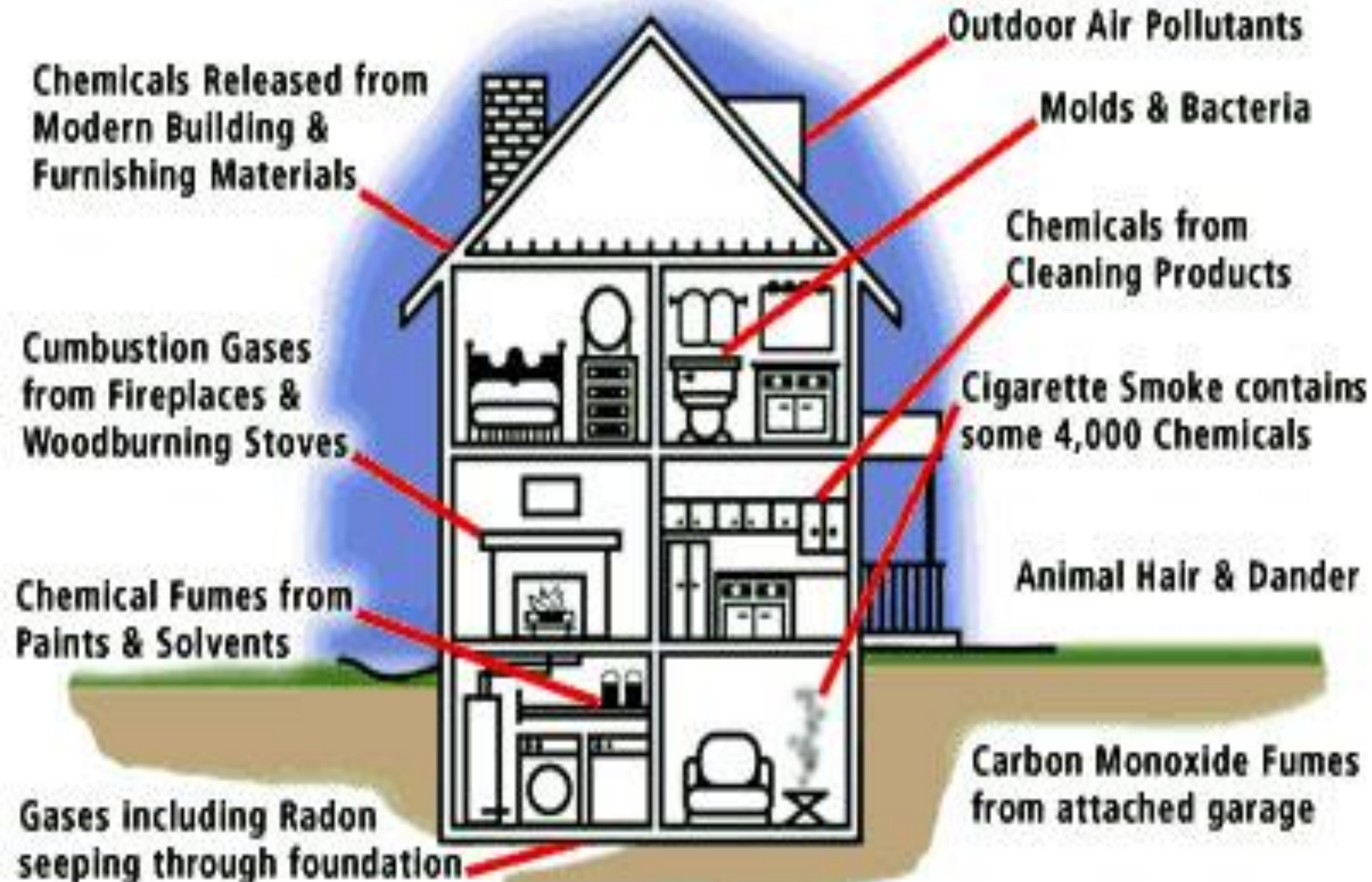
In NJ, there is a particularly uranium-rich geological formation which stretches from Pennsylvania through northwestern New Jersey into Southern New York State.

NJ, of the annual 4,700 lung cancer deaths, as many as 140-250 may be associated with radon exposure.

Section 5 Review

- How serious is indoor air pollution?
- Are you being exposed to radon gas?

SOURCES OF INDOOR POLLUTANTS



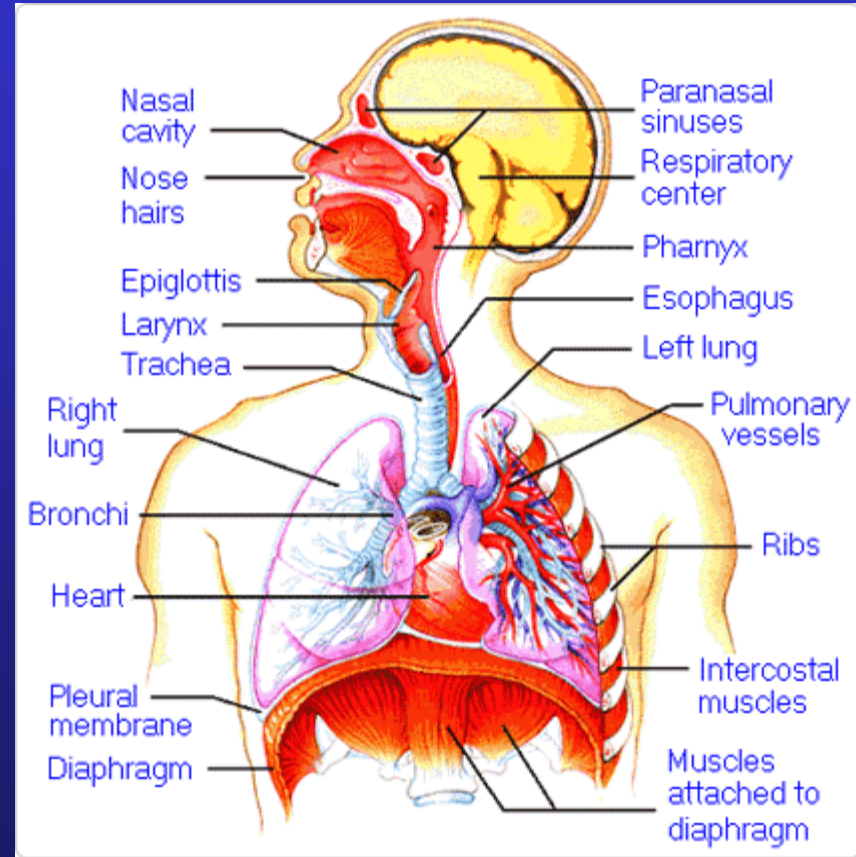
Section 6 Effects Of Air Pollution

- How does our body protect us from air pollutants?
- What types of diseases are caused by air pollution?

Respiratory System Protections

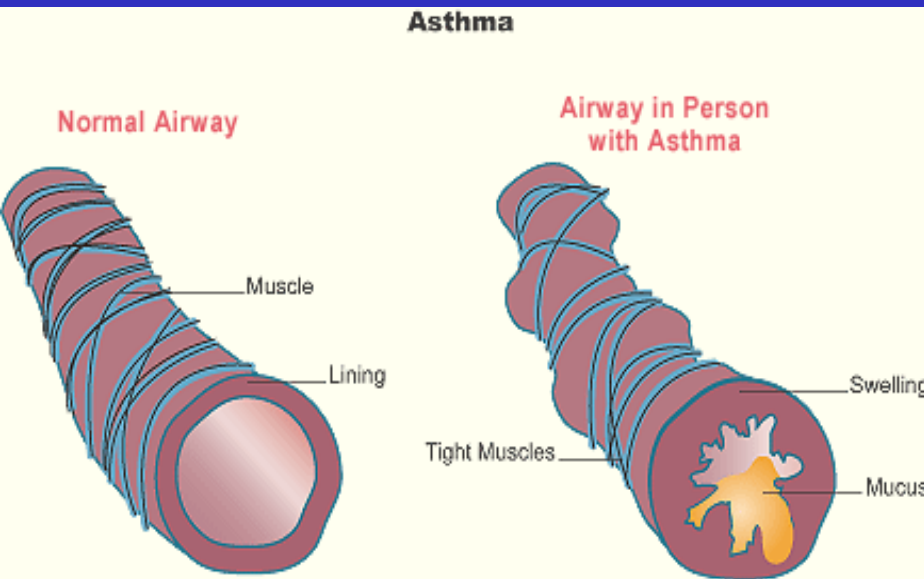
Your respiratory system has several ways to help protect you from air pollution.

- hairs in nose
- Mucus lining throat
- Cilia lining respiratory tract
- Sneezing, coughing



Respiratory System Protections

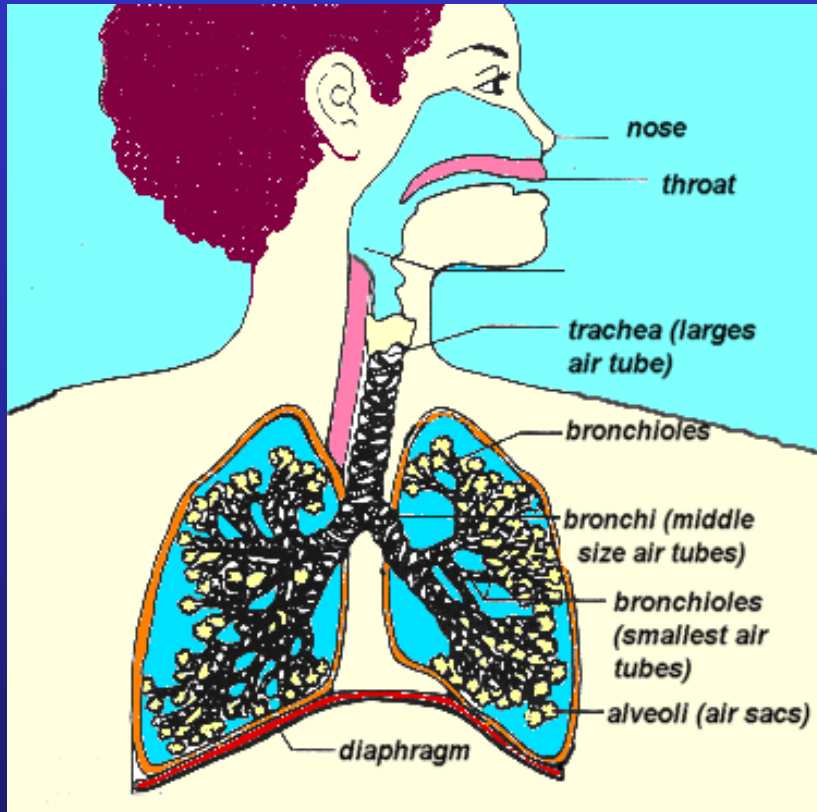
Respiratory system can be overwhelmed by pollutants.



Asthma: typically an allergic reaction causing muscles in the lung walls to spasm and shortness on breath.

From 1980 to 1994 asthma rates 160% increase in school age children.

Diseases Caused By Air Pollution



Prolonged exposure to air pollutants can lead to:

- Lung cancer
- Chronic bronchitis
- Emphysema
- Decreased lung function
- Acute shortness of breath

Children, elderly, people with heart disease are especially at risk

Premature Deaths Due To Air Pollution

*According to the WHO:
each year 3 million
premature deaths due to
air pollution.*

- 8,200 per day*
- 93% from indoor air pollution*

*In U.S. EPA estimates
150,000 to 350,000*



Premature Deaths Due To Air Pollution

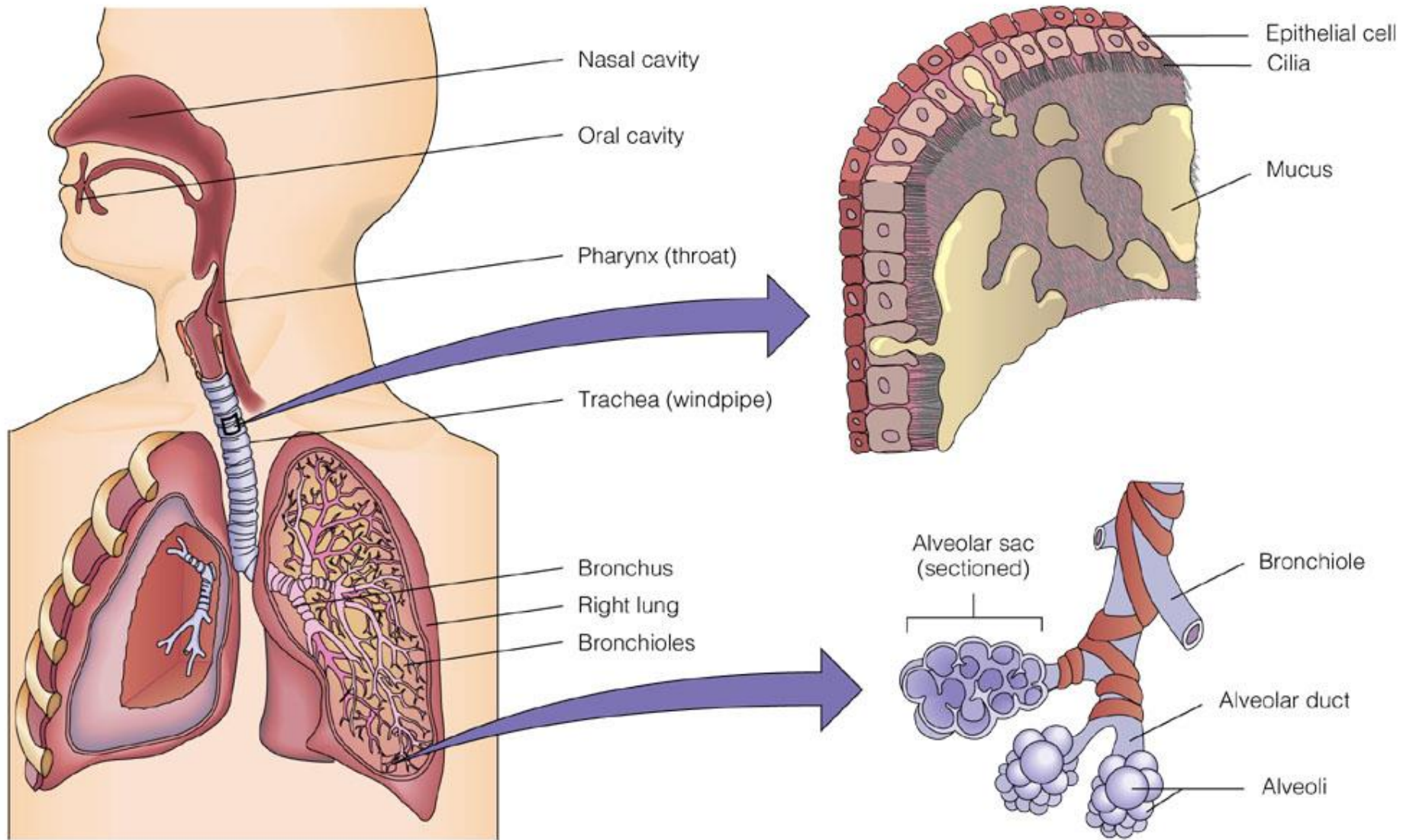


EPA:

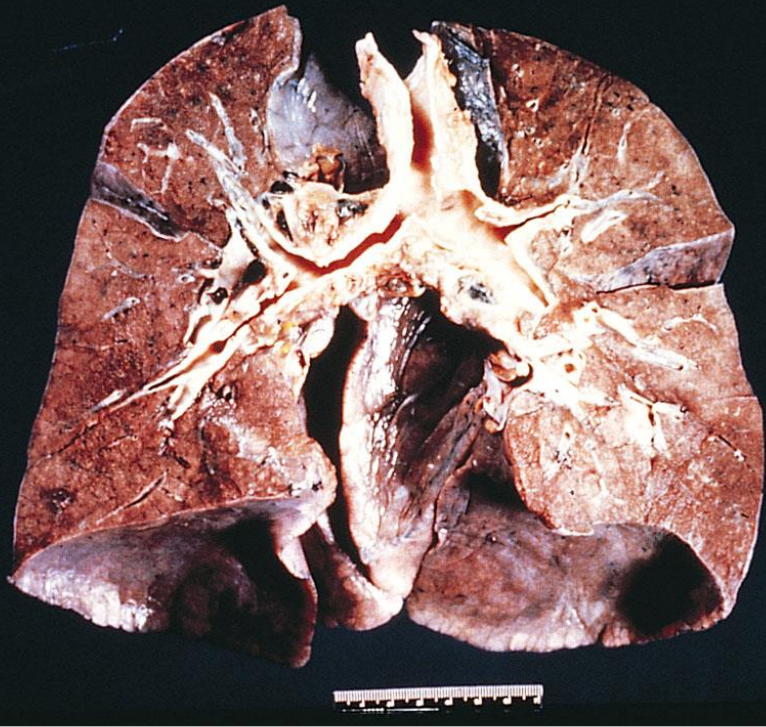
*Each year 125,000
Americans get lung
cancer from PM from
diesel exhaust .*

Effects of Air Pollution on People

- **Respiratory diseases** (see *Fig. 20-15 p. 452*)
- **Asthma**
- **Lung cancer**
- **Chronic bronchitis**
- **Emphysema**
- **Premature death**



Normal human lung



**Lung exposed to
prolonged
smoking and air
pollution**

Section 6 Review

- How does your respiratory system help protect us from air pollution?
- How many people die prematurely from air pollution?

Section 7 Key Ideas

- How have laws helped to reduce air pollution in the U.S.?
- What does the Clean Air Act require?
- How can U.S. air pollution laws be improved?
- What is emission trading and how does it work?
- Jigsaw Sections At End

Solutions: Preventing and Reducing Air Pollution

➤ **Clean Air Act**

➤ **National Ambient Air Quality Standards (NAAQS)**

➤ **Primary and secondary standards**

➤ **Emissions trading**

Clean Air Act

Congress passed CAA in 1970 with amendments in 1977 and 1990.



Establishing air pollution regulations enforced by the states.

Original law very optimistic for clean air



Clean Air Act



Clean Air Act:

- National Ambient Air Standards (NAAQS) for 6 criteria pollutants
- Risk assessment for levels of outdoor pollutants
- EPA is lead federal authority (EPA created in 1970)

Clean Air Act

Regulates:

- Mobile sources
(manufacturers and fuels)
by Federal Government
- Stationary sources by
SIPS put together by
states

*Designates non-attainment
areas based upon
NAAQS*



Clean Air Act



Requires:

- Regular review of NAAQS based upon best available science
- Allows citizens to sue if efforts not being made to clean air
- Fines states or industries failing to meet standards

Clean Air Act

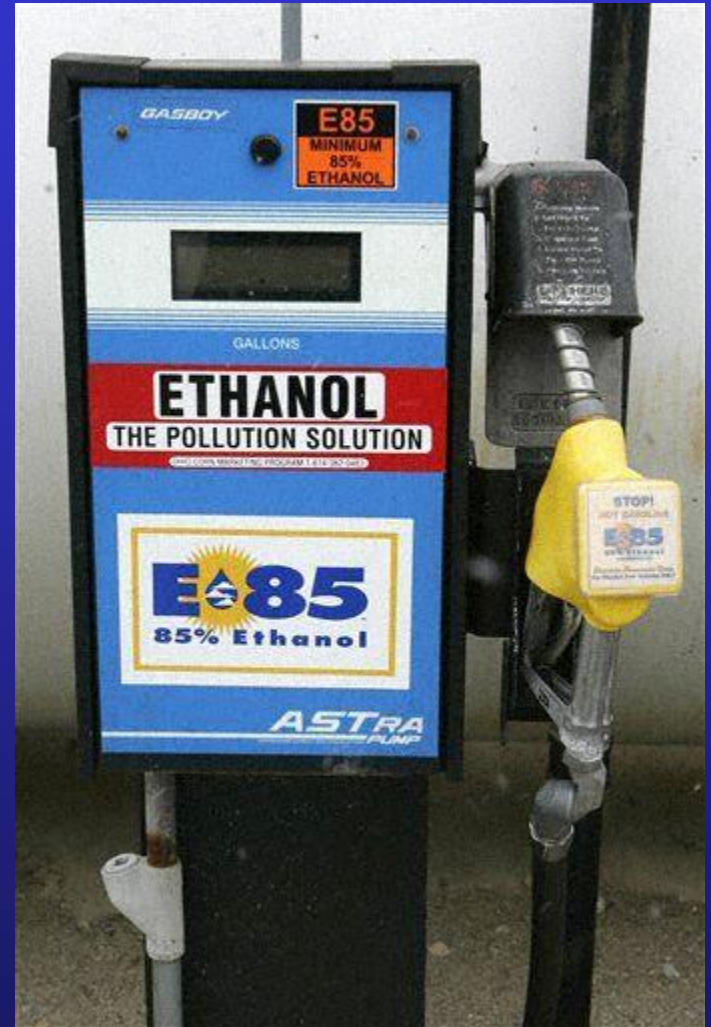
Primary Standards: set to protect human health.

Secondary: is intended to prevent environmental harm.

Hazardous Air Pollutants:
(HAPS)

188 toxic chemicals

Each standard set for maximum allowable amount in ambient air



Clean Air Act: Successes

According to EPA:

- 1970 to 2002: 48% **decrease in criteria pollutants** while GDP, miles traveled, energy and population all saw huge increase.
- 93% lower Pb, 41% CO, 40% VOCs, 34% PM-10, 33% SO₂, 15% NO_x, 14% O₃, PM-2.5 8%



Clean Air Act: Bad News

HAPs: increased over last 30 years.

Estimated 100 million Americans live in areas where HAPs risk of cancer is 10 in 1 million (standard is 1 per million)

Smog levels stuck between 1993 and 2003 – most “bad” cities only violate smog standard a few days a year



Wesley Bocxe/Photo Researchers, Inc.

Clean Air Act Improvements

CAA Huge Success because

- citizens demanded change
- Country was wealthy enough to afford controls

BUT (how can it be improved)

- Focus shifted from cleanup to prevention
- Increase CAFÉ standards
- Two-cycle engines need more regs.



Clean Air Act Improvements

- Ocean going vessels need to be regulated (1 ship can = 2,000 trucks)
- Greenhouse gasses need to be dealt with
- Better enforcement of current regs.

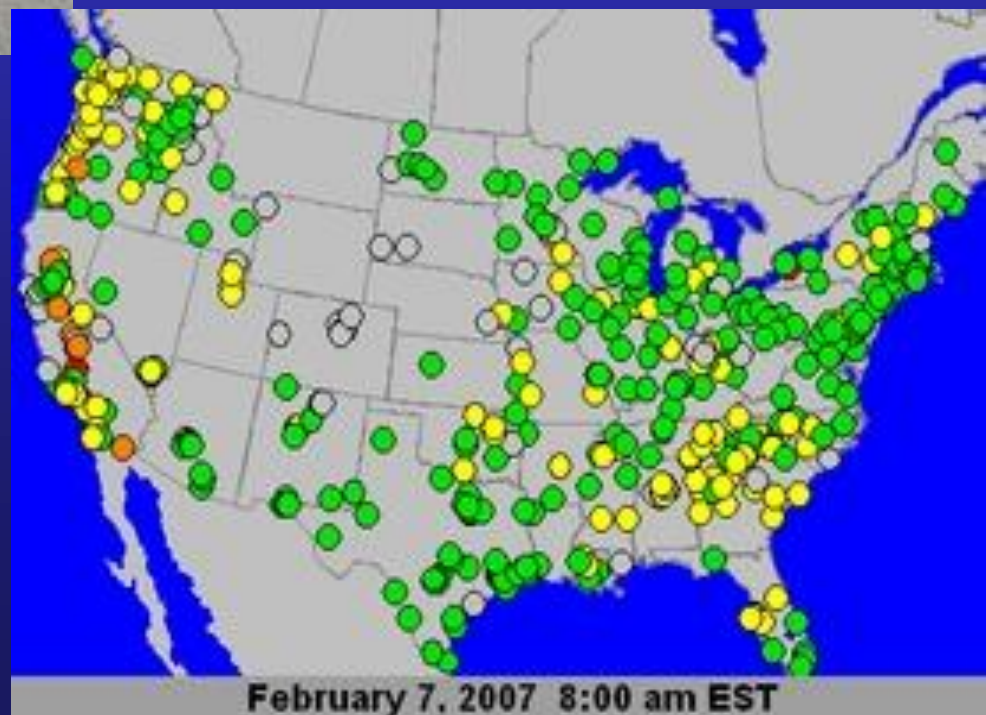
What would be benefits/
costs of these
improvements?





*Air quality monitors
set up around the
country*

*Particulate air
quality monitors and
data found at
<http://airnow.gov/>*



Emission Reduction

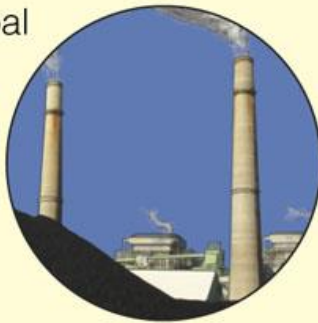
Fig. 20-18a p. 457

Solutions

Stationary Source Air Pollution

Prevention

Burn low-sulfur coal



Remove sulfur from coal

Convert coal to a liquid or gaseous fuel



Shift to less polluting fuels

Dispersion or Cleanup

Disperse emissions above thermal inversion layer with tall smokestacks

Remove pollutants after combustion

Tax each unit of pollution produced

Fig. 20-17 p. 456

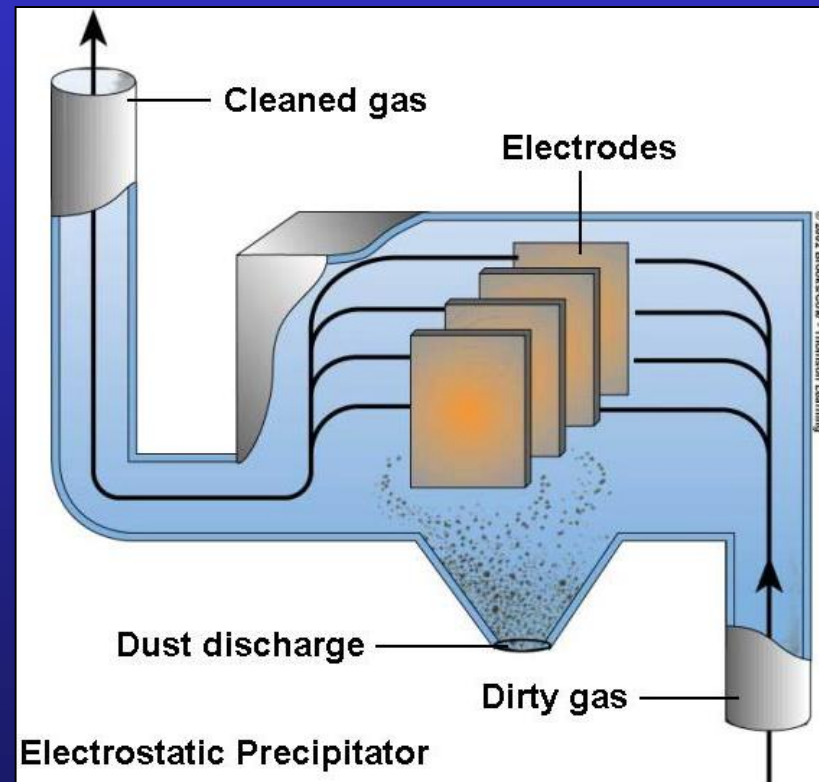
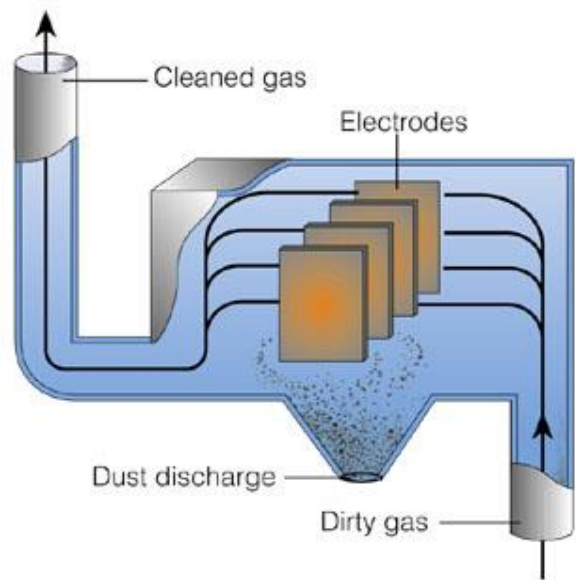
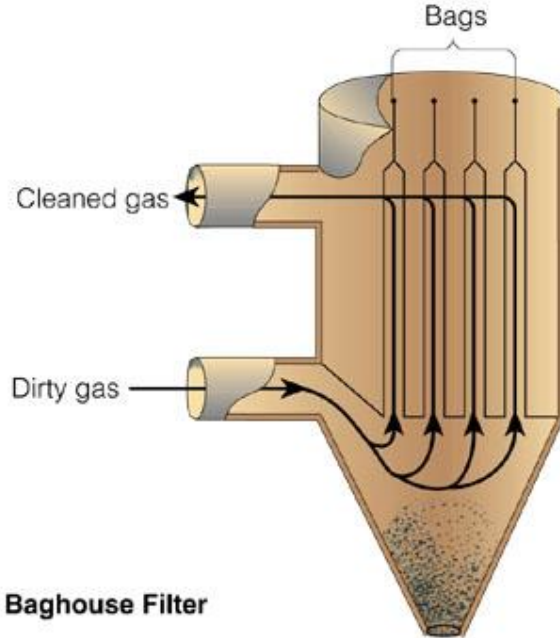


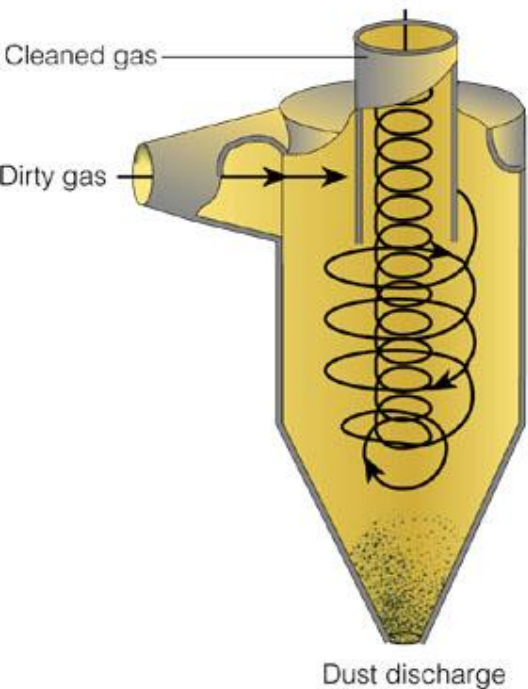
Fig. 20-18a p. 457



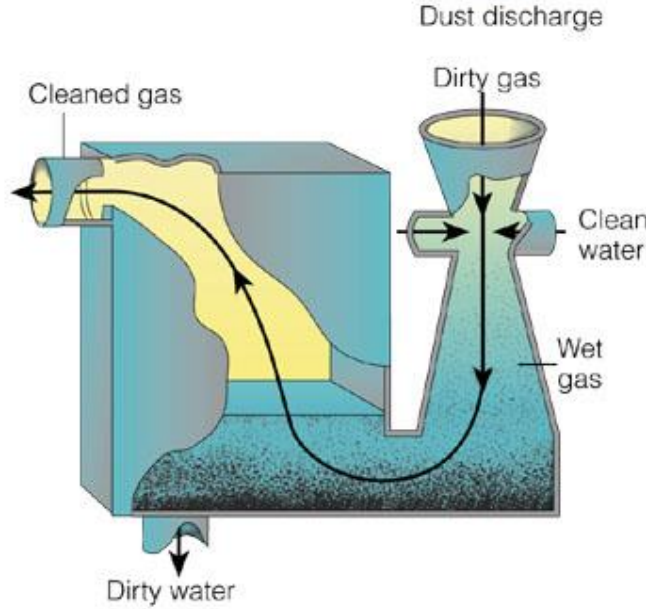
a. Electrostatic Precipitator



b. Baghouse Filter



c. Cyclone Separator



d. Wet Scrubber

Several types of filters or scrubbers that can be placed on smokestacks and other stationary sources.

Similar to catalytic converter put on mobile sources

Reducing Motor Vehicle Air Pollution



Reducing Indoor Air Pollution

Solutions

Indoor Air Pollution

Prevention

Cover ceiling tiles and 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



Cleanup or Dilution

Use adjustable fresh air vents for work spaces

Increase intake of outside air

Change air more frequently

Circulate a building's air through rooftop greenhouses

Use exhaust hoods for stoves and appliances burning natural gas

Install efficient chimneys for wood-burning stoves

Solutions

Air Pollution

Outdoor

Indoor

Improve energy efficiency to reduce fossil fuel use



Reduce poverty

Rely more on lower-polluting natural gas



Distribute cheap and efficient cookstoves to poor families in developing countries

Rely more on renewable energy (especially solar cells, wind, and solar-produced hydrogen)



Reduce or ban indoor smoking

Transfer technologies for latest energy efficiency, renewable energy, and pollution prevention to developing countries



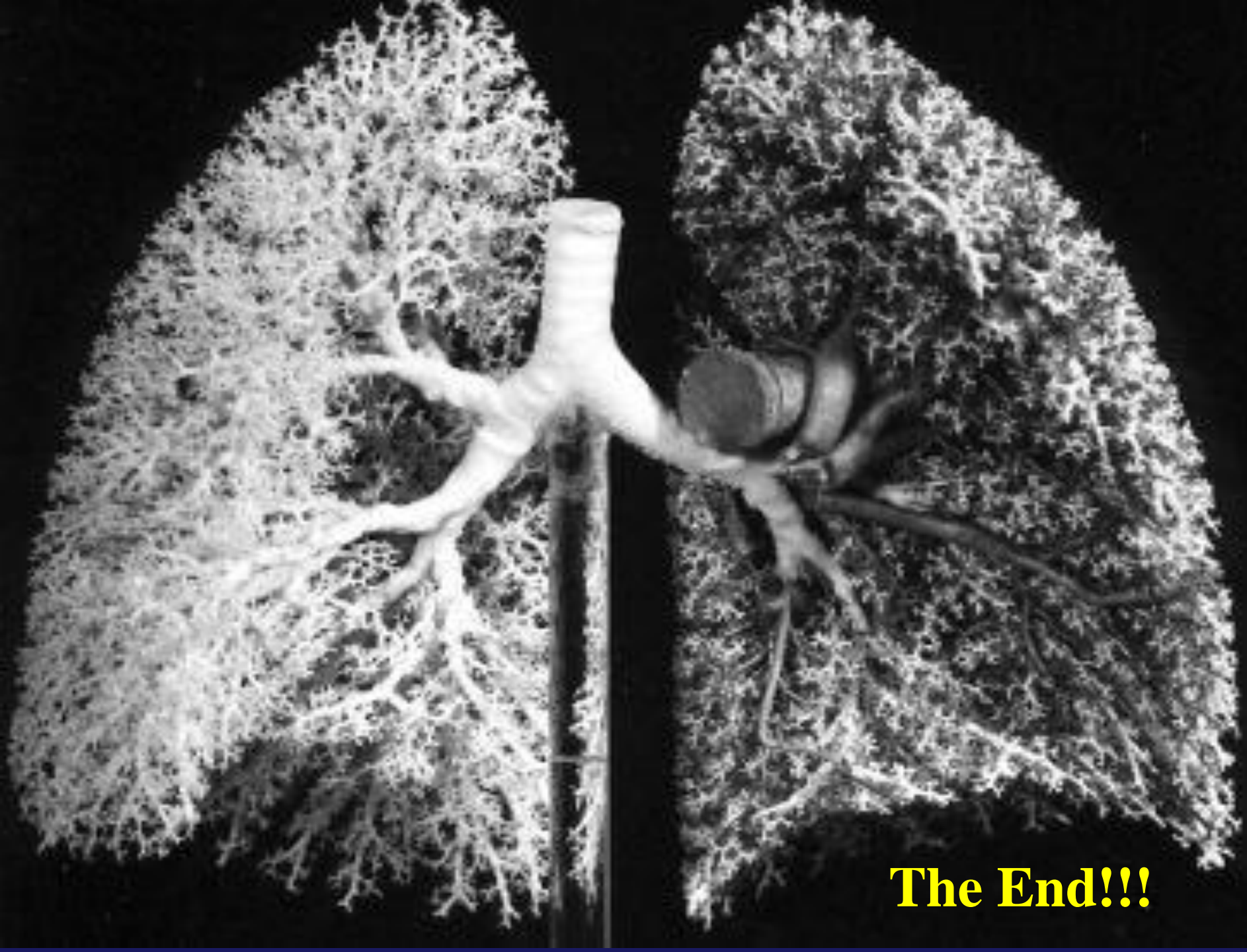
Develop simple and cheap tests for indoor pollutants such as particulates, radon, and formaldehyde

Section 7 Review

- How have laws helped to reduce air pollution in the U.S.?
- What does the Clean Air Act require?
- How can U.S. air pollution laws be improved?
- What is emission trading and how does it work?
- Jigsaw Sections At End

Jigsaw Assignment: 20-7

- 1) Should we use the marketplace to reduce pollution? Emissions Trading.
- 2) How can we reduce air pollution from coal burning facilities?
- 3) How can we reduce air pollution from mobile sources?
- 4) What should we do about ultrafine particles?
- 5) How can we reduce indoor air pollution?
- 6) What are the next steps? Individuals matter.



The End!!!