- **“It isn’t pollution that’s harming the environment. It’s the impurities in our air and water that are doing it.”**

  Former U.S. Vice President Dan Quayle

www.aqmd.gov/pubinfo/ 97annual.html

Beijing, China…11 days before Summer Olympics 2008.

London: 1952


15
KEW GREEN


P
741

- London:
  - Dec. 1952: unusually cold
  - Fog mixed with smoke (smog), 4 days due to temperature inversion
  - 4,000 people died (Dec 5-9) and 8000 deaths in following months due to fine particles (carbon, lead, zinc and iron)

Industrial Smog

- Industrial smog is a mixture of sulfur dioxide, droplets of sulfuric acid, and a variety of suspended solid particles emitted mostly by burning coal.
- AKA: Sulfurous Smog
  - Examples: London – type fog

Anthropogenic Outdoor Air Pollution

- ***Primary pollutants*** enter the atmosphere *directly*
  - Vehicles and industry
  - CO_2, NO_x, SO_x, Particulates and Hydrocarbons
- ***Secondary pollutants*** form due to chemical reactions that occur in the atmosphere
  - **Ozone & Acid Rain**

Criteria Air Pollutants

EPA uses six "criteria pollutants" as indicators of air quality (See table on pg 412 of text)

1. **Nitrogen Dioxide: NO_2**
2. **Ozone: ground level O_3**
3. **Carbon monoxide: CO**
4. **Lead: Pb**
5. **Particulate Matter:**
6. **Sulfur Dioxide: SO_2**

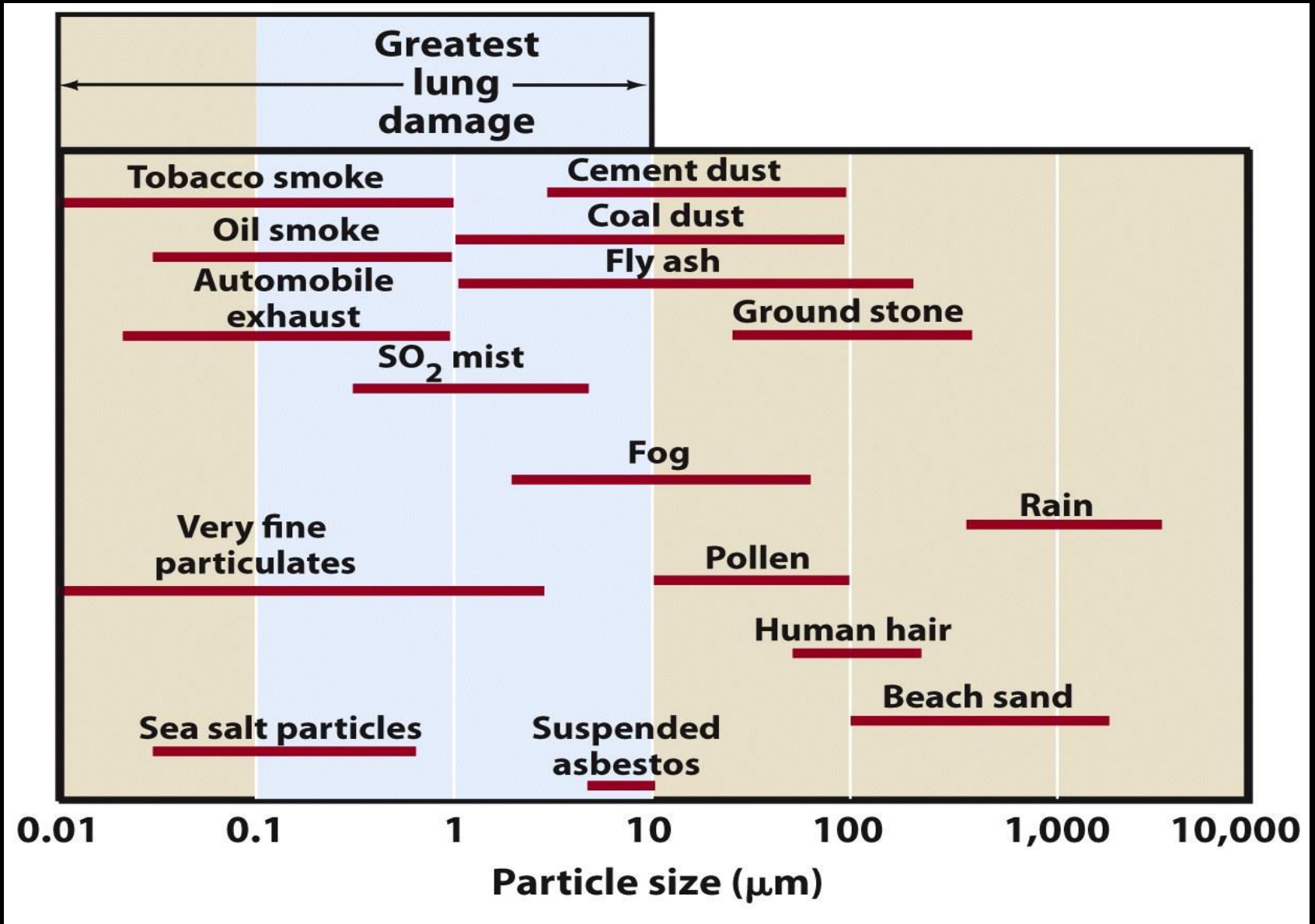
- **Volatile Organic Compounds: (VOCs)**

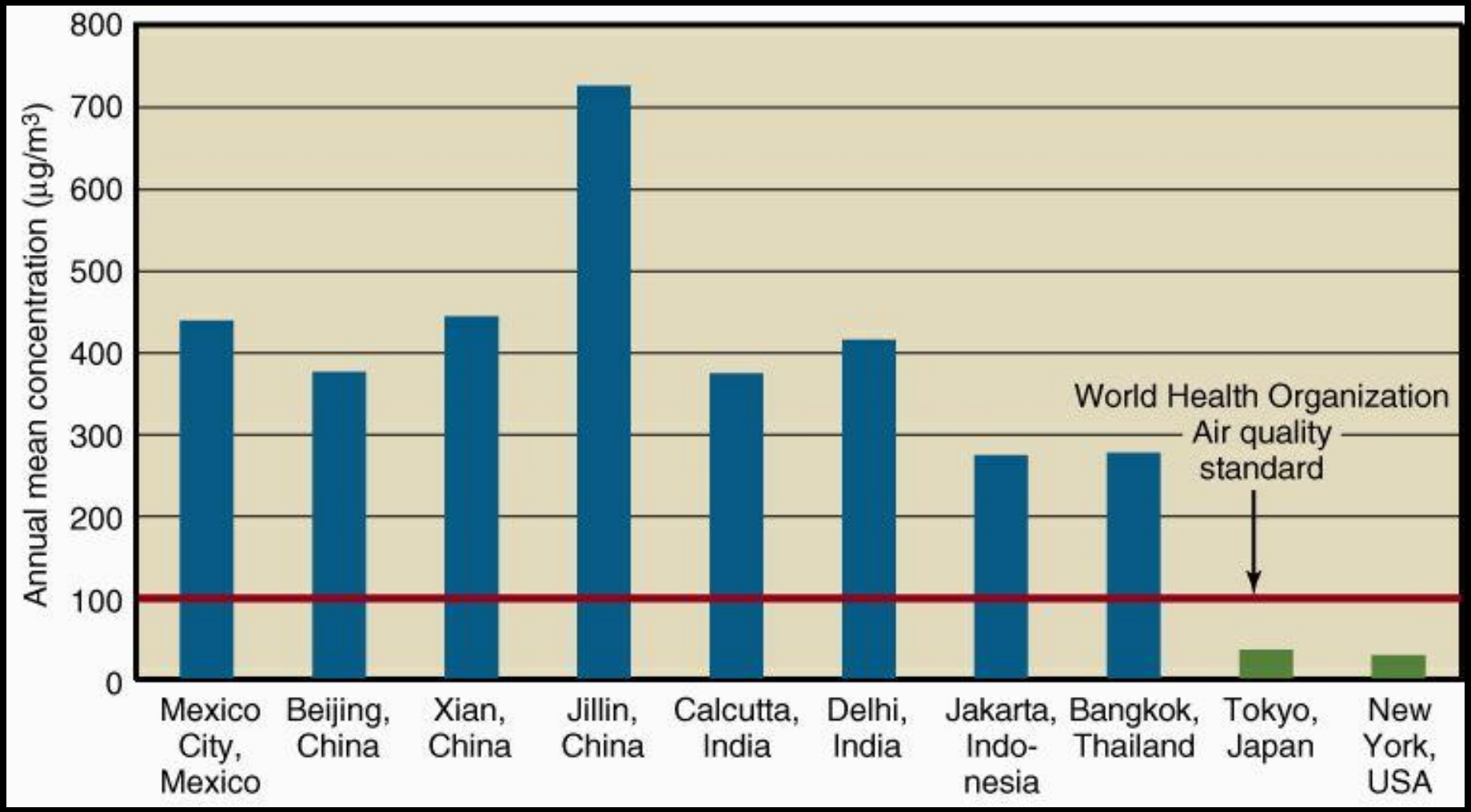
TABLE 15.1 Major air pollutants

Compound	Symbol	Human-derived sources	Effects/impacts
Criteria air pollutants			
Sulfur dioxide	SO_2	Combustion of fuels that contain sulfur, including coal, oil, gasoline.	Respiratory irritant, can exacerbate asthma and other respiratory ailments. SO_2 gas can harm stomates and other plant tissue. Converts to sulfuric acid in atmosphere, which is harmful to aquatic life and some vegetation.
Nitrogen oxides	NO_x	All combustion in the atmosphere including fossil fuel combustion, wood, and other biomass burning.	Respiratory irritant, increases susceptibility to respiratory infection. An ozone precursor, leads to formation of photochemical smog. Converts to nitric acid in atmosphere, which is harmful to aquatic life and some vegetation. Also contributes to overfertilizing terrestrial and aquatic systems (as discussed in Chapter 3).
Carbon monoxide	CO	Incomplete combustion of any kind, malfunctioning exhaust systems, and poorly ventilated cooking fires	Bonds to hemoglobin thereby interfering with oxygen transport in the bloodstream. Causes headaches in humans at low concentrations; can cause death with prolonged exposure at high concentrations.
Particulate matter	PM_{10} (smaller than 10 micrometers) $PM_{2.5}$ (2.5 micrometers and less)	Combustion of coal, oil, and diesel, and of biofuels such as manure and wood. Agriculture, road construction, and other activities that mobilize soil, soot, and dust.	Can exacerbate respiratory and cardiovascular disease and reduce lung function. May lead to premature death. Reduces visibility, and contributes to haze and smog.
Lead	Pb	Gasoline additive, oil and gasoline, coal, old paint.	Impairs central nervous system. At low concentrations, can have measurable effects on learning and ability to concentrate.
Ozone	O_3	A secondary pollutant formed by the combination of sunlight, water, oxygen, VOCs, and NO_x.	Reduces lung function and exacerbates respiratory symptoms. A degrading agent to plant surfaces. Damages materials such as rubber and plastic.
Other air pollutants			
Volatile organic compounds	VOC	Evaporation of fuels, solvents, paints; improper combustion of fuels such as gasoline.	A precursor to ozone formation.
Mercury	Hg	Coal, oil, gold mining.	Impairs central nervous system. Bioaccumulates in the food chain.
Carbon dioxide	CO_2	Combustion of fossil fuels and clearing of land.	Affects climate and alters ecosystems by increasing greenhouse gas concentrations.

Table 15.1
Environmental Science

Particulate Matter




Annual mean concentration (µg/m³)
800
700
600
500
400
300
200
100
0
World Health Organization
Air quality
standard
Mexico City, Mexico
Beijing, China
Xian, China
Jillin, China
Calcutta, India
Delhi, India
Jakarta, Indo-nesia
Bangkok, Thailand
Tokyo, Japan
New York, USA

- Air Quality Index (AQI) - A Guide to Air Quality and Your Health

Ozone

- Ground-level: “bad”
- Stratospheric: “Good”

- Tropospheric Ozone:
  - NOx, CO and VOC’s react in presence of sunlight
  - These are called Ozone “Precursors”.

The Perfect Storm

- Topography:
  - “Basin”
    - Example: Mexico City and L.A.
- Sunlight and warm temperatures
- Temperature Inversion

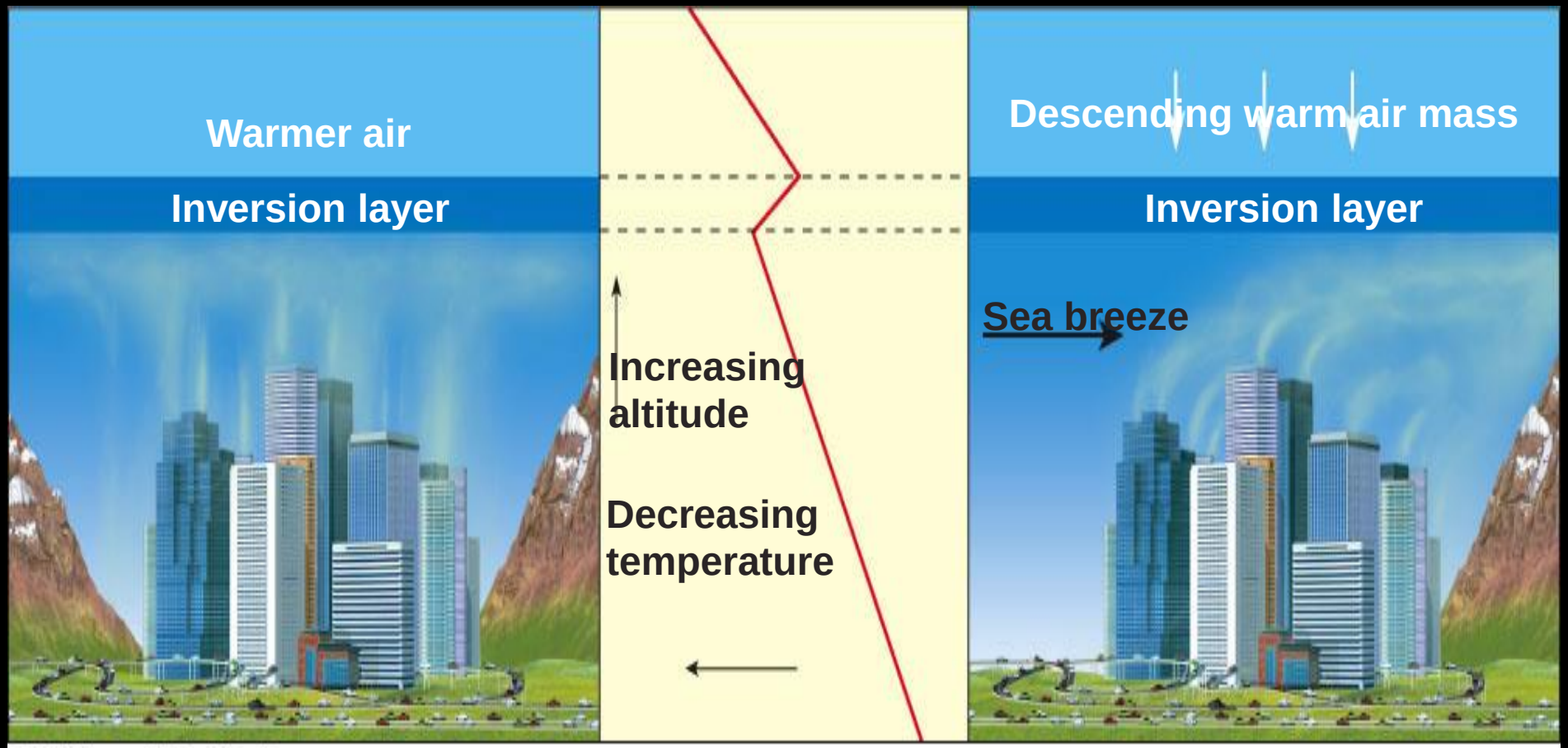
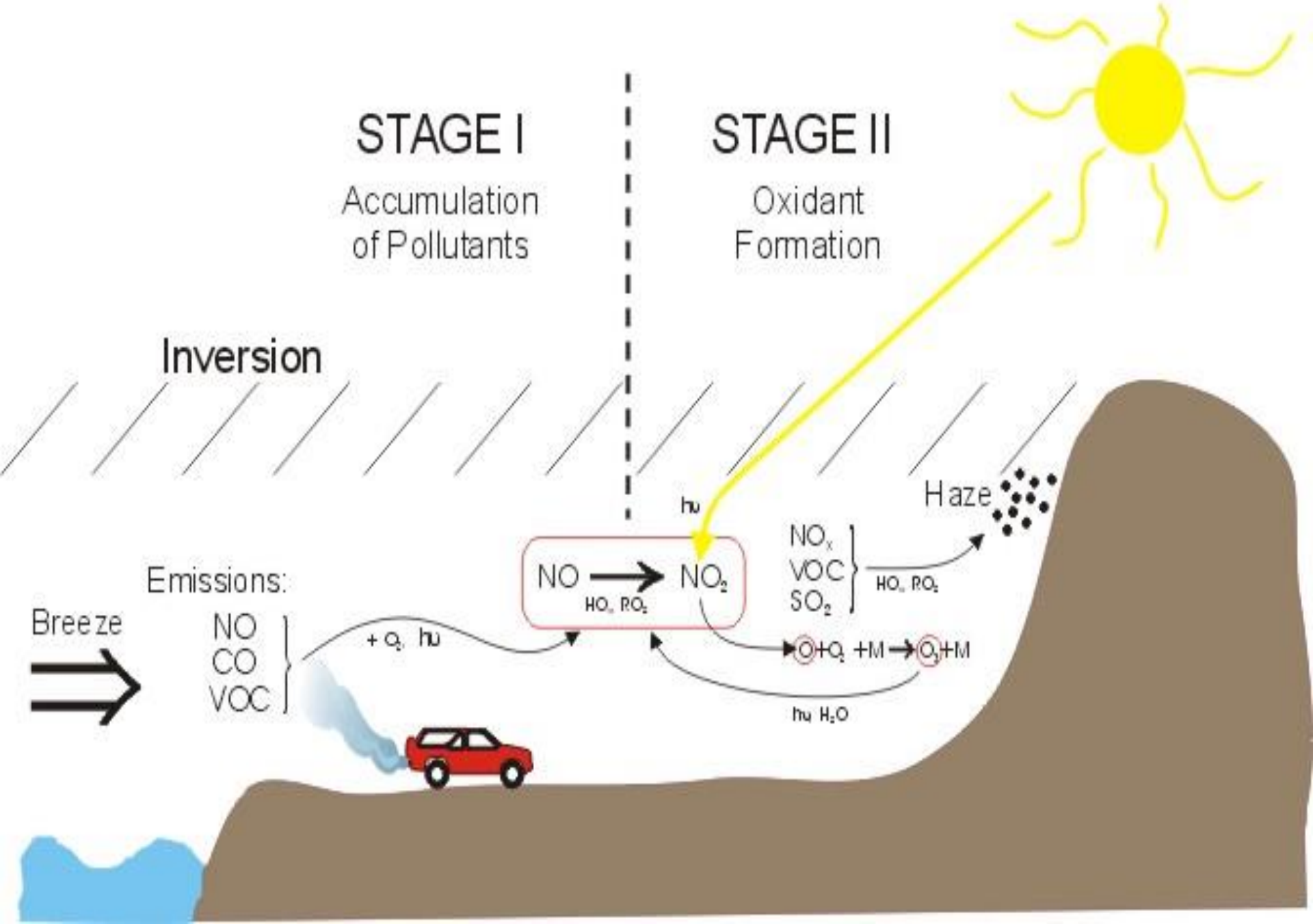


Fig. 19-5, p. 447

PHOTOCHEMICAL SMOG



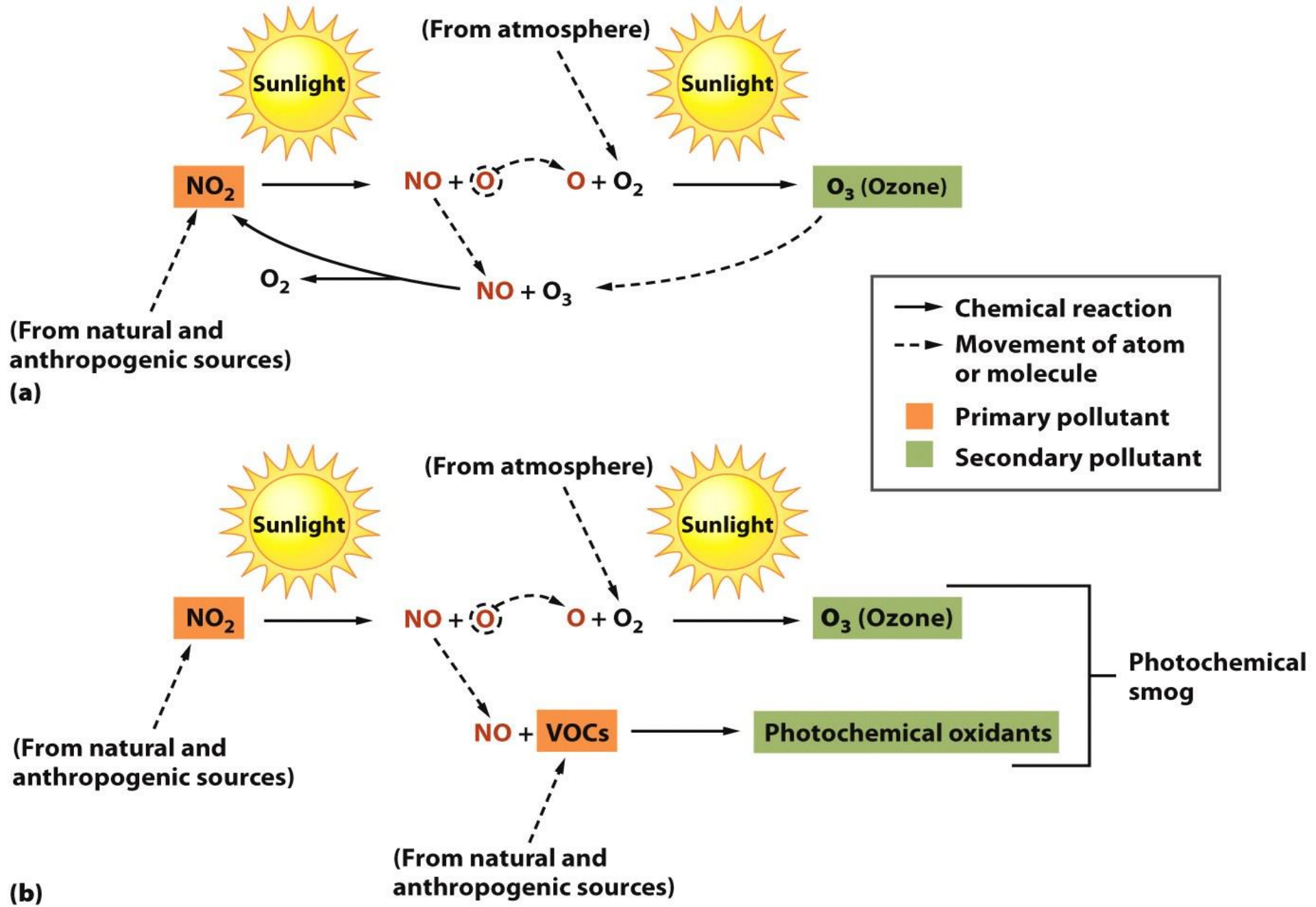
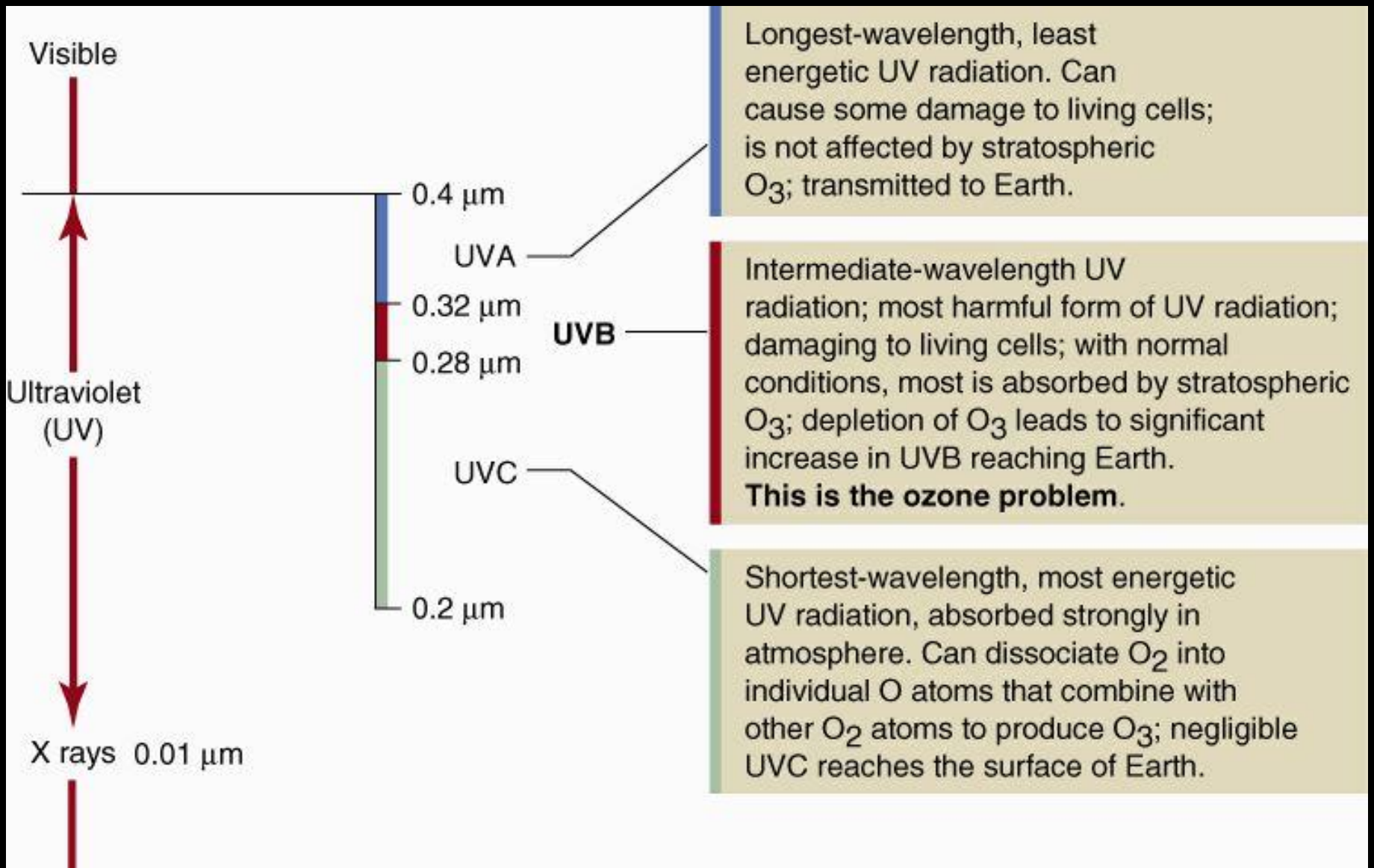


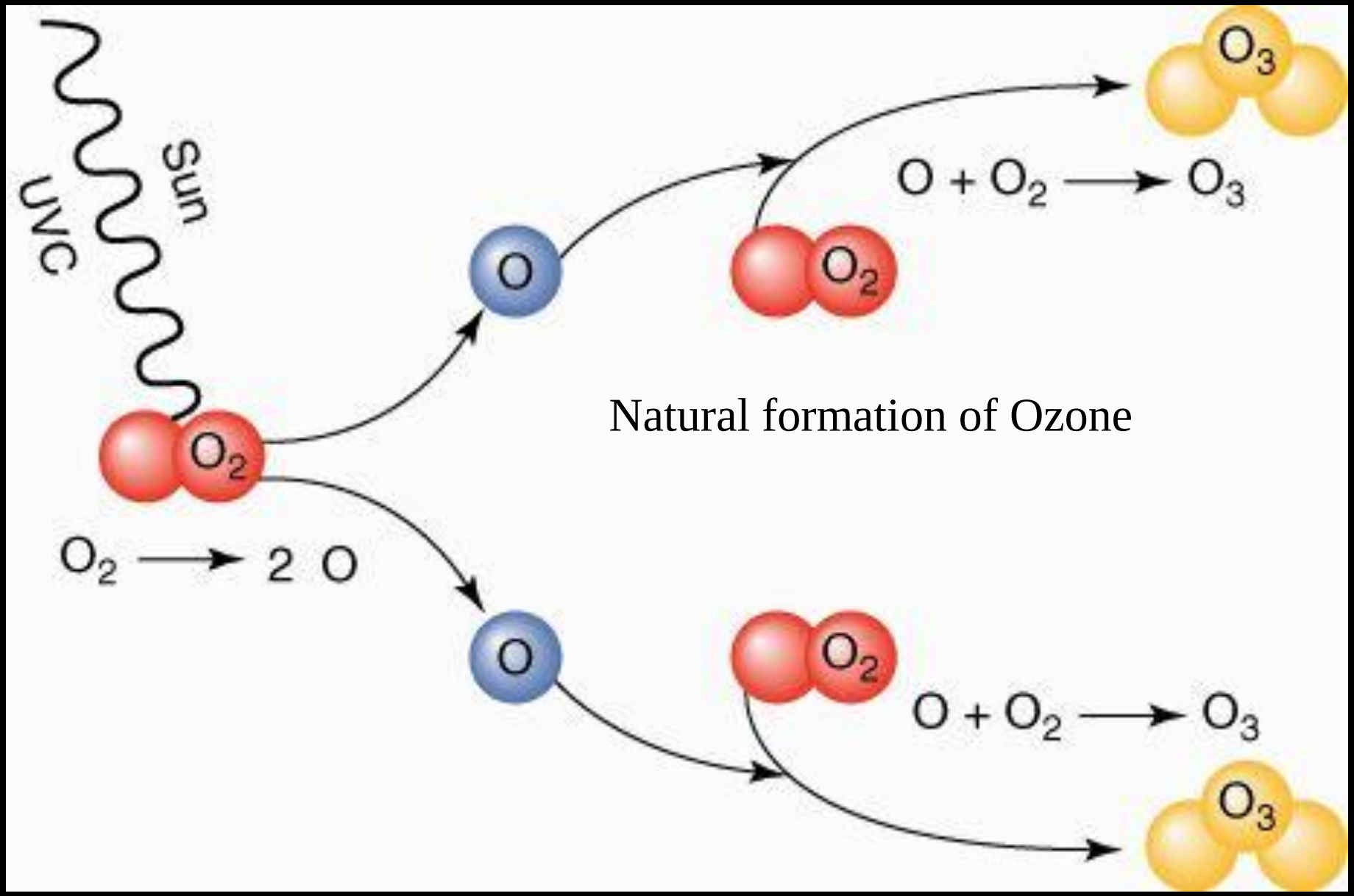
Figure 15.7
Environmental Science

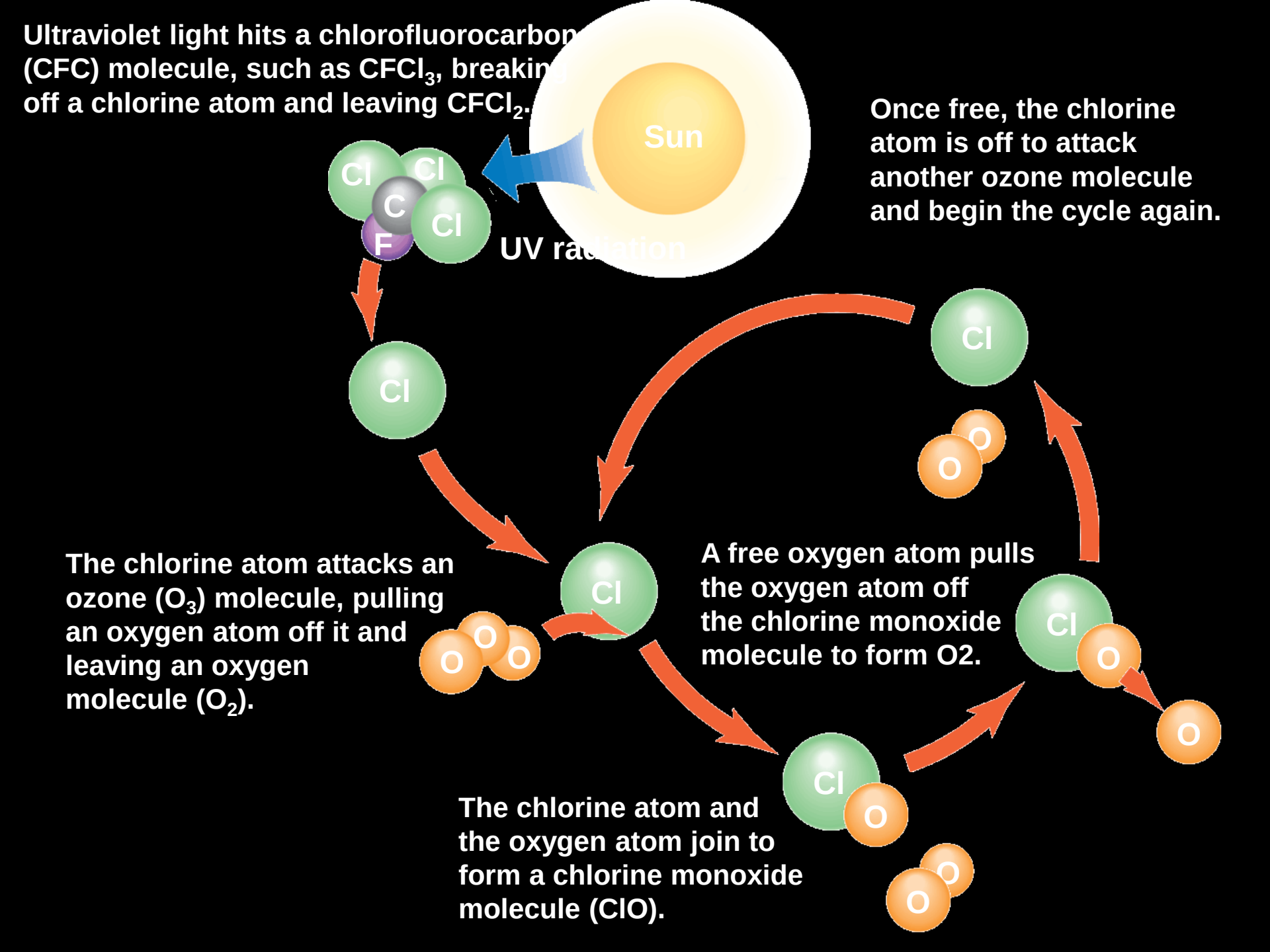
Stratospheric Ozone

- 1973 Rowland and Molina study CFC's in atmosphere
- Gardiner, Farman and Shanklin discovered "ozone hole" above Haley Bay (South Pole) in 1985
- Disputed by CEO of DuPont : "a science fiction tale…a load of rubbish…utter nonsense" (Roan p. 56)

Ultraviolet Radiation and Ozone




Sun
UVC
O_2
$O_2 \longrightarrow 2\ O$
O
O
O_2
O_2
$O + O_2 \longrightarrow O_3$
$O + O_2 \longrightarrow O_3$
O_3
O_3
Natural formation of Ozone


Ultraviolet light hits a chlorofluorocarbon (CFC) molecule, such as $CFCl_3$, breaking off a chlorine atom and leaving $CFCl_2$.
Sun
UV radiation
Cl
C
F
Once free, the chlorine atom is off to attack another ozone molecule and begin the cycle again.
The chlorine atom attacks an ozone (O_3) molecule, pulling an oxygen atom off it and leaving an oxygen molecule (O_2).
A free oxygen atom pulls the oxygen atom off the chlorine monoxide molecule to form O2.
The chlorine atom and the oxygen atom join to form a chlorine monoxide molecule (ClO).
O

Montreal Protocol

- An international treaty designed to protect the ozone layer
- phasing out production of number of substances believed to be responsible for ozone depletion
  - Effective January 1, 1989
  - Five revisions
    - 1990 (London)
    - 1992 (Copenhagen)
    - 1995 (Vienna)
    - 1997 (Montreal)
    - 1999 (Beijing)

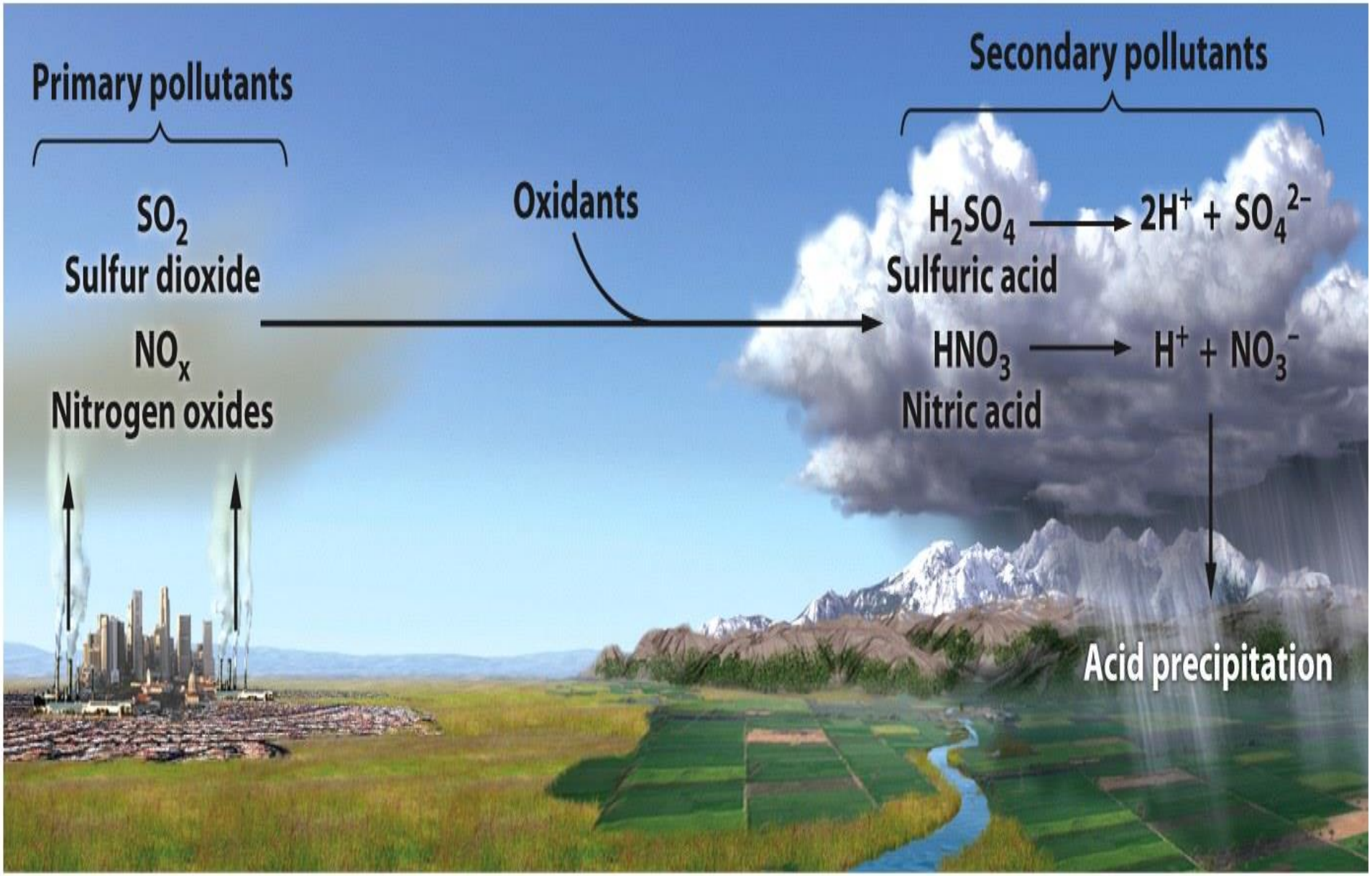
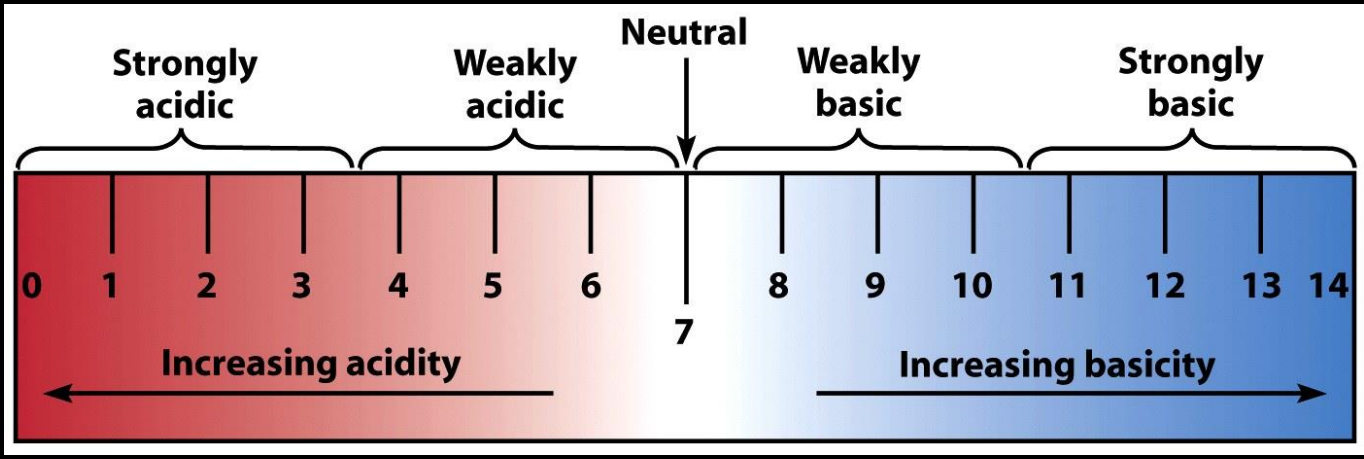


Figure 15.9
Environmental Science

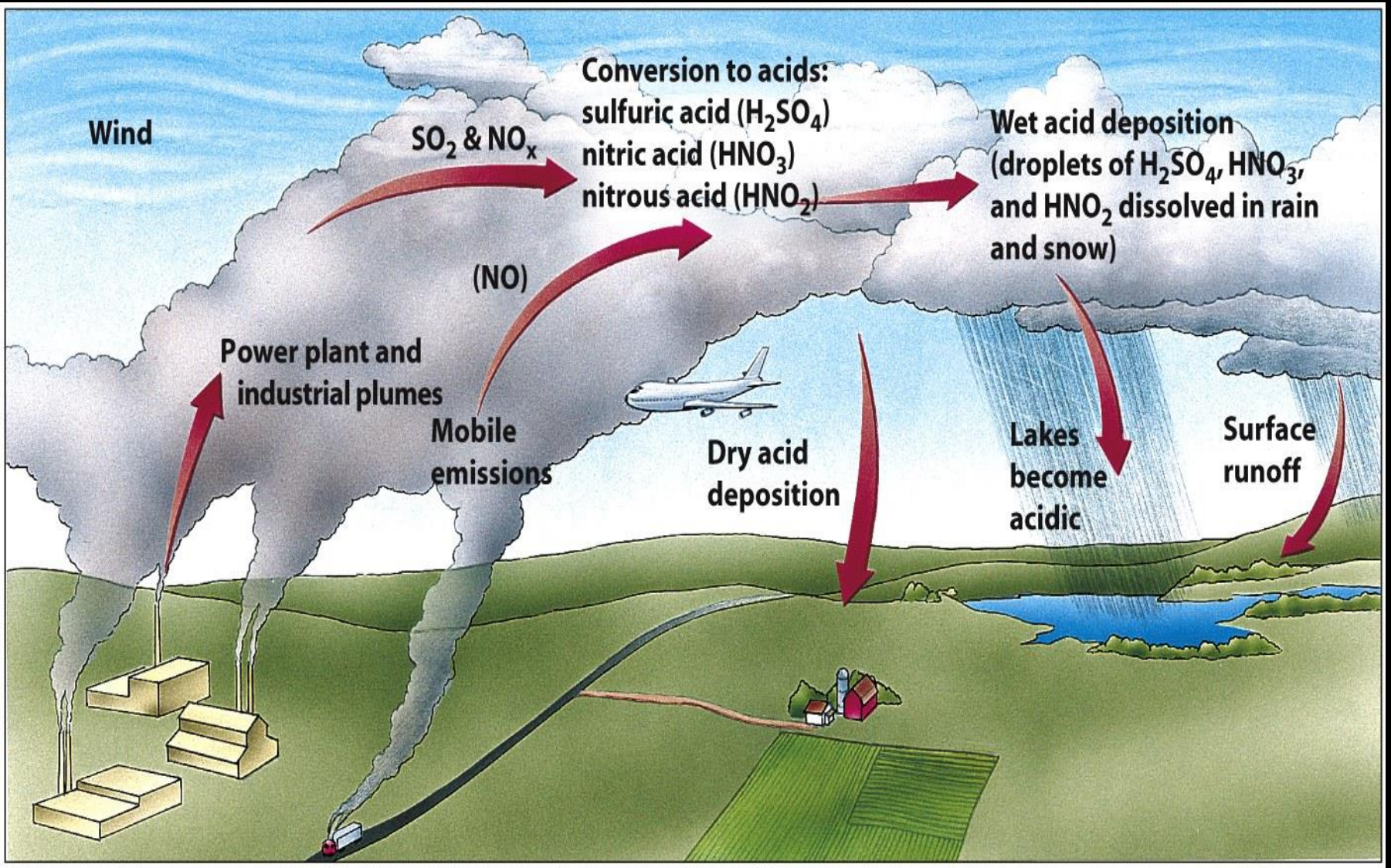
Acid Deposition

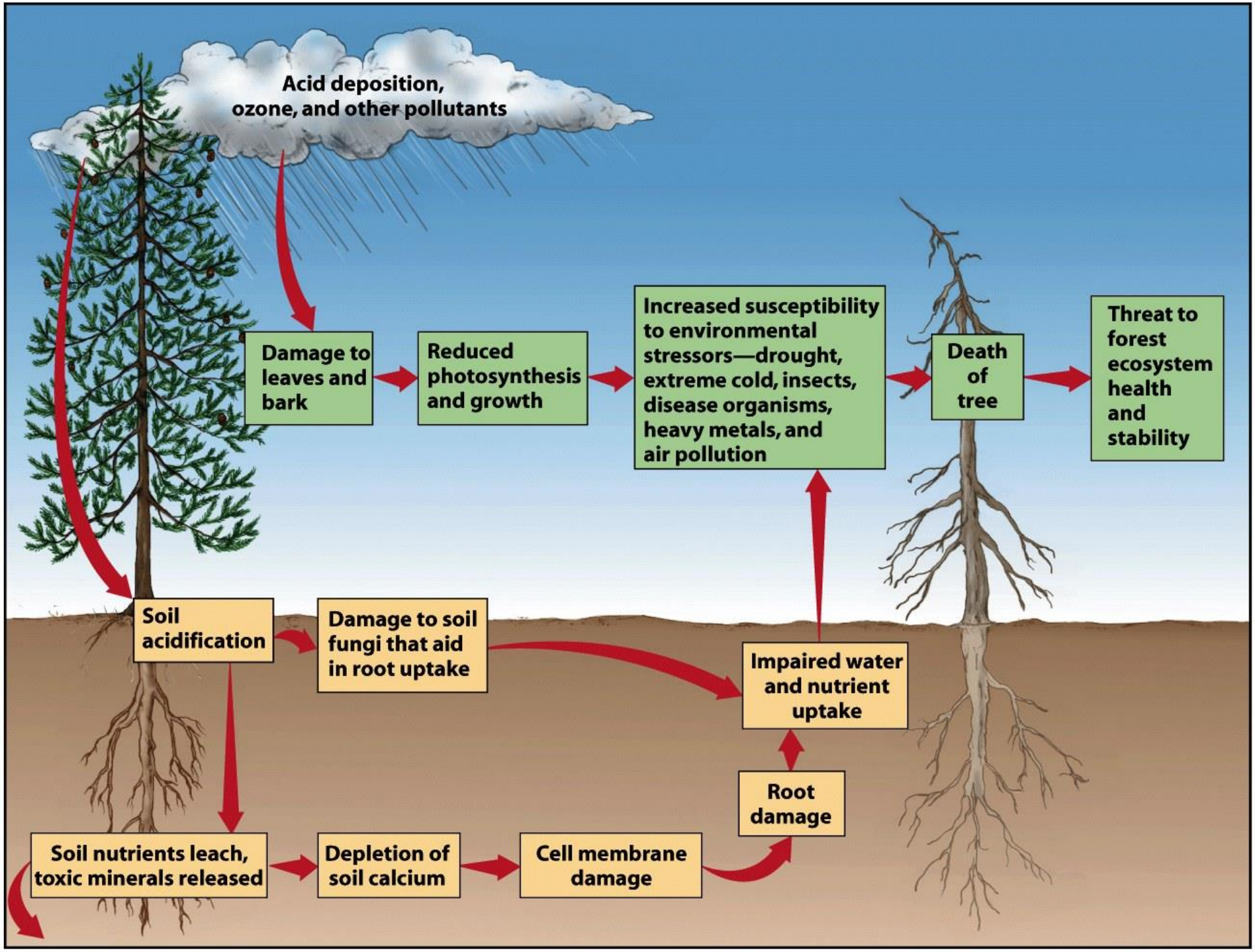
- Acids that return to the surface as either dry or wet deposition
- pH scale



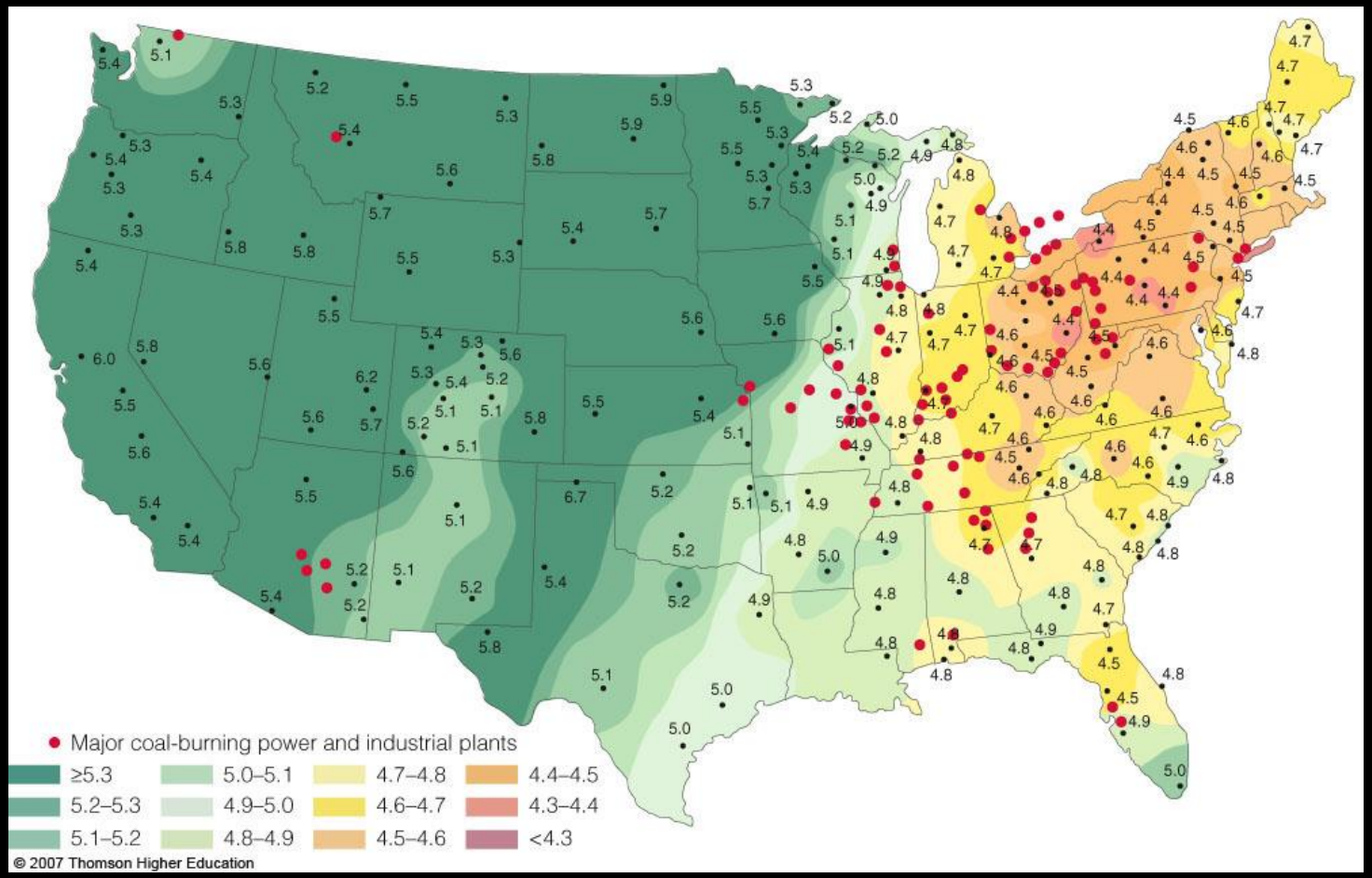
NOTE: pH of rainwater is 5.6 since $CO_2 + H_2O \rightarrow H_2CO_3$

How Acid Deposition Develops



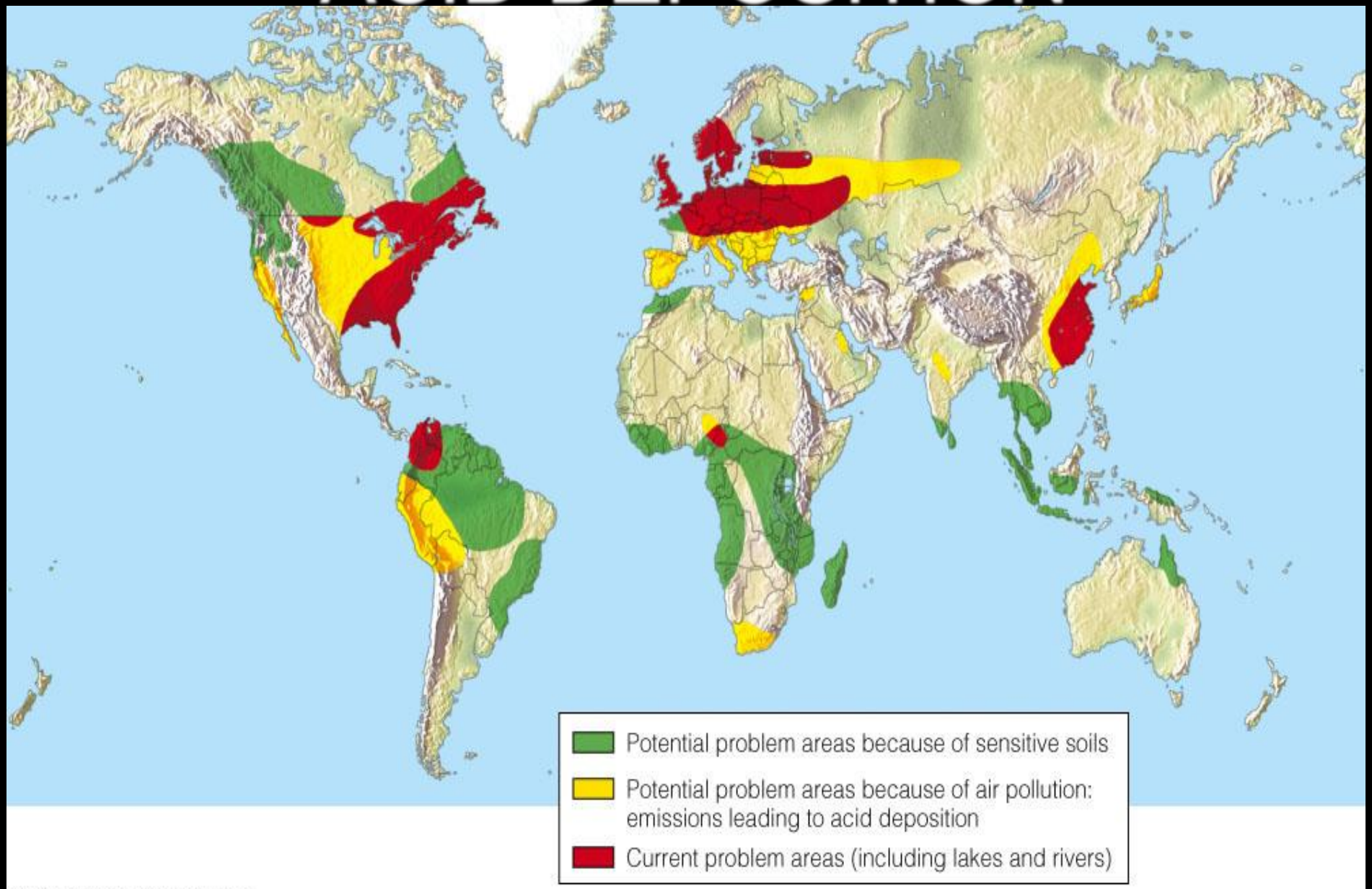

Acid deposition, ozone, and other pollutants
Damage to leaves and bark
Reduced photosynthesis and growth
Increased susceptibility to environmental stressors—drought, extreme cold, insects, disease organisms, heavy metals, and air pollution
Death of tree
Threat to forest ecosystem health and stability
Soil acidification
Damage to soil fungi that aid in root uptake
Impaired water and nutrient uptake
Root damage
Soil nutrients leach, toxic minerals released
Depletion of soil calcium
Cell membrane damage

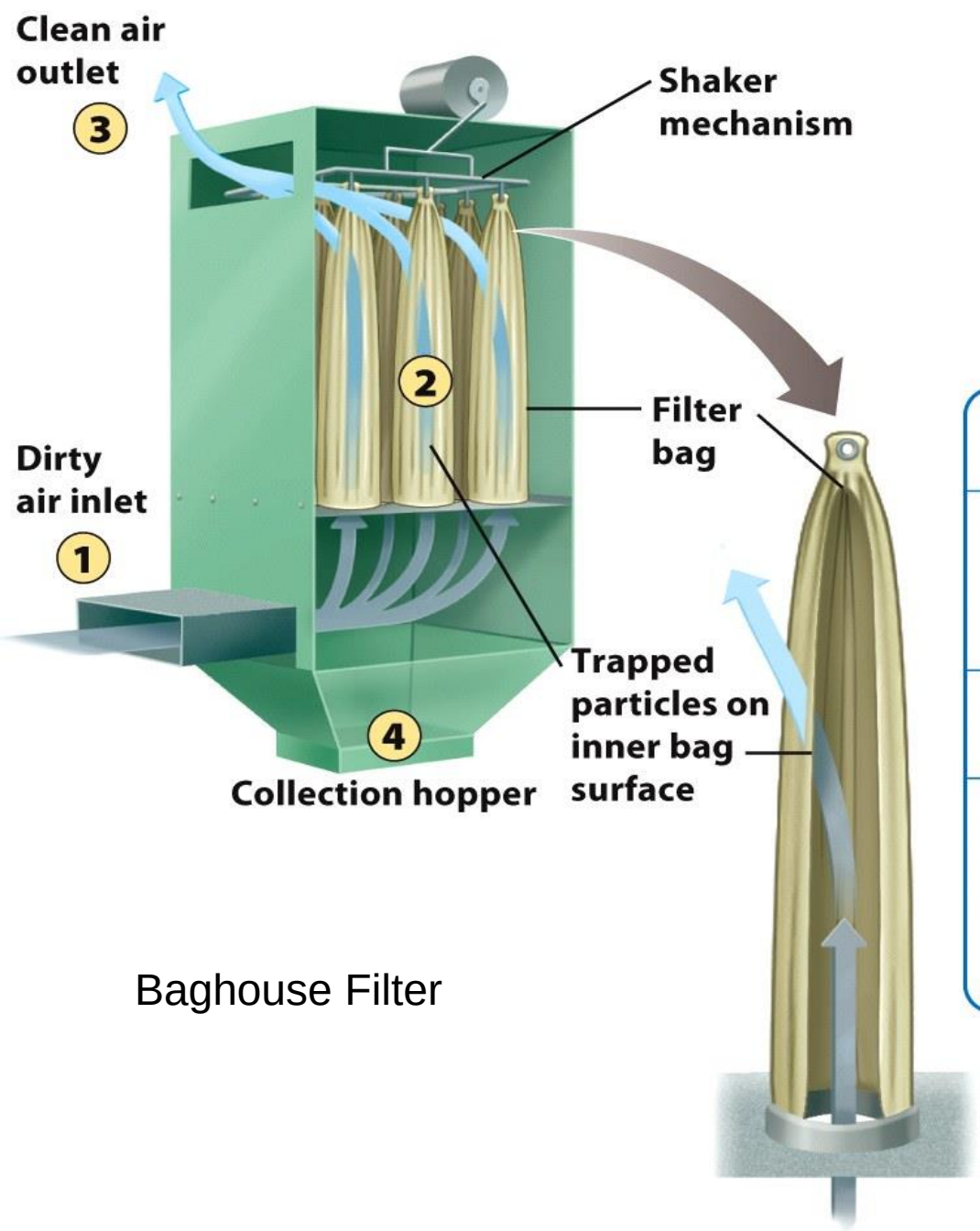
ACID DEPOSITION



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

ACID DEPOSITION

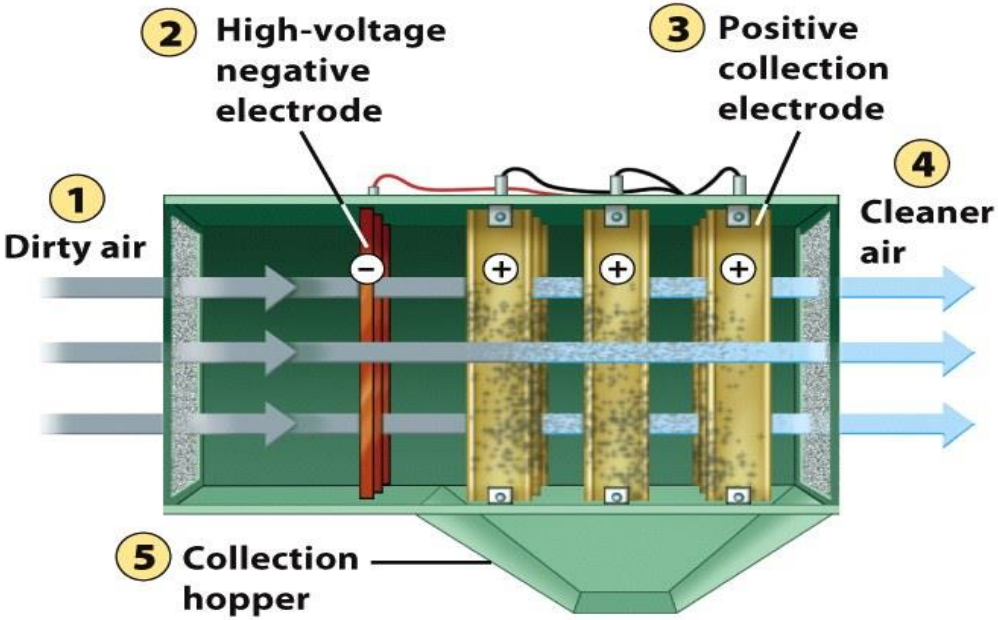




Baghouse Filter

1. Dirty air enters housing.
2. Combustion exhaust stream moves through and dust particles are trapped in a series of filter bags.
3. Cleaner, filtered air moves out of unit.
4. A shaker mechanism is activated periodically to dislodge trapped particles, which can then be collected from beneath the unit.

Figure 15.11
Environmental Science



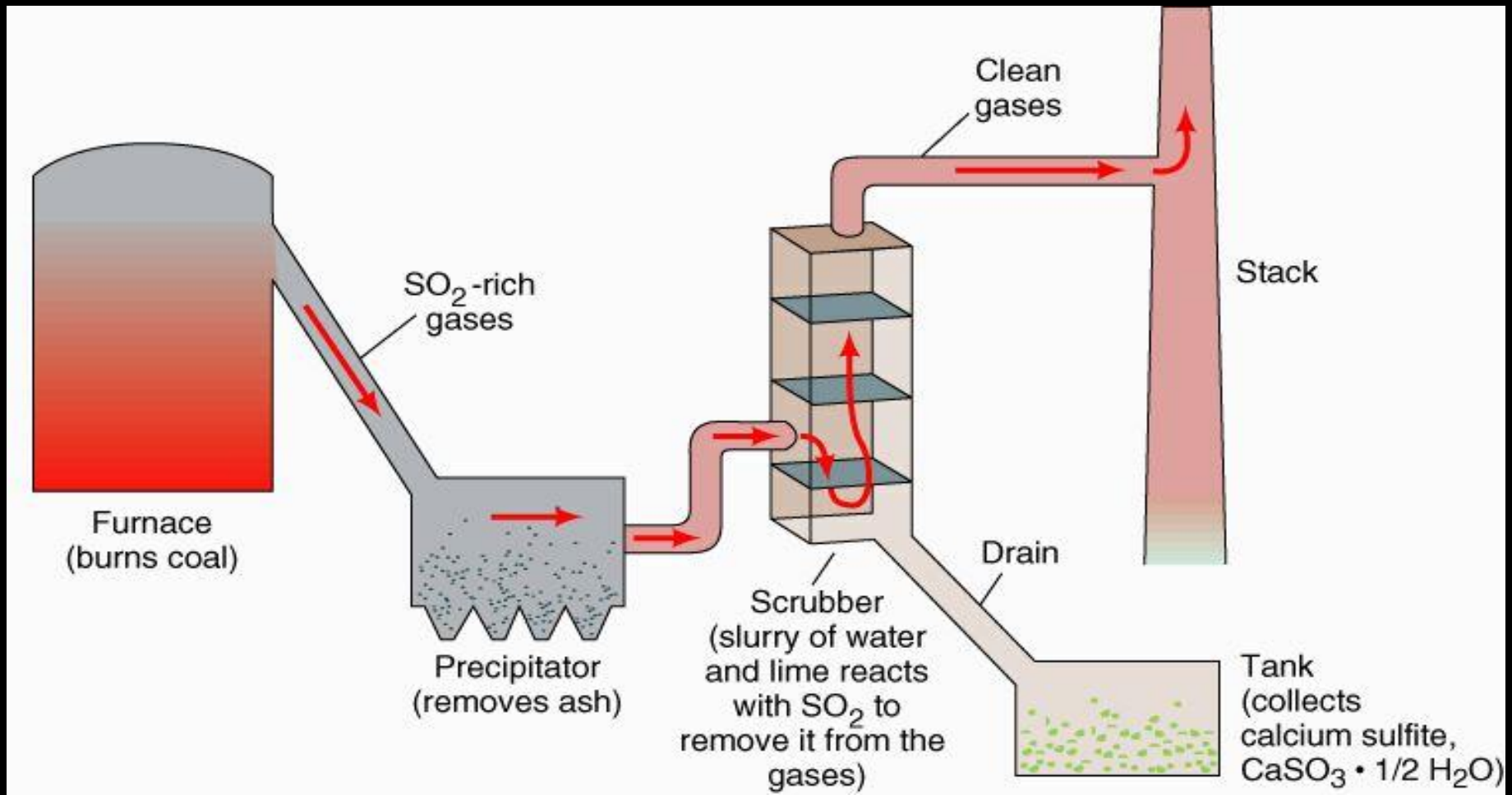
1. Dirty air enters precipitator unit.
2. Particles in combustion exhaust stream pass by negatively charged plates, which gives them a negative charge.
3. The negatively charged particles are attracted to positively charged collection plates.
4. Cleaner air moves out of the unit.
5. The positive collection plates are periodically discharged, which causes the particles to fall off so that they can be removed from the system.

Figure 15.12
Environmental Science

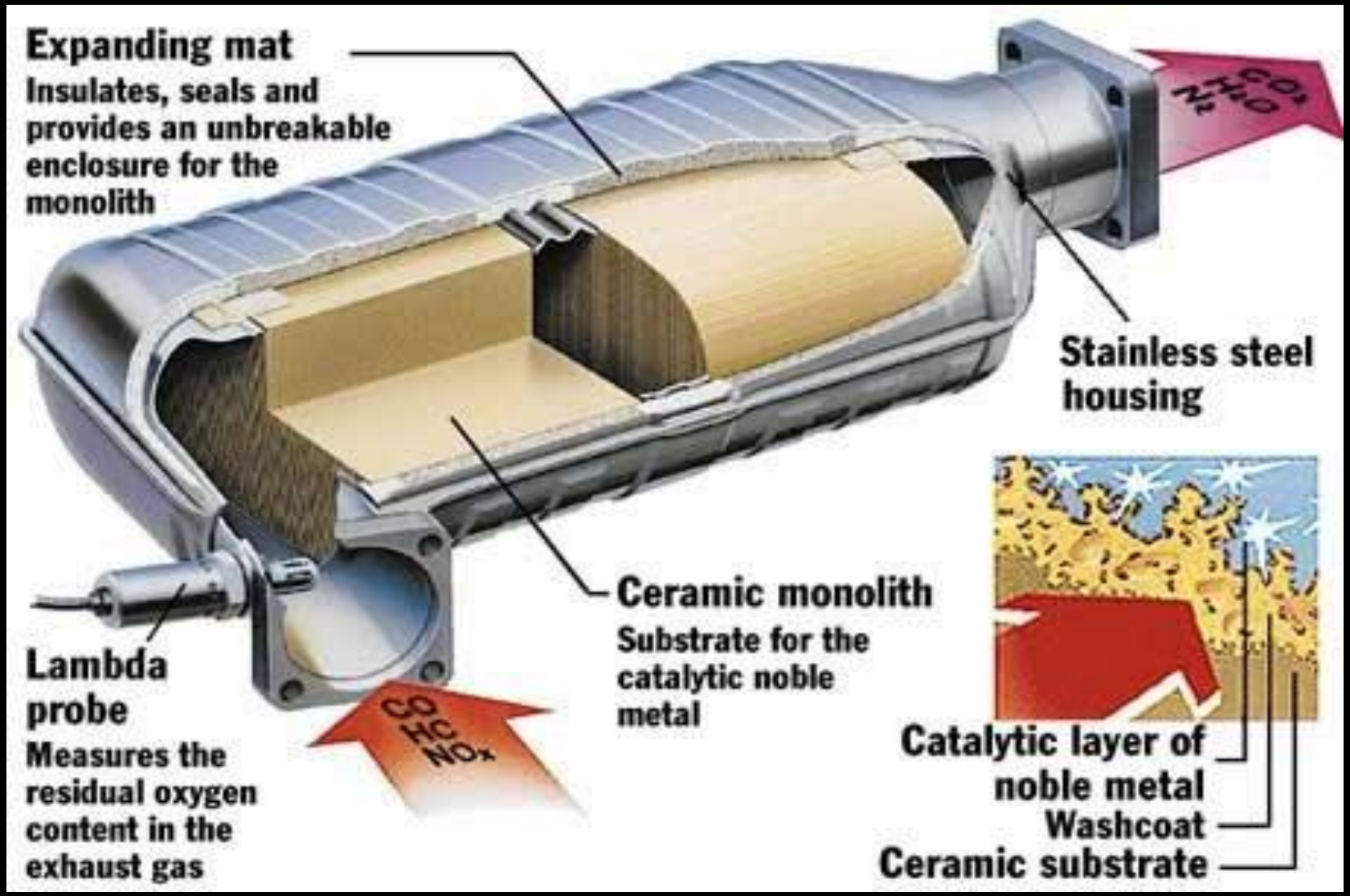
Electrostatic Precipitator

Scrubbing

- Remove oxides of sulfur after the coal is burned but before they reach the atmosphere
- Sulfur Dioxide reacts with limestone forming calcium sulfite
- This is then disposed of



Catalytic converters – Uses platinum-palladium & rhodium catalysts to reduce the amount of nitrogen oxides by 90%, also reduce hydrocarbons & CO.



Clean Air Act Amendments of 1990

- Comprehensive regulations enacted by the U.S. Congress that address acid rain, toxic emissions, ozone depletion, and automobile exhaust.
- Buying and selling of sulfur dioxide emissions
- One step back occurred in 2003 when the president and EPA allowed companies to upgrade w/o new pollution controls.

PREVENTING AND REDUCING AIR POLLUTION

- Environmental scientists point out several deficiencies in the Clean Air Act:
  - The U.S. continues to rely on cleanup rather than prevention.
  - The U.S. Congress has failed to increase fuel-efficiency standards for automobiles.
  - Regulation of emissions from motorcycles and two-cycle engines remains inadequate.
  - There is little or no regulation of air pollution from oceangoing ships in American ports.

PREVENTING AND REDUCING AIR POLLUTION

- Airports are exempt from many air pollution regulations.
- The Act does not regulate the greenhouse gas CO_2.
- The Act has failed to deal seriously with indoor air pollution.
- There is a need for better enforcement of the Clean Air Act.

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.

PREVENTING AND REDUCING AIR POLLUTION

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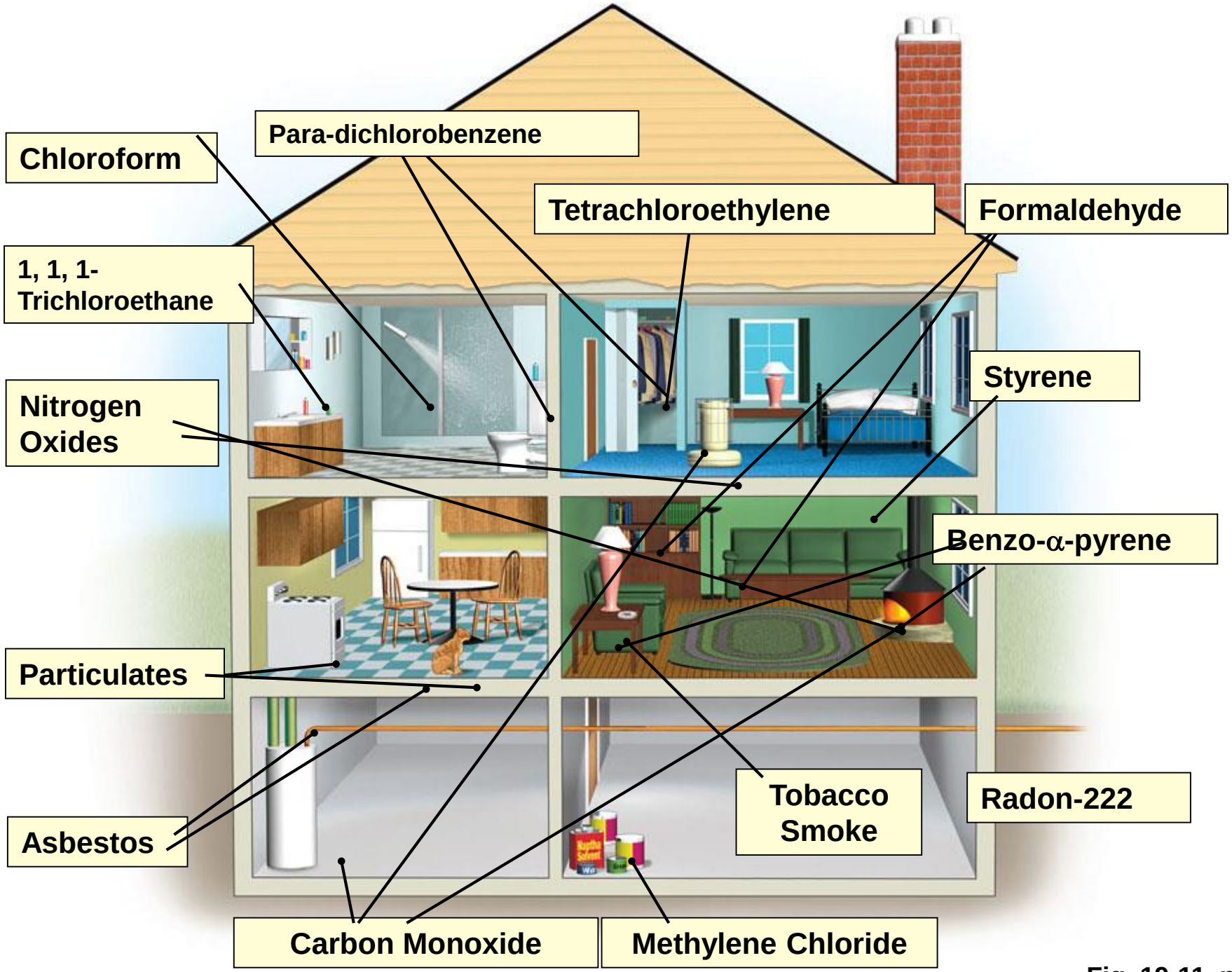

Fig. 19-11, p. 45