Chapter 15 Opener
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In a bowl, ringed by mountains…

Chapter 15
Air Pollution and Stratospheric Ozone Depletion

Air Pollution

- Air pollution- the introduction of chemicals, particulate matter, or microorganisms into the atmosphere at concentrations high enough to harm plants, animals, and materials such as buildings, or to alter ecosystems.

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Major Air Pollutants

- Sulfur Dioxide
- Nitrogen Oxides
- Carbon Oxides
- Particulate Matter
- Volatiles Organic Compounds
- Ozone
- Lead
- Mercury

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.

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Sulfur Oxides - SO_2

Major Sources:

- **#1 = Coal**
- **#2 = Oil**
- **Also Volcanic eruptions**

Env. and Health Effects:

- **Acid Rain…forms Sulfuric Acid**
- **Aquatic life**
- **Plant tissues**
- **Respiratory…asthma**

Nitrogen Oxides - NOx

Major Sources:

- **#1= Fossil Fuels…esp. petroleum**
- **#2 = Any Biomass**

Env. and Health Effects:

- **Tropospheric Ozone precursor →Smog!**
- **Acid Rain…forms Nitric Acid**
- **Aquatic life**
- **Eutrophication**
- **Respiratory**

Carbon oxides - COx

Major Sources:

- **Incomplete combustion**
- **Bad Exhaust Syst.**
- **Poor ventilation for any combustion source**

Env. and Health Effects:

- **Smog component**
- **Haze**
- **O_2 deprivation (carbon monoxide bonds to hemoglobin instead of oxygen in blood)**
- **Respiratory and Cardiovascular death/headache.**

Particulate Matter – PM_{10}

Major Sources:

Coal, Oil, Diesel, Biomass fuels (wood, manure)

Agriculture: dust, soil, silt, pollen.

Industry: coal fines, asbestos, etc.

Natural: volcanic, fires

Env. and Health Effects:

- **Reduced visibility (haze)**
- **Smog component**
- **Respiratory disease (lung disease)**
- **Cardiovascular disease.**

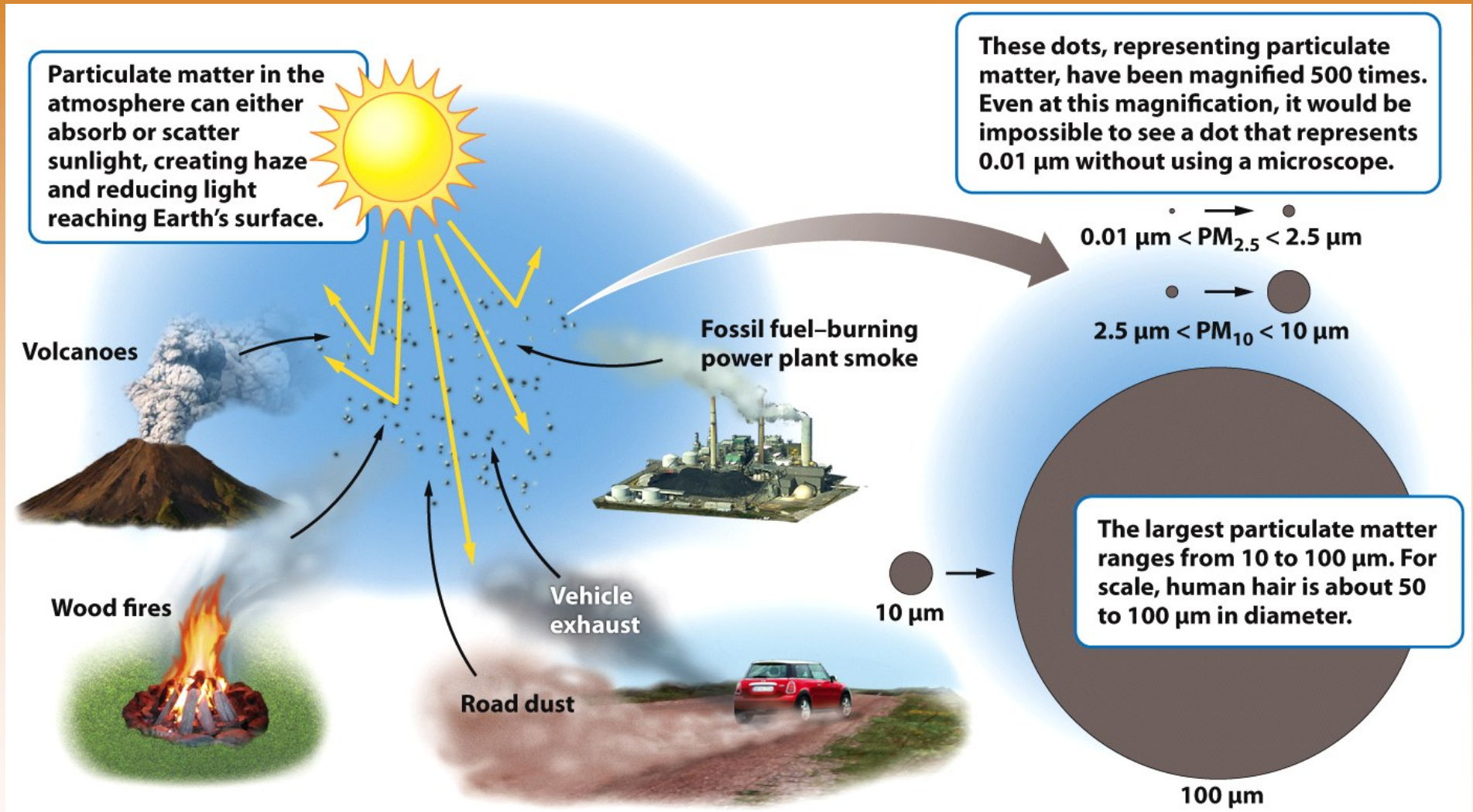
Particulate Matter – $PM_{2.5}$

Major Sources:

- **Same as PM10, but especially products with asbestos.**

Env. and Health Effects:

- **Most dangerous pollutant for respiratory tract**
- **Asbestosis**
- **Emphysema**
- **Mesothelioma**



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Lead - Pb

Major Sources:

- **Gasoline additive***
- **Coal**
- **Metal smelting**
- **Paint (chips, dust)**

Env. and Health Effects:

- **Accumulates in soil, tissues.**
- **Nervous system development and function.**
- **Learning disability**
- **Concentration**

Ground Level Ozone – O_3

Major Sources:

Secondary Pollutant

Reaction of NO_x, H_2O, O_2, Sunlight (vis + UV) and VOC's.

Env. and Health Effects:

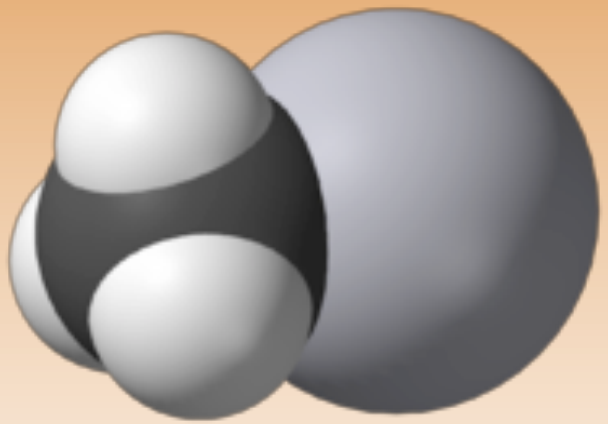
- **Plant tissues**
- **Oxidizes most organic compounds.**
- **Respiratory damage esp. to lung tissue.**

Volatile Organic Compounds (VOC's)

From volatile fuels, hydrocarbons, solvents, paints, adhesives, and natural sources.

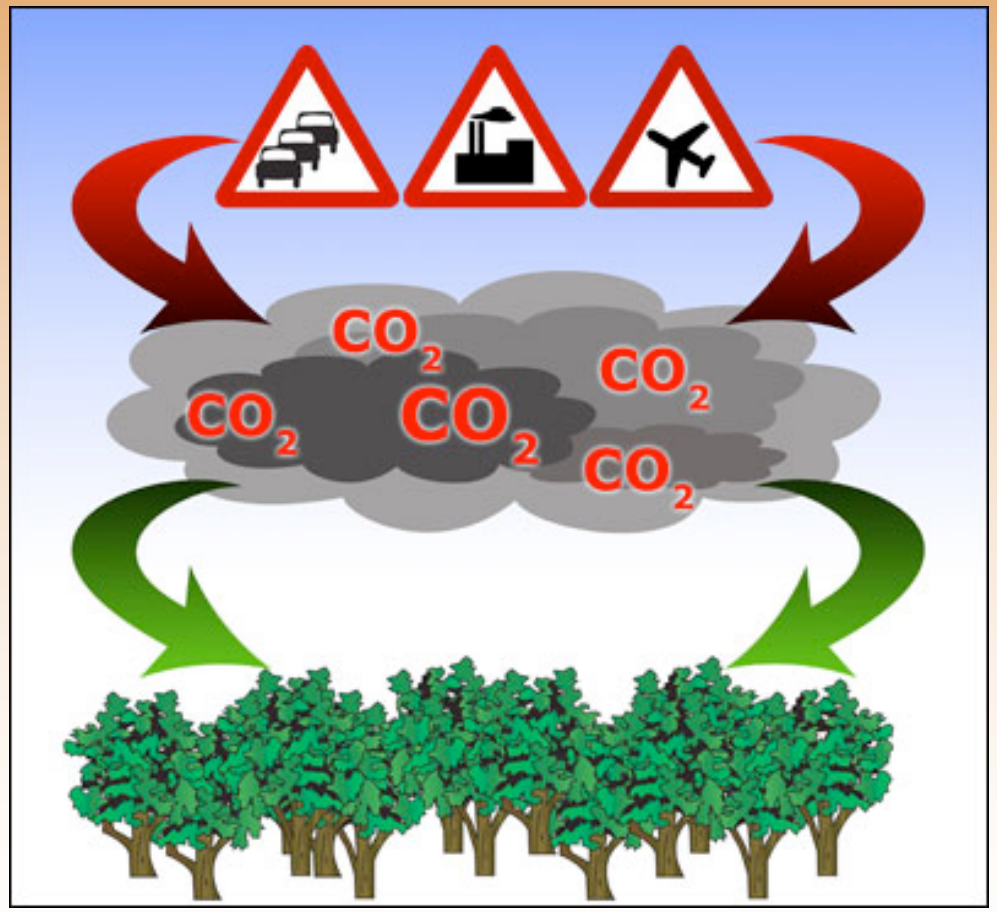
Volatile – evaporates easily, strong smell

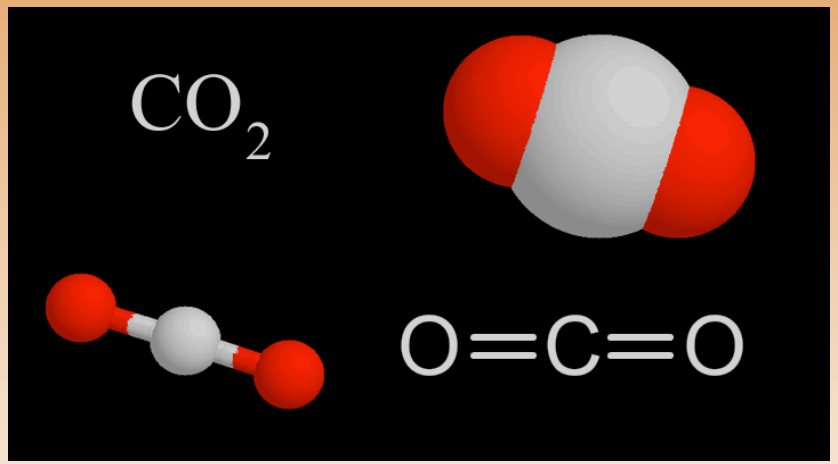
Mercury (Hg)



From Coal and Oil
Methyl Mercury can
Bioaccumulate in tissues

Carbon Dioxide (CO_2)





Primary Pollutants

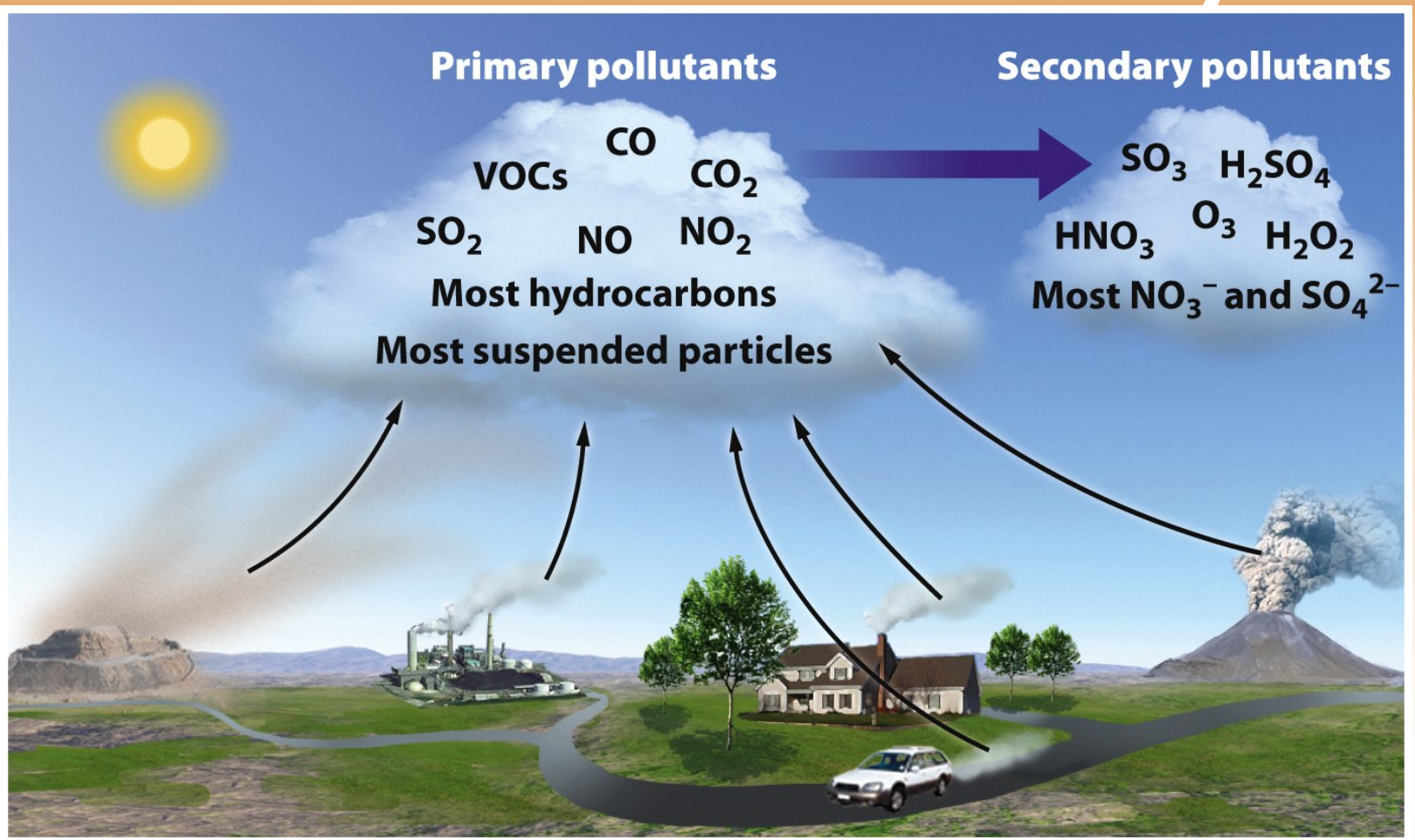
- **Primary pollutants- polluting compounds that come directly out of the smoke-stack, exhaust pip, or natural emission source.**

- **Examples: CO, CO2, SO2, NOx, and most suspended particulate matter.**

Secondary Pollutants

- **<u>Secondary pollutants</u>- pollutants that have undergone transformation in the presence of sunlight, water, oxygen, or other compounds.**
- **Examples: ozone, sulfate and nitrates. This includes PAN's (Peroxyacyl Nitrates), as well as sulfuric and nitric acids.**

Primary to Secondary Pollutants Pathway



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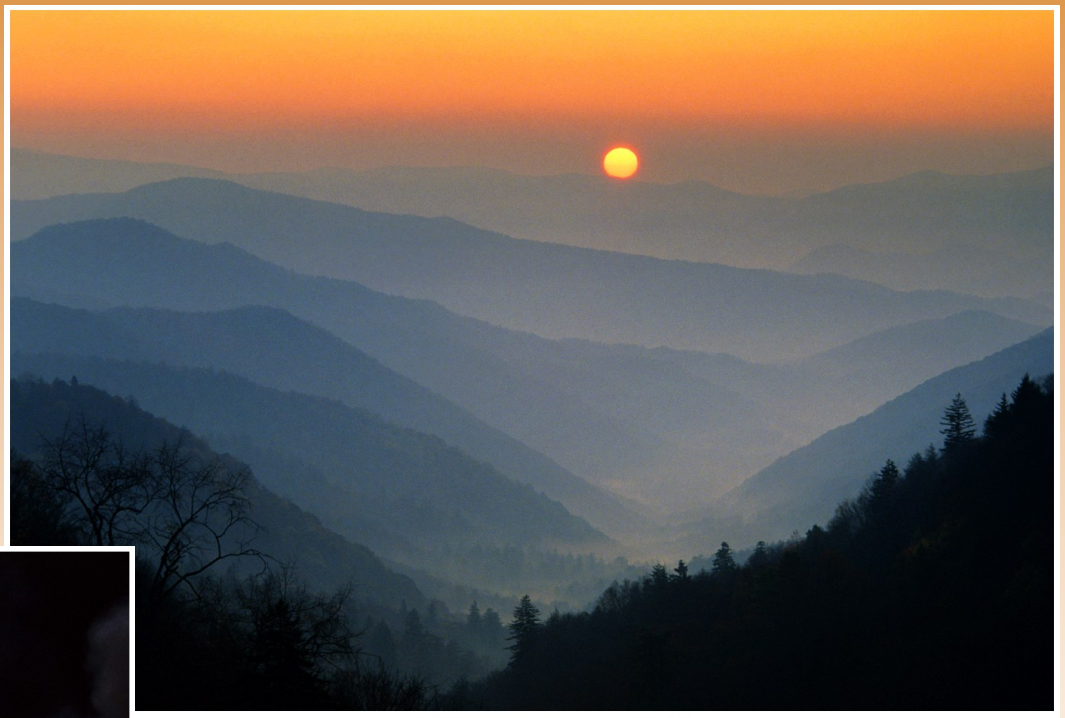
Natural Sources of Air Pollution

- Volcanoes
- Lightning
- Forest fires
- Plants



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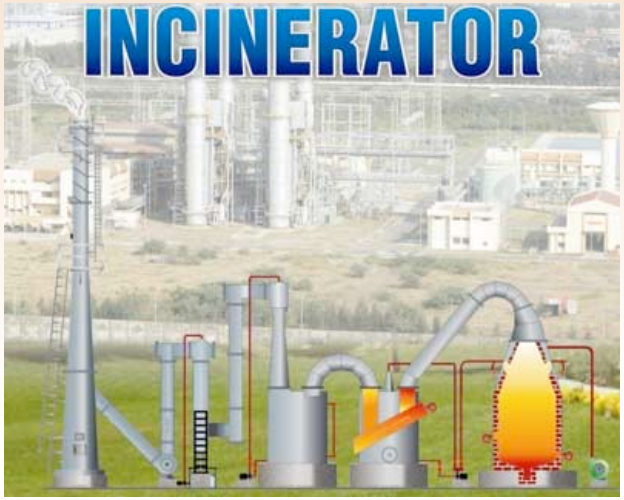
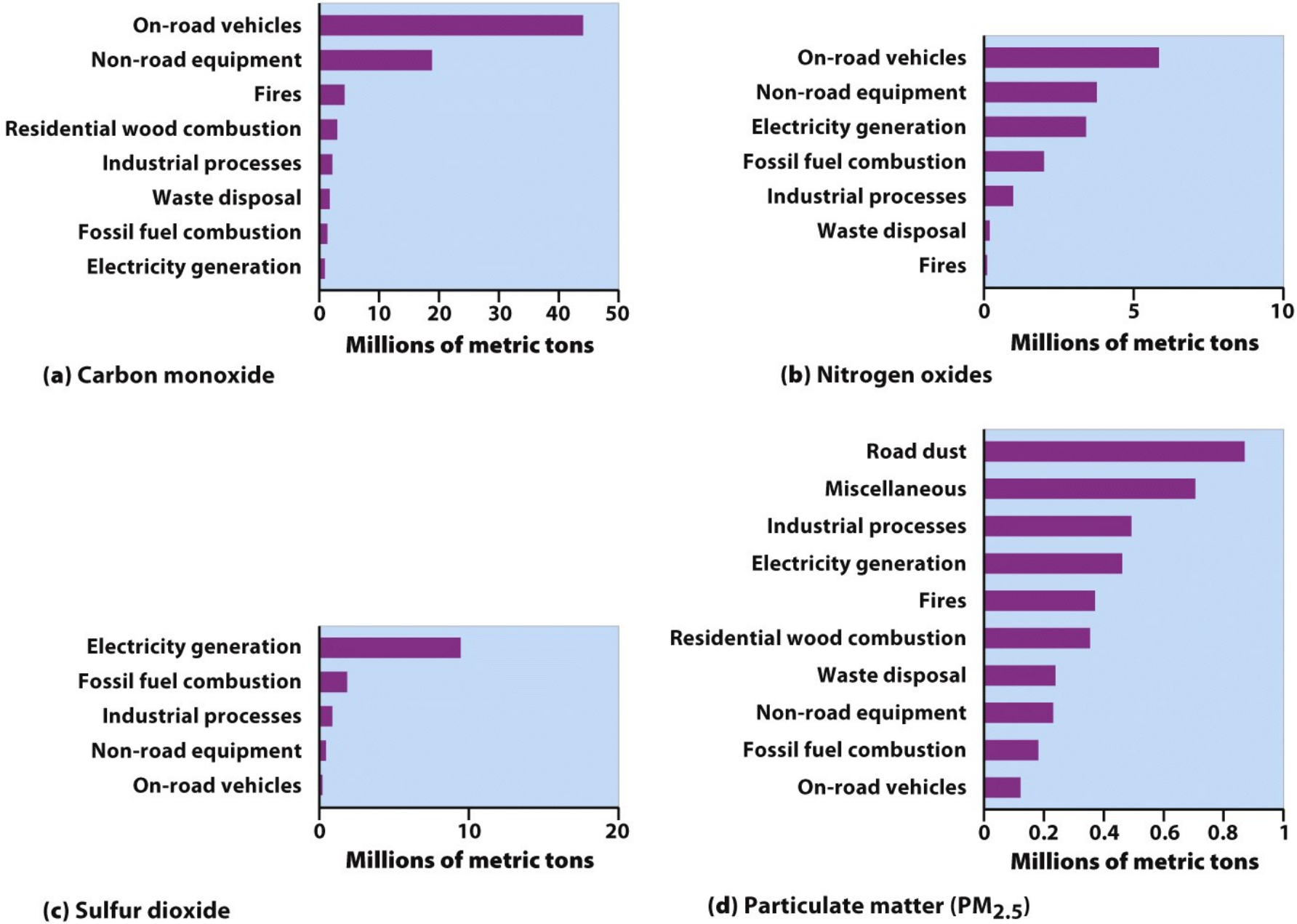
Anthropogenic Sources of Air Pollution

- On-road vehicles
- Power plants
- Industrial processes
- Waste disposal





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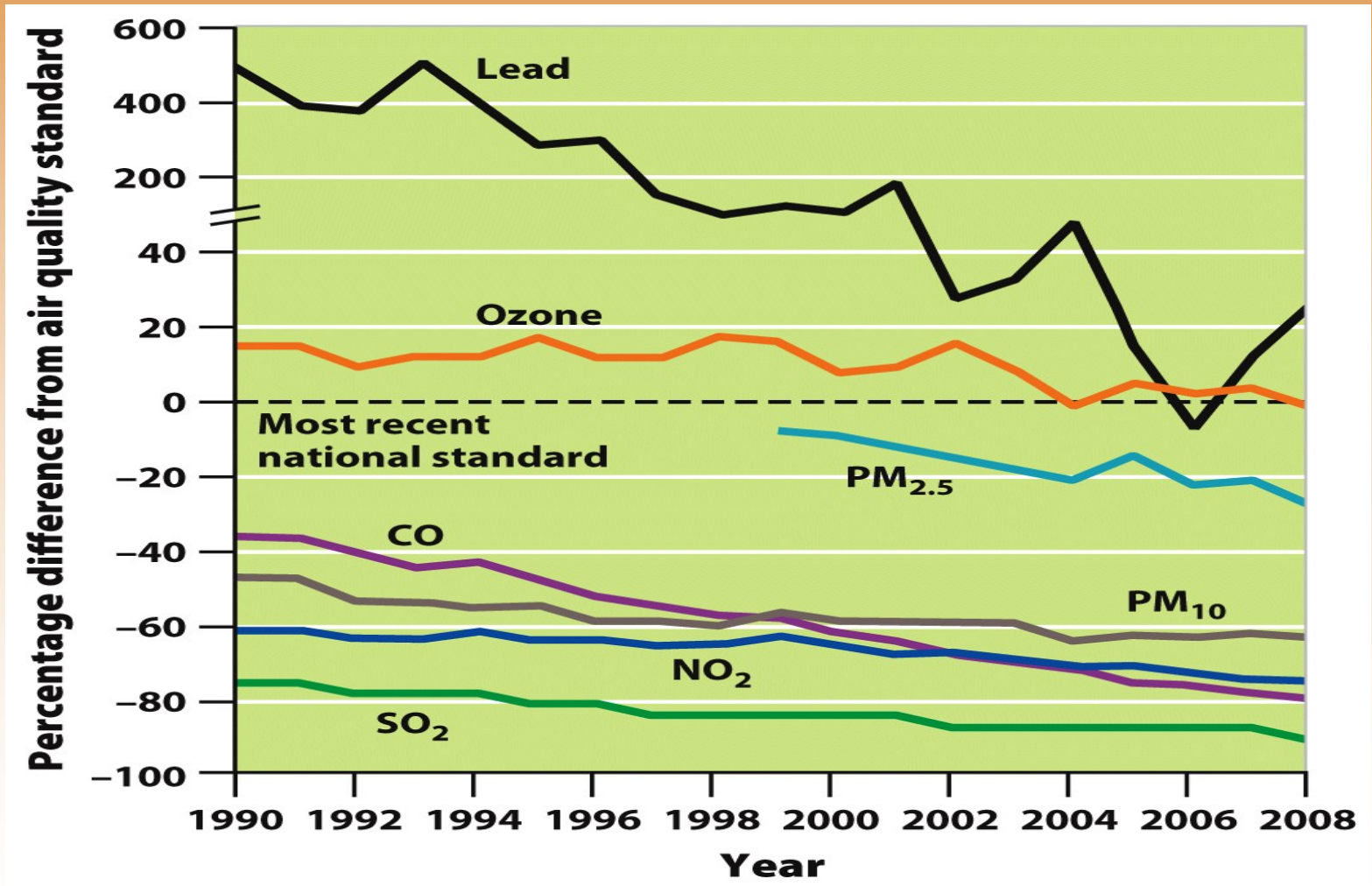
Trends in Criteria Pollutants



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Smog

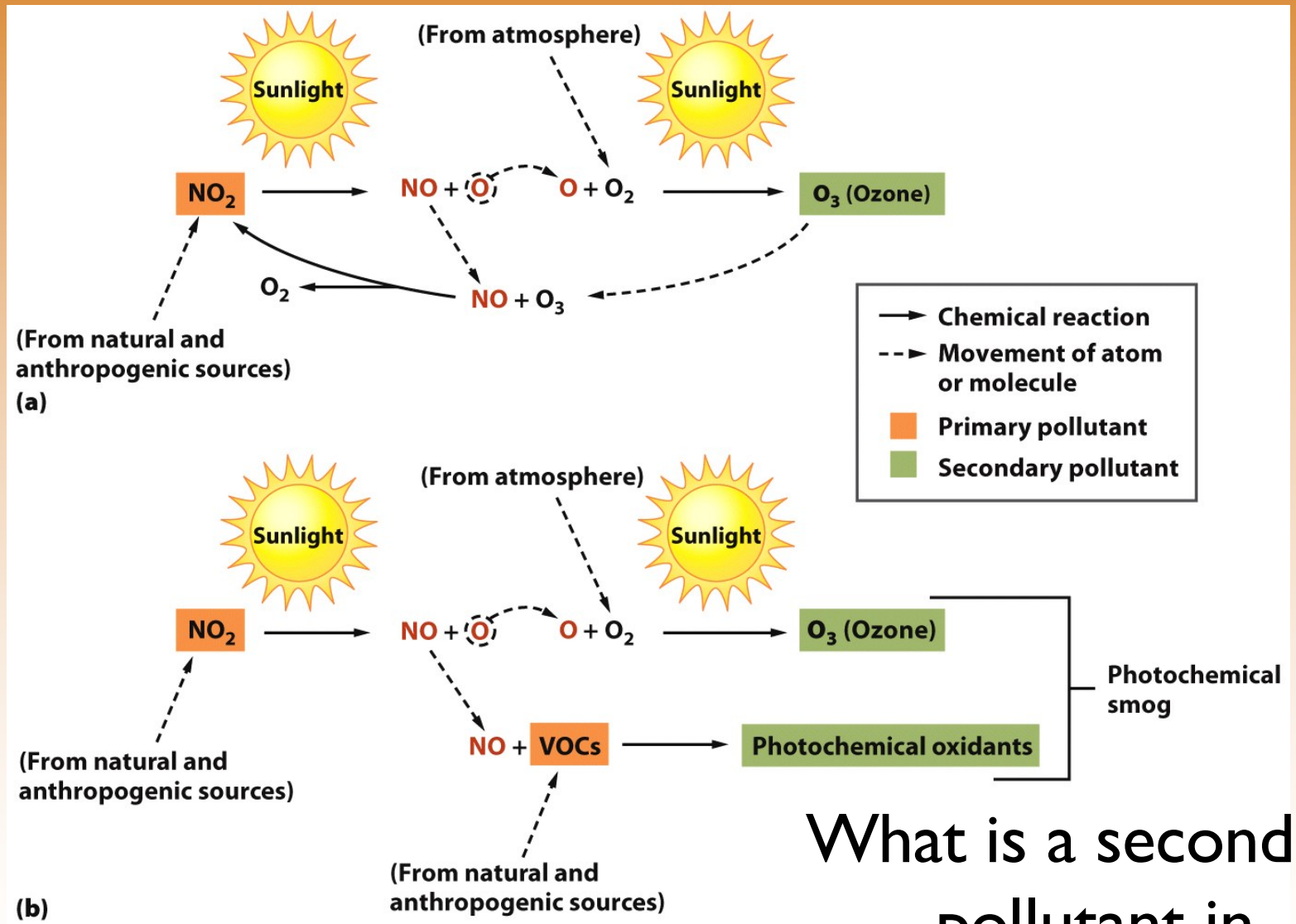
Photochemical/LA type Smog

- Brown smog
- ozone

Sulfurous smog

- Gray smog
- Sulfur dioxide

Photochemical Smog



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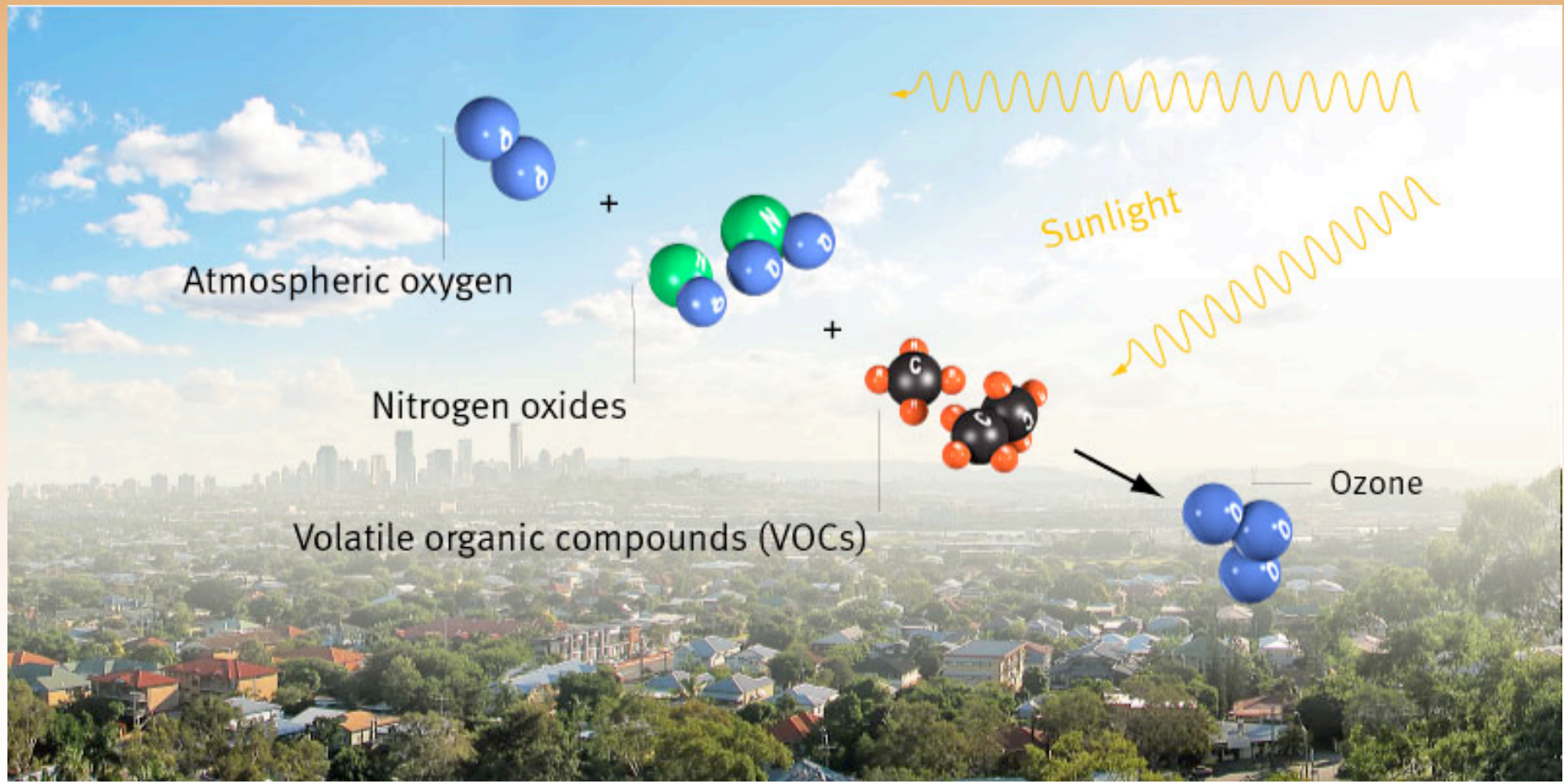
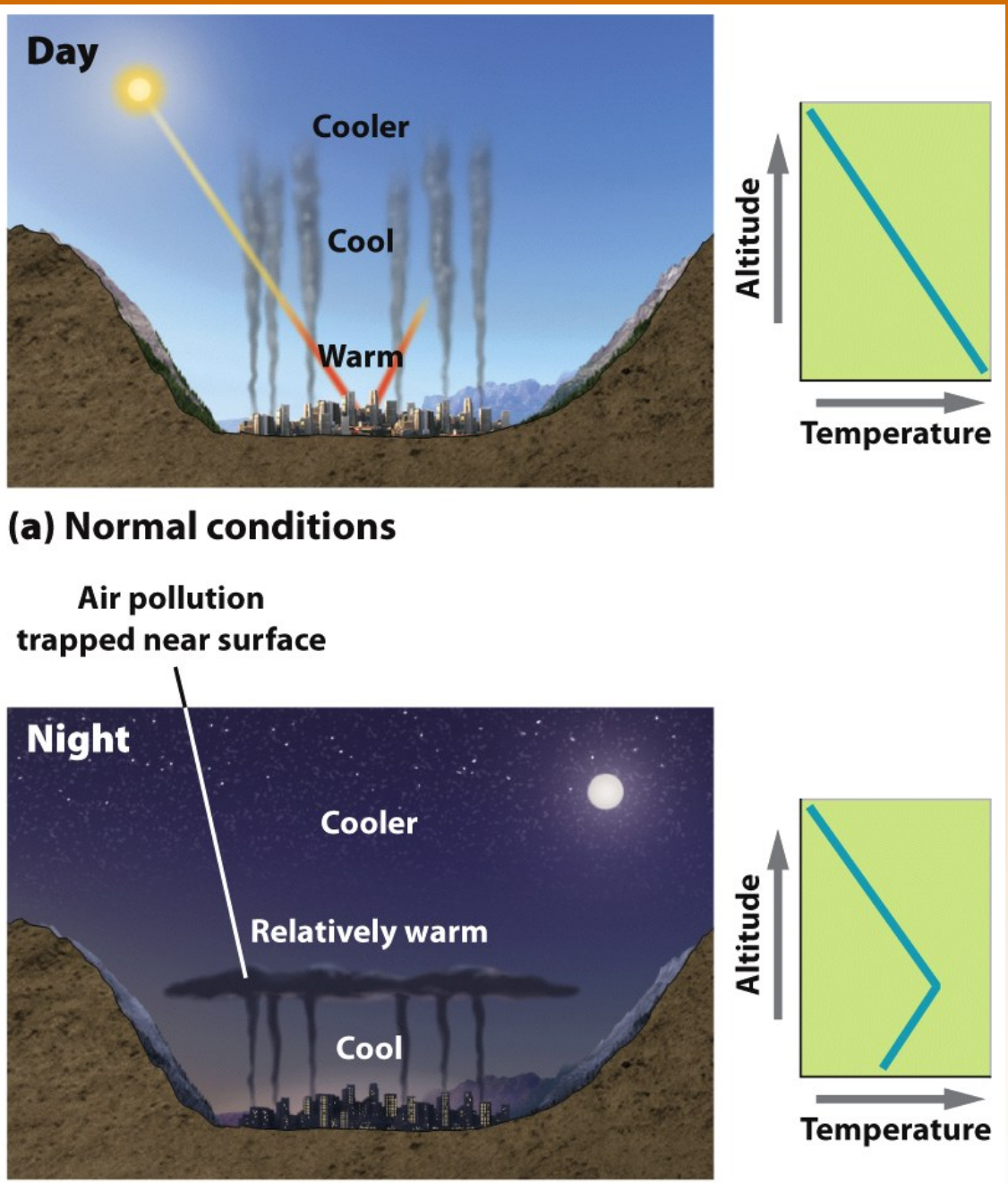
What is a secondary pollutant in photochemical smog?

Ozone formation simplified



Thermal Inversions

- Thermal Inversion- when a relatively warm layer of air at mid-altitude covers a layer of cold, dense air below.
- The warm inversion layer traps emissions that then accumulate beneath it.



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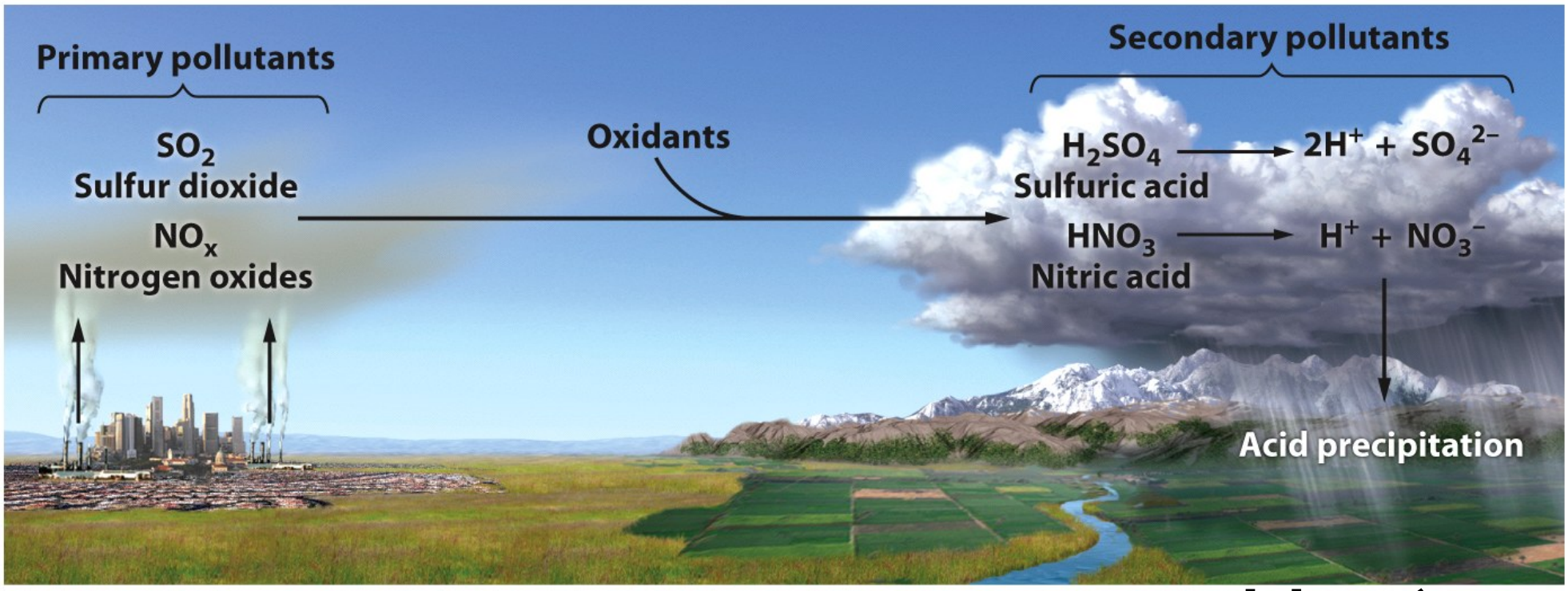
Acid Deposition



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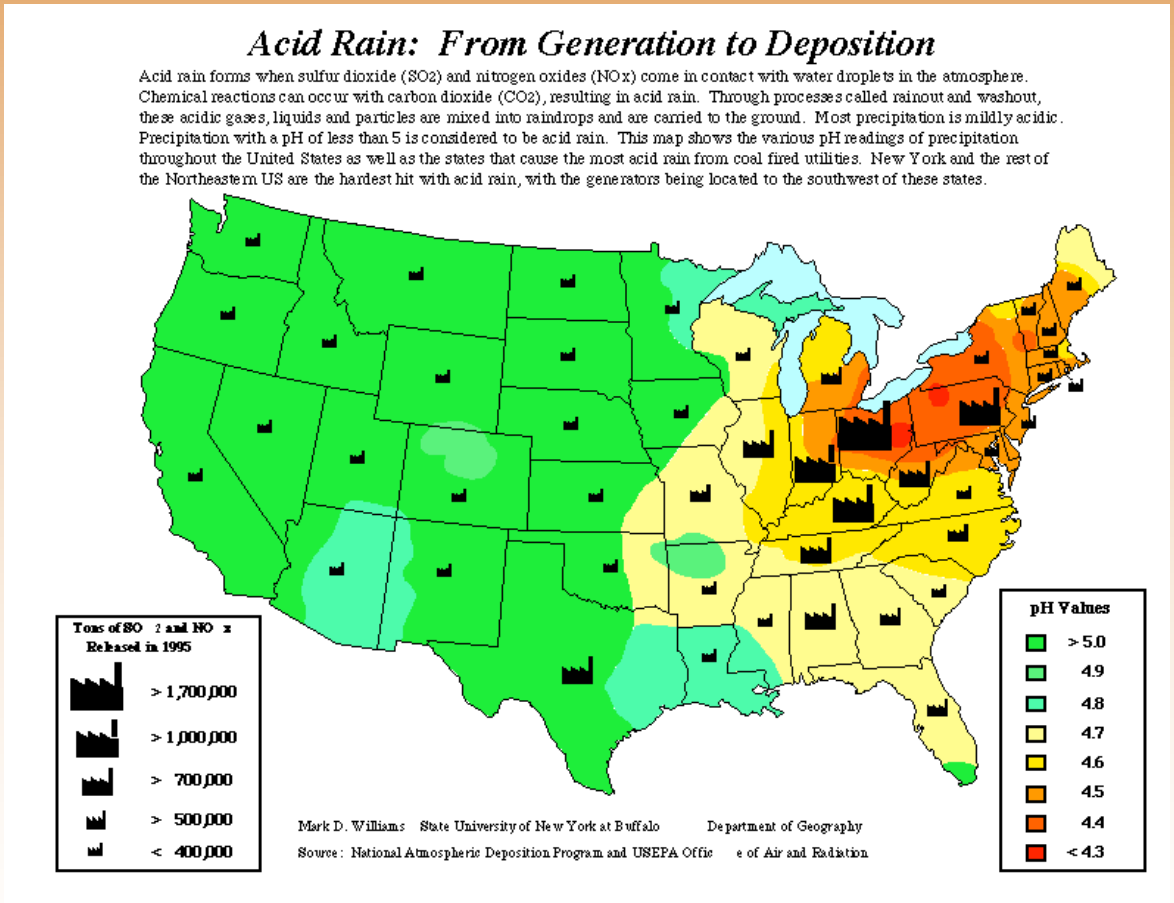
pH< 6

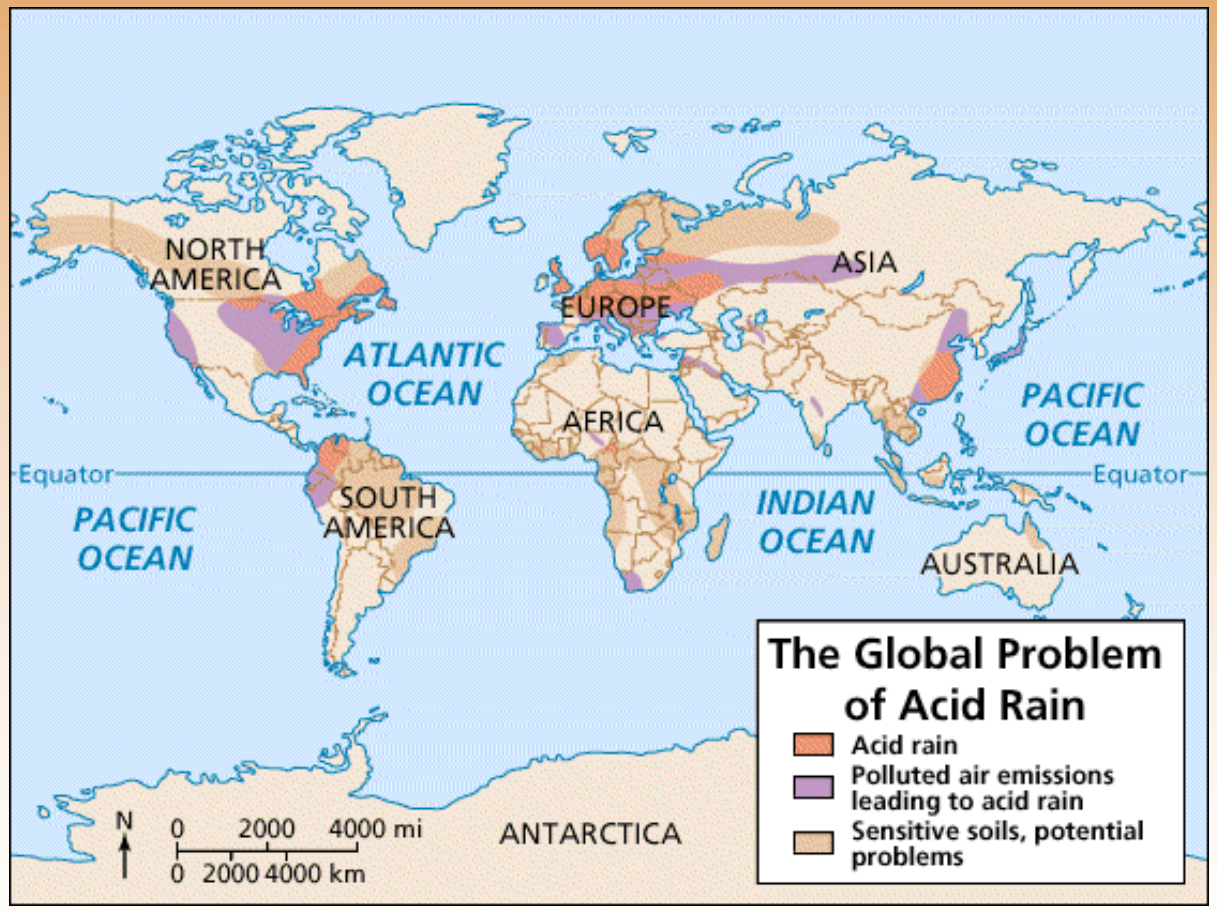
Acid Deposition

1. Nitrogen oxides and sulfur oxides in air combine with atmospheric oxygen and water.
2. Form secondary pollutants - nitric acid and sulfuric acid.
3. These secondary pollutants further break down into nitrate and sulfate and H+ ions (which make run-off acidic).
4. Deposit on land and water→run-off to water bodies.

Acid Precipitation Mobilization - USA

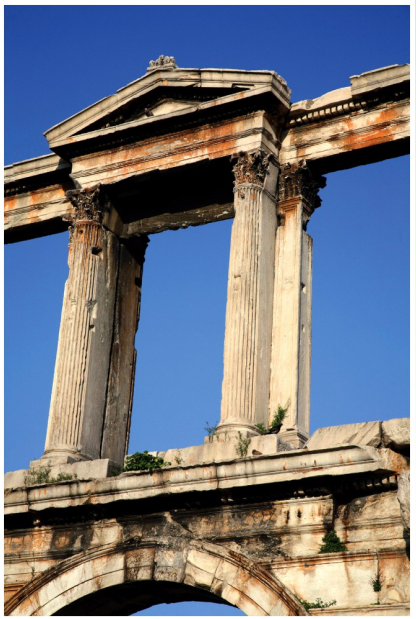


Acid Rain Mobilization



Effects of Acid Deposition

- Lowering the pH of lake water
- Decreasing species diversity of aquatic organisms
- Mobilizing metals that are found in soils and releasing these into surface waters
- Damaging statues, monuments, and buildings



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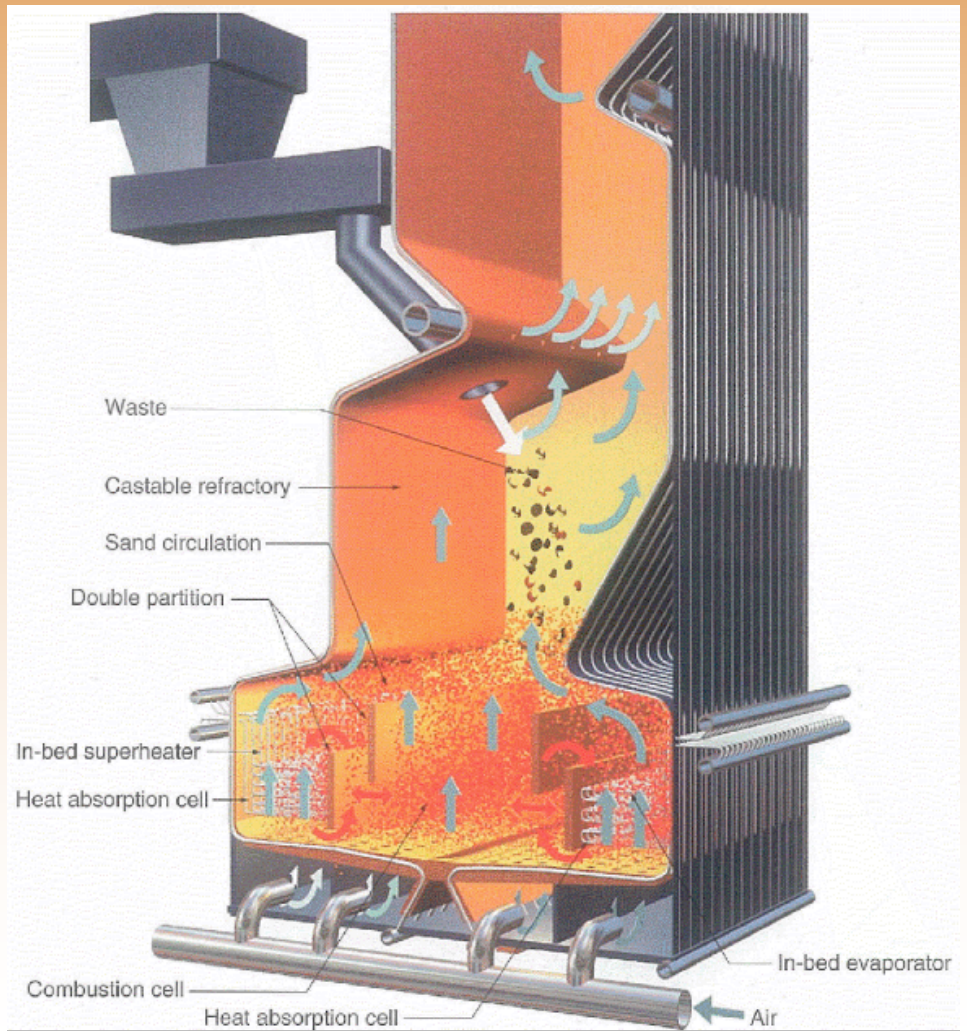
Ways to Prevent Air Pollution

- Removing sulfur dioxide from coal by fluidized bed combustion
- Catalytic converters on cars
- Scrubbers on smoke stacks
- Baghouse filters
- Electrostatic precipitators

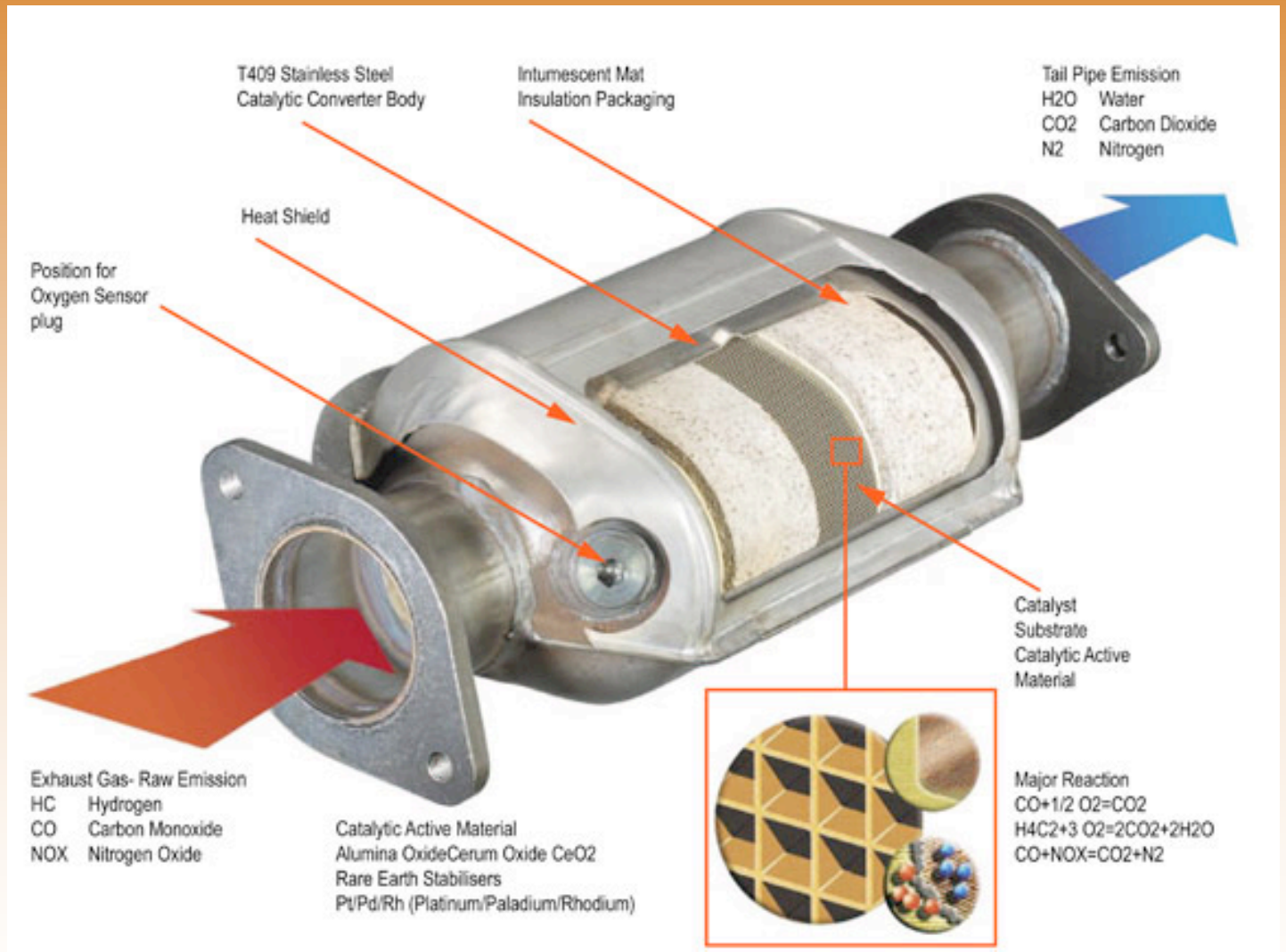
Car exhaust

- Driving cars every other day
- Carpool lanes (HOV)
- Tolls at certain times of day or parts of city
- No idling zones
- Auto inspections for emissions
- Sleeves at gas pumps to collect VOCs

Fluidized Bed burning of coal

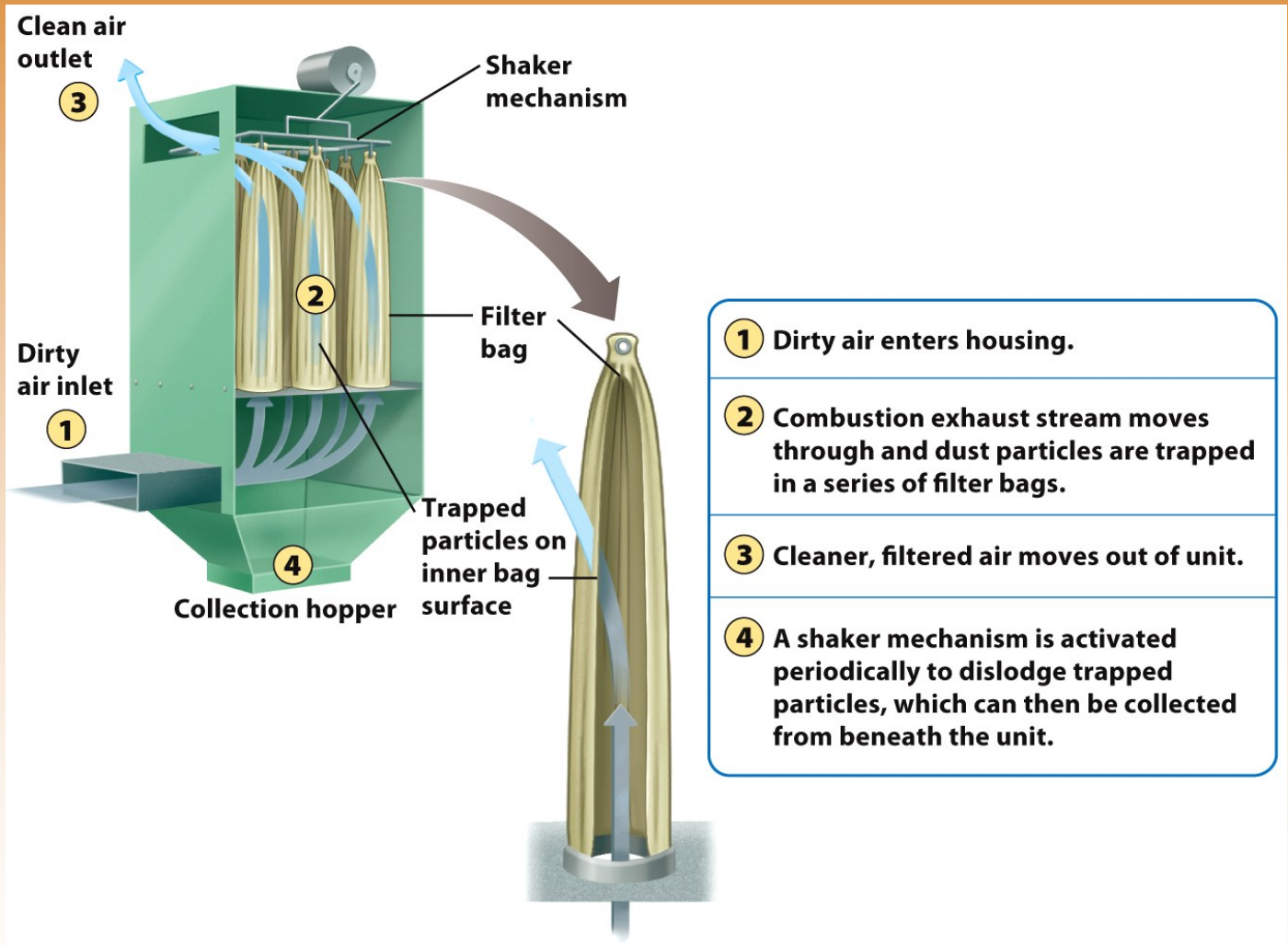


Catalytic Converters



Removes NOx & CO

Baghouse Filter



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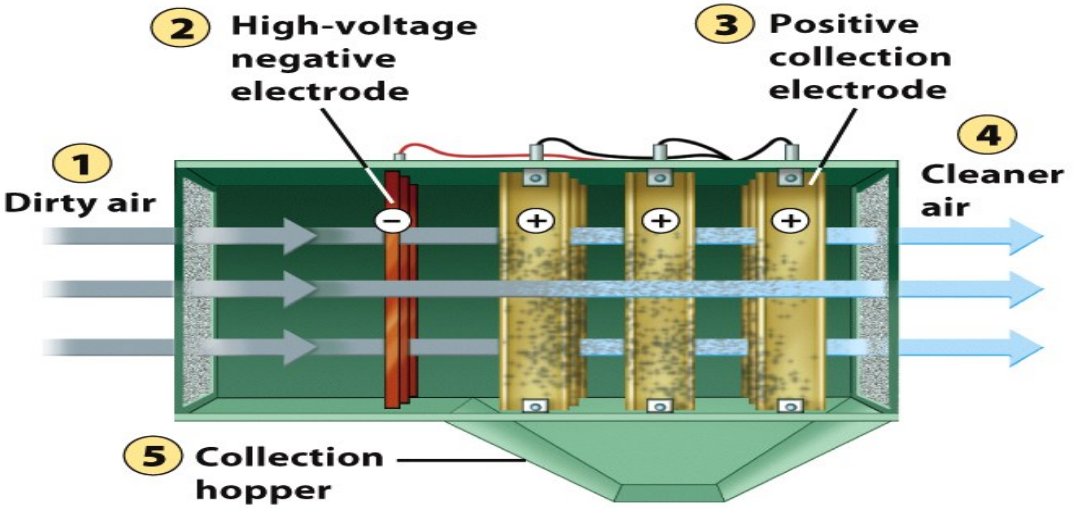
Electrostatic Precipitator



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.

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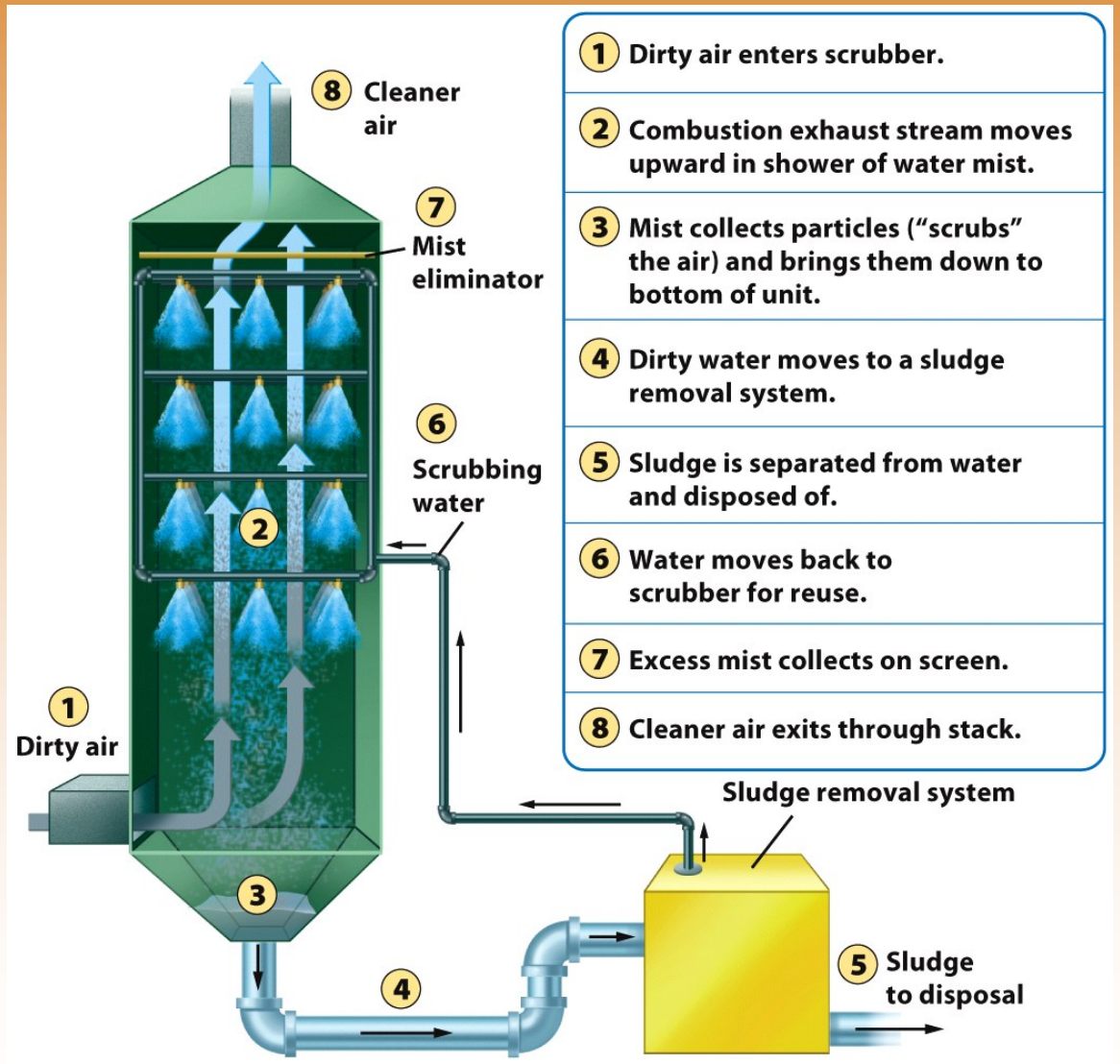
A "Scrubber"



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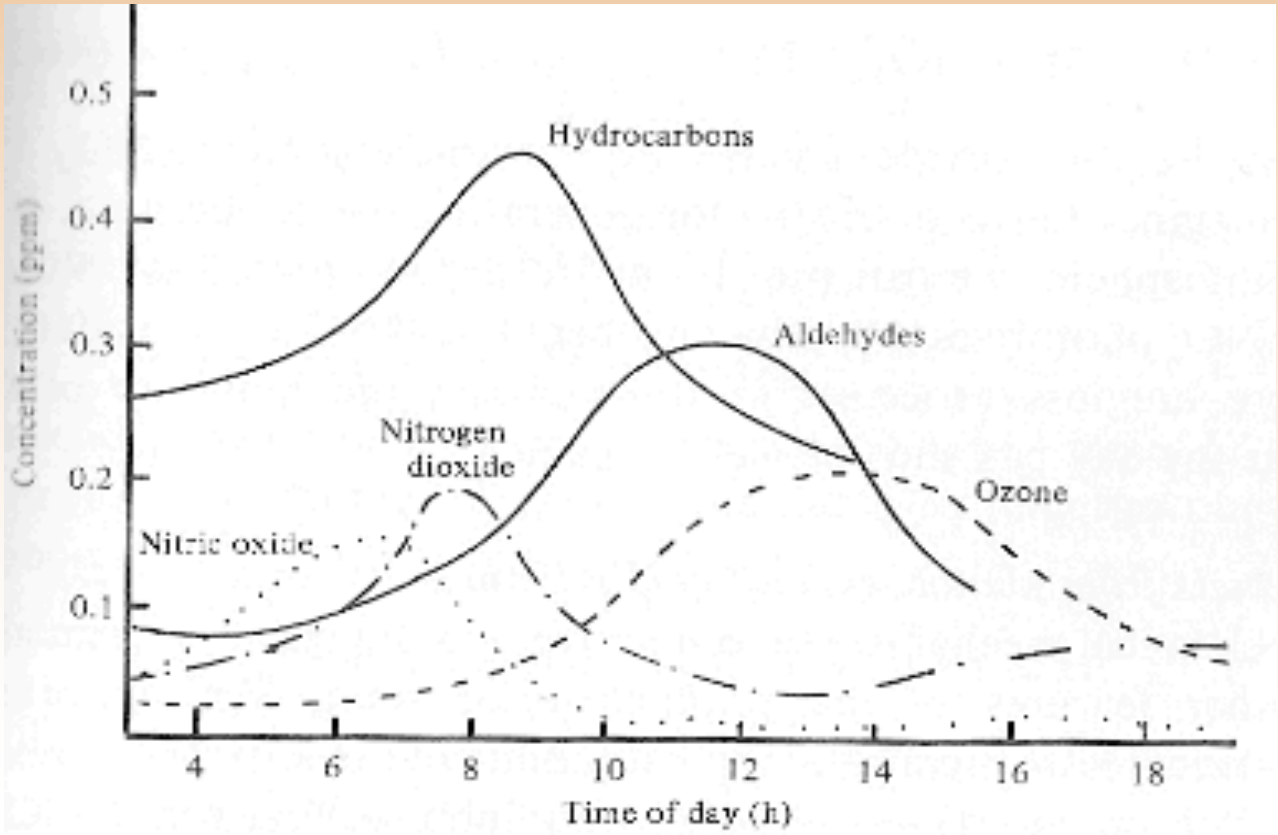
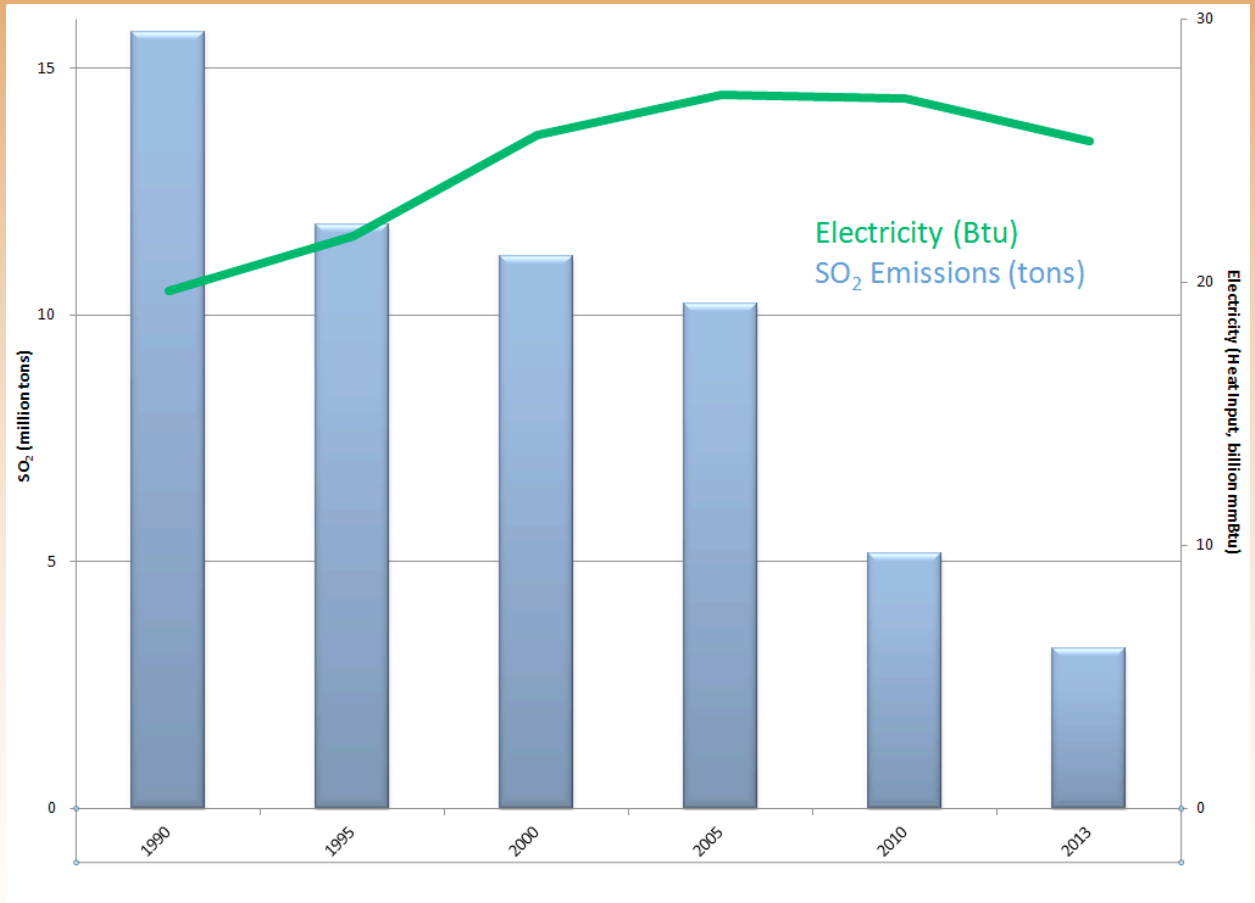
Smog Reductions

- **Reducing the release of VOC's and NOx in urban areas, especially during daylight working hours.**

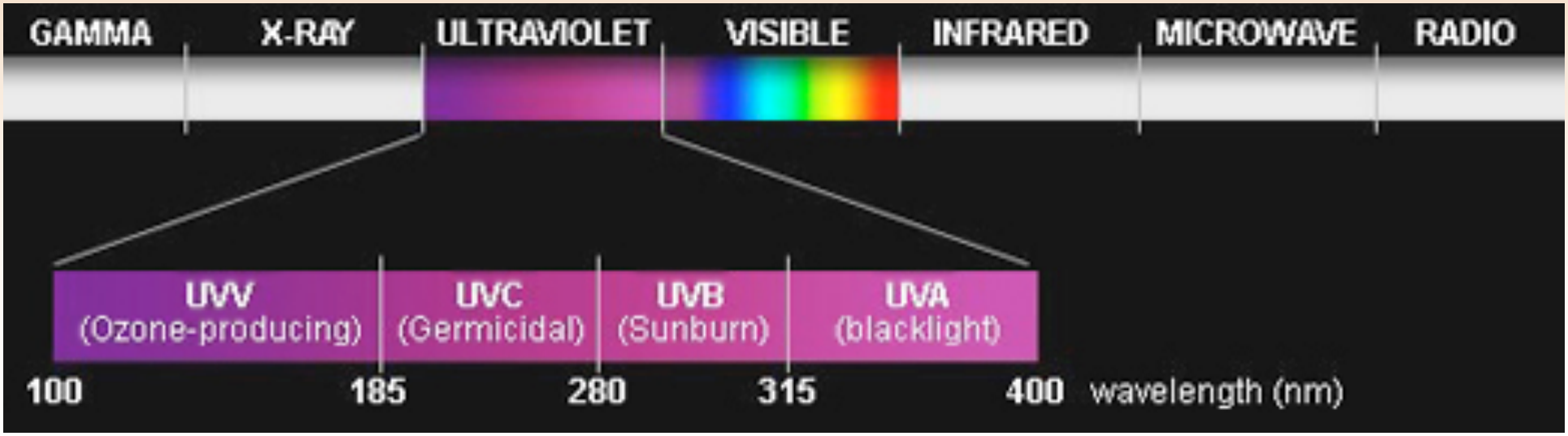


Innovative Pollution Control – Market Solutions

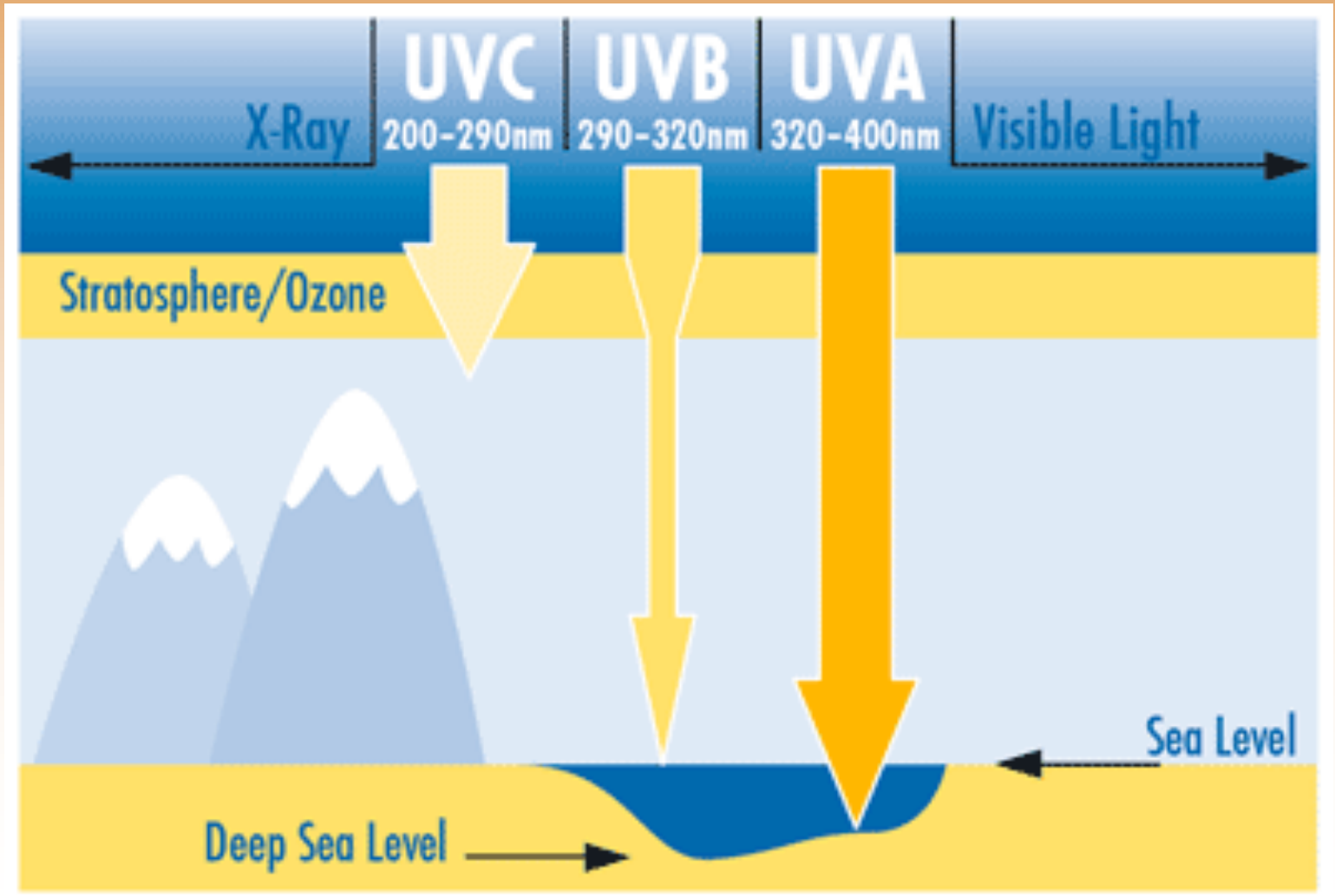


Stratospheric Ozone

- The stratospheric ozone layer exists roughly 45-60 kilometers above the Earth.
- Ozone has the ability to absorb ultraviolet radiation and protect life on Earth.



UV and Ozone


X-Ray
UVC
200-290nm
UVB
290-320nm
UVA
320-400nm
Visible Light
Stratosphere/Ozone
Sea Level
Deep Sea Level

Ultraviolet (UV) light
The Good, the Bad, and the Really Bad

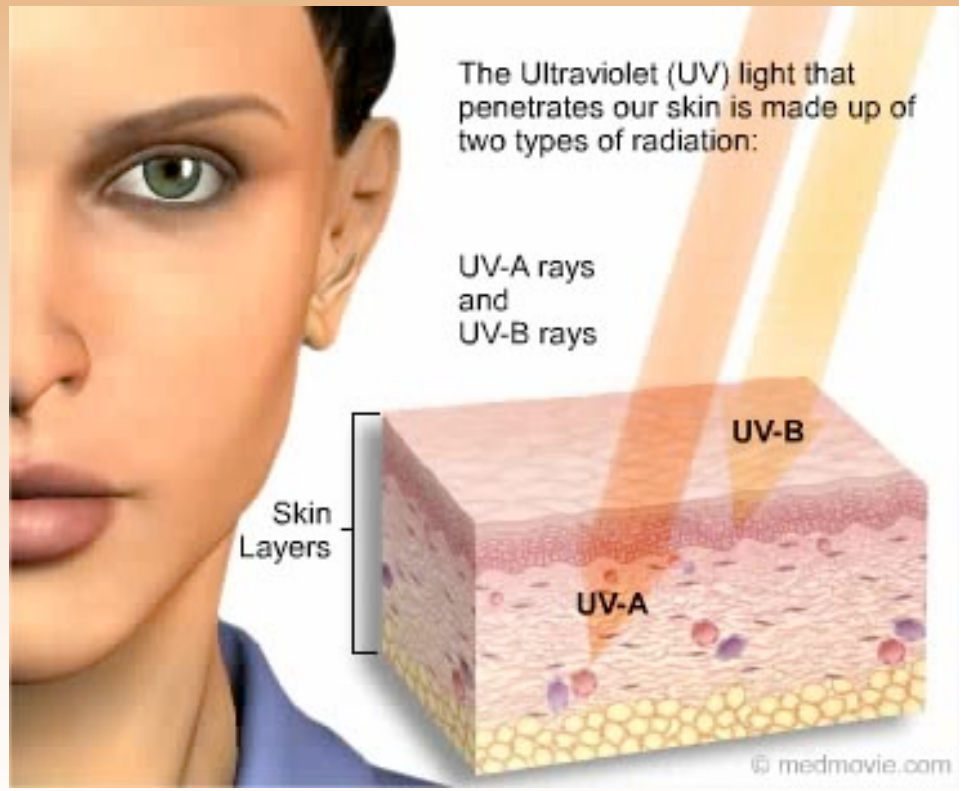
Sunlight consists of 3 types of ultraviolet rays:

UVA rays are most common and cause skin aging and wrinkling. Tanning beds usually use UVA rays.

UVB rays cause sunburns, cataracts, and immune system damage.

UVC rays, the most dangerous, are absorbed by our ozone layer.

Fig. 2



The Ozone layer absorbs UV - B & C

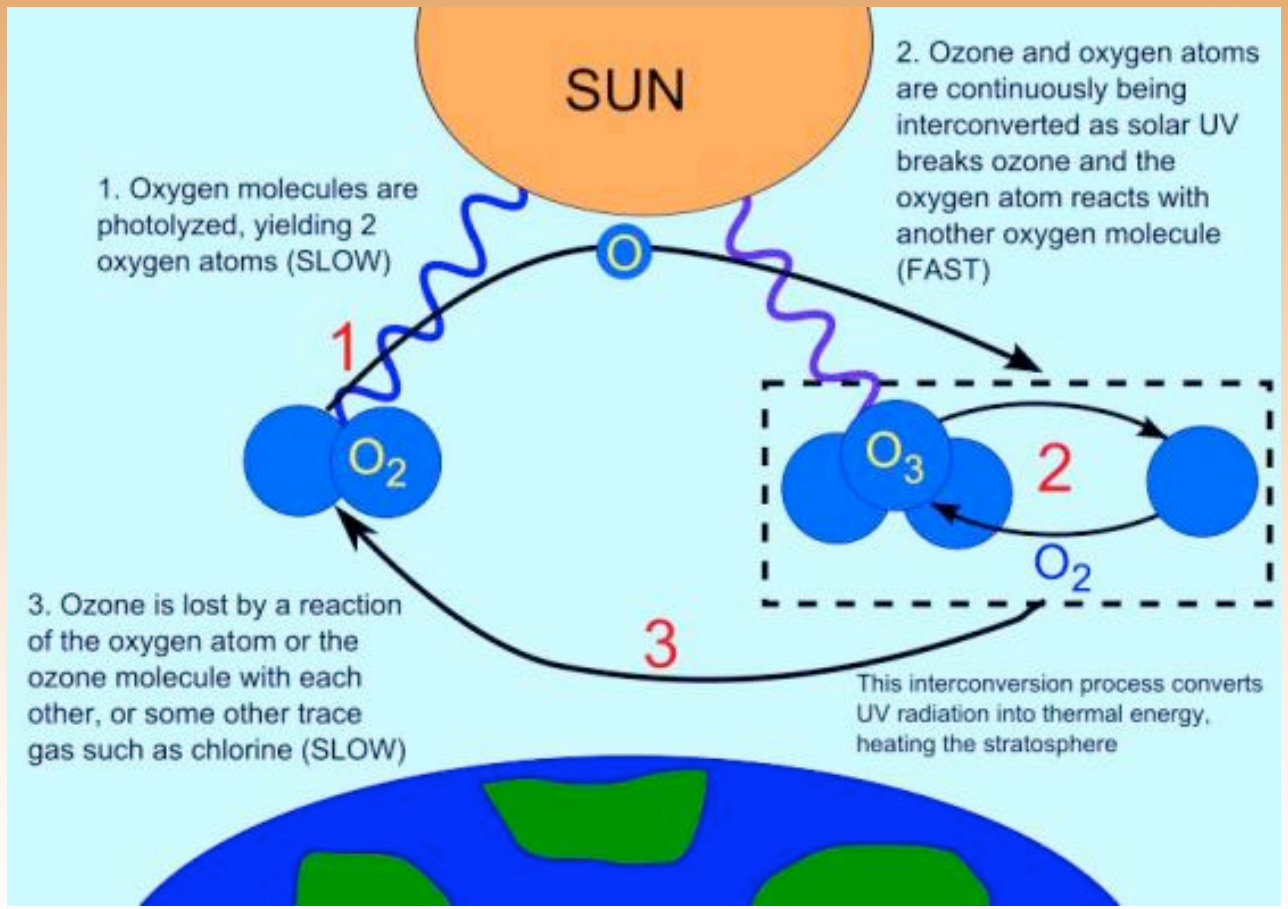
Stratosphere

Formation and Breakdown of Ozone

- First, UV-C radiation breaks the bonds holding together the oxygen molecule)2, leaving two free oxygen atoms:
  O2 + UV-C -> 2O
- Sometimes the free oxygen atoms result in ozone:
  O2 + O -> O3
- Ozone is broken down into O2 and free oxygen atoms when it absorbs both UV-C and UV-B ultraviolet light:
  O3 + UV-B or UV-C -> O2 + O

The Ozone Layer Depletion and Global Warming are NOT the SAME!!!!!

Natural Ozone formation and breakdown…



Anthropogenic Contributions to Ozone Destruction

- **Certain chemicals break down ozone, particularly chlorine.**
- **The major source of chlorine - chlorofluorocarbons (CFCs)**
- **CFCs used in refrigeration and air conditioning, as propellants in aerosol cans and as "blowing agents" to inject air into foam products like Styrofoam.**

Sources of OZD's (ozone depleters)

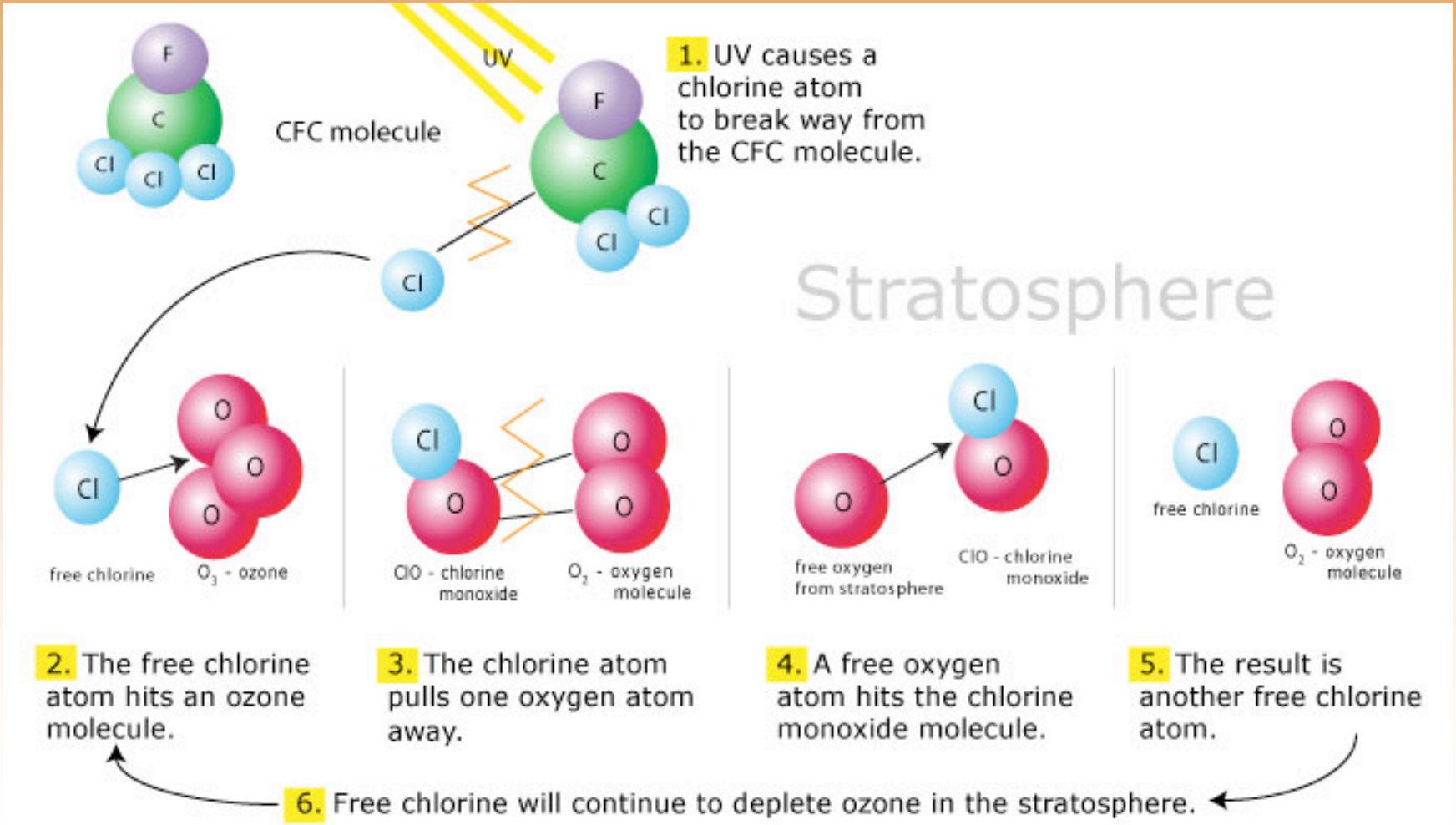
Anthropogenic Contributions to Ozone Destruction

- When CFCs are released into the troposphere they make their way to the stratosphere.
- The ultraviolet radiation present has enough energy to break the bond connecting chlorine to the CFC molecule.
- which can then break apart the ozone molecules.

Anthropogenic Contributions to Ozone Destruction

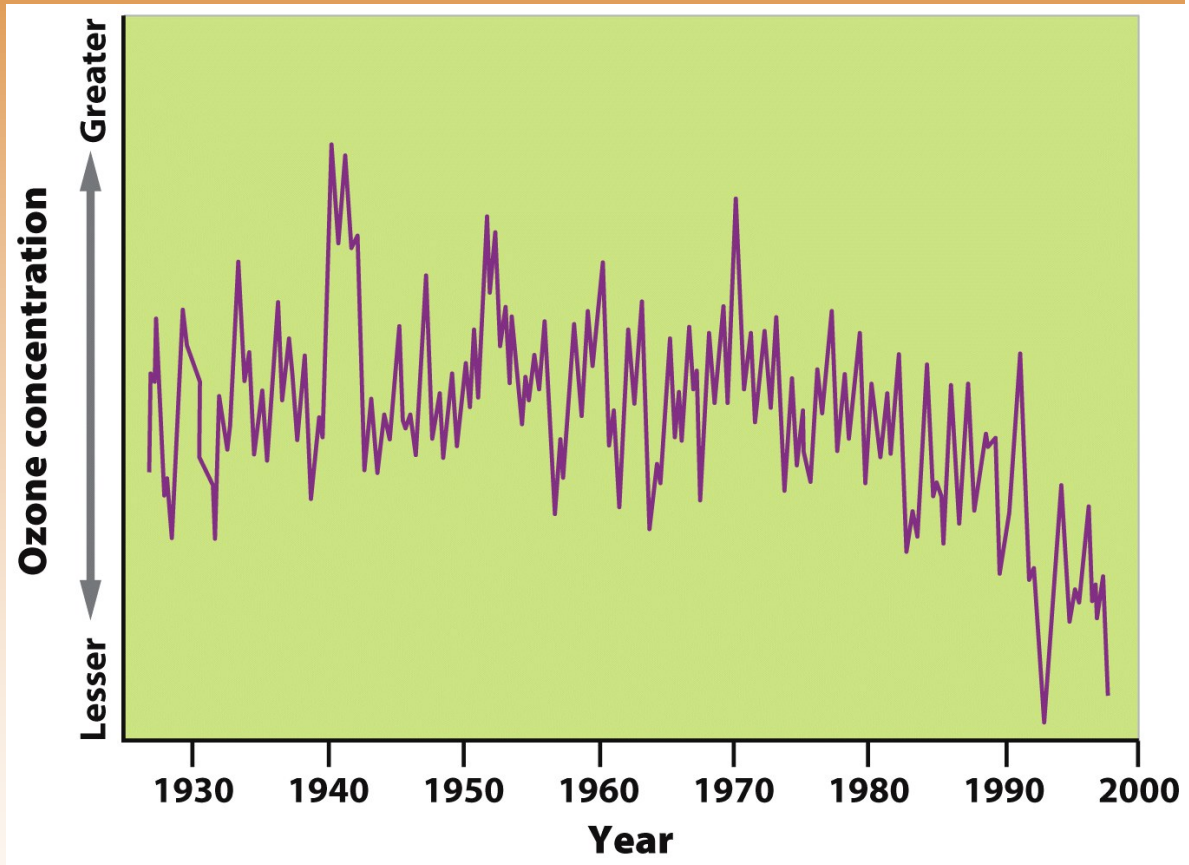
- First, chlorine breaks ozone's bonds and pulls off one atom of oxygen, forming a chlorine monoxide molecule and O2:
  $O_3 + Cl \rightarrow ClO + O_2$
- Next, a free oxygen atoms pulls the oxygen atom from ClO, liberating the chlorine and creating one oxygen molecule:
  $ClO + O \rightarrow Cl + O_2$
- One chlorine atom can catalyze the breakdown of as many as 100,000 ozone molecules before it leaves the stratosphere.

Cycle of Ozone Destruction



Depletion of the Ozone Layer

- Global Ozone concentrations had decreased by more than 10%.
- Depletion was greatest at the poles
- Decreased stratospheric ozone has increased the amount of UV-B radiation that reaches the surface of Earth.



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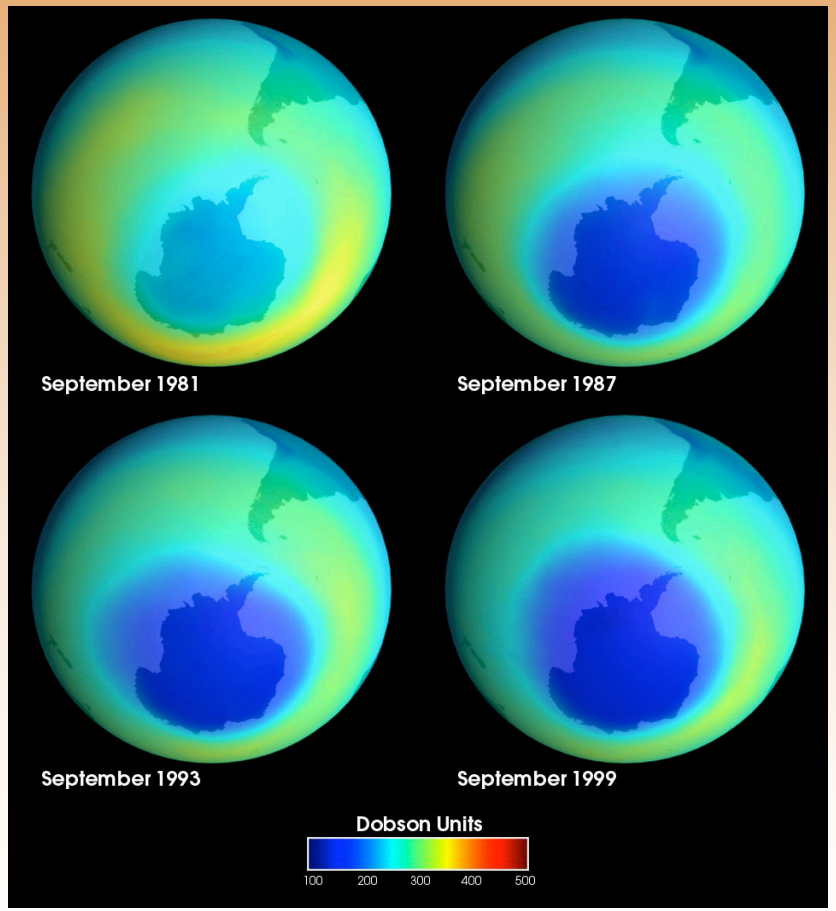
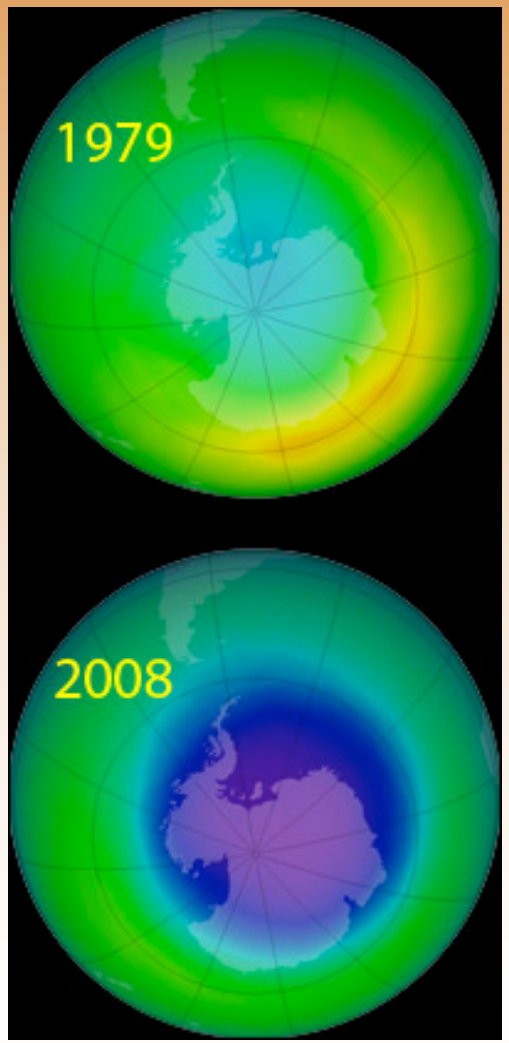
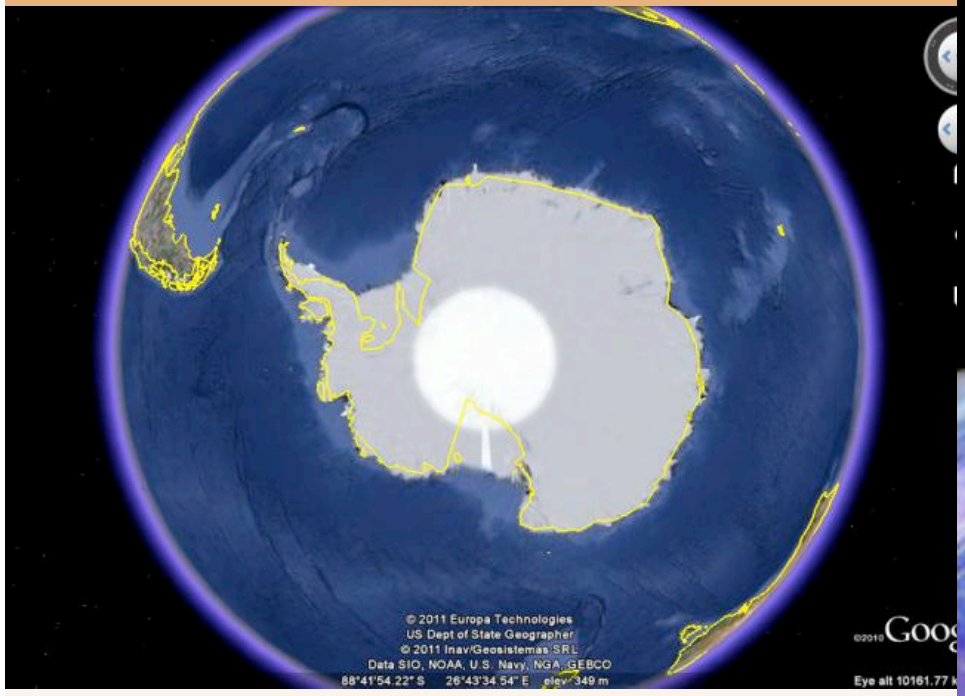
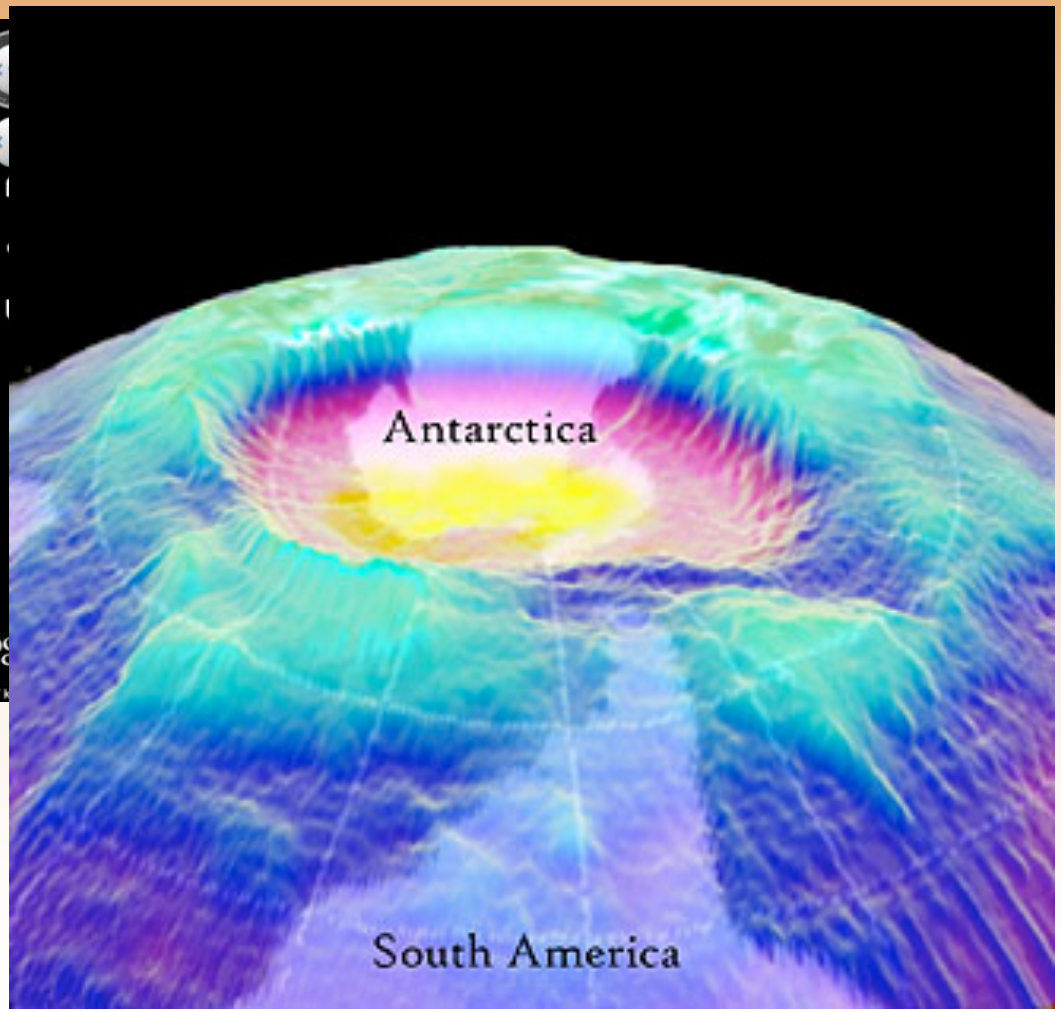
Ozone “hole”


September 1981
September 1987
September 1993
September 1999
Dobson Units
100
200
300
400
500

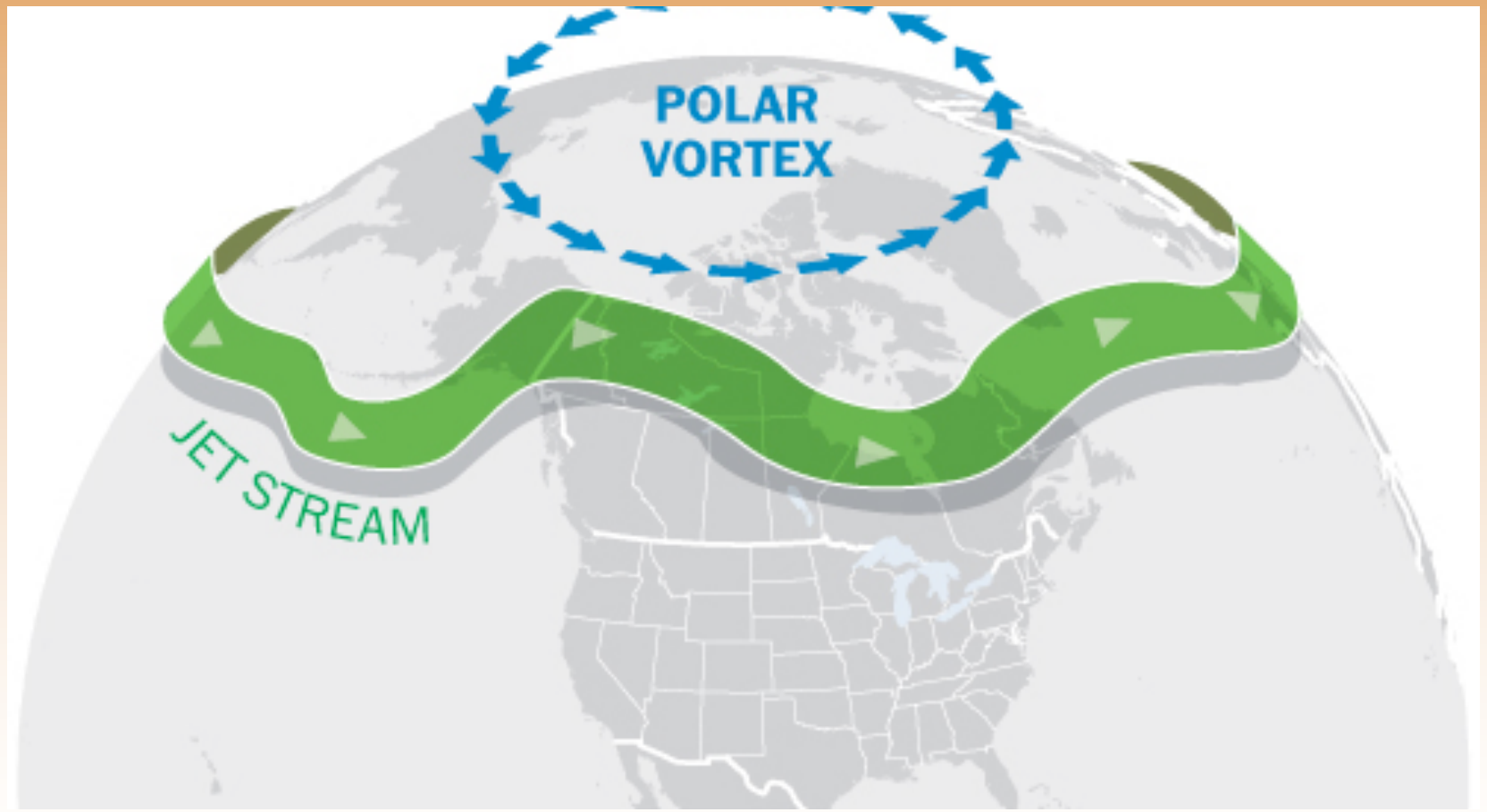

1979
2008

South Polar vortex





North Polar vortex



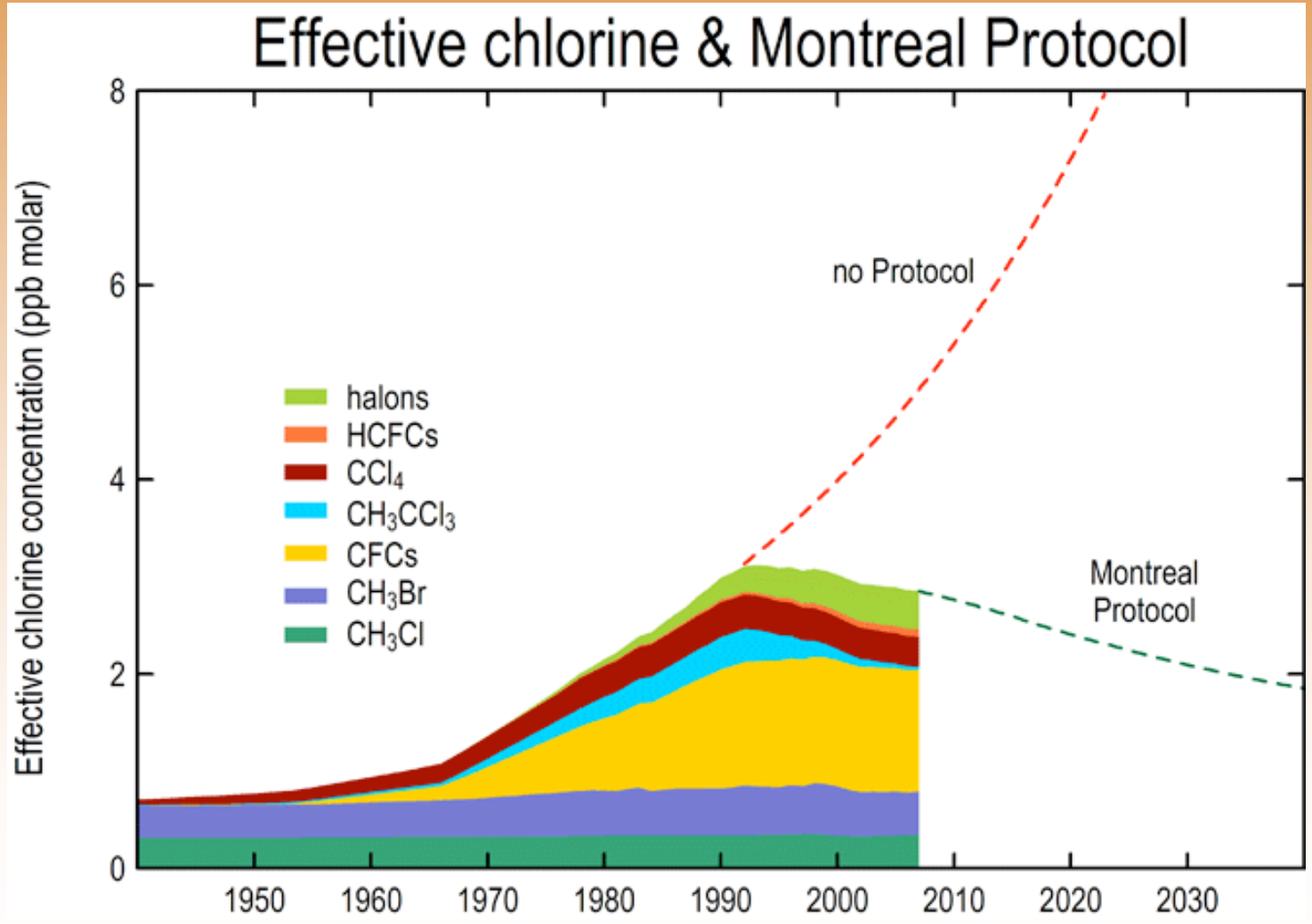
Clean Air Act of 1970

- Criteria pollutants (SO2, NOx, CO, PM, tropospheric ozone, and lead)
- Now also monitor CO2, mercury, VOCs
- National Ambient Air Quality Standards (NAAQS) – concentration limits not to be exceeded
- Acid rain program – emission proportional to pre-90s, sell allowances, fines if over

Solutions to the Problem:
1987 Montreal Protocol

Reduction and elimination of CFC production.

Solutions to the Problem: 1987 Montreal Protocol



Indoor Air Pollutants

- Wood, animal manure or coal used for cooking and heating in developing countries.
- Asbestos
- Carbon Monoxide
- Radon
- VOCs in home products

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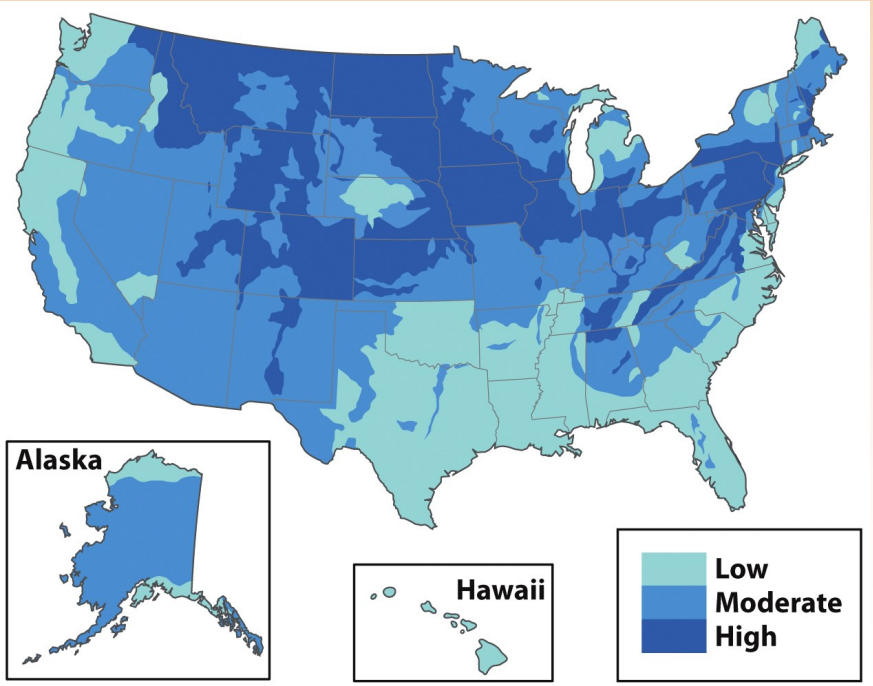

Figure 15.17
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Indoor Air Pollutants

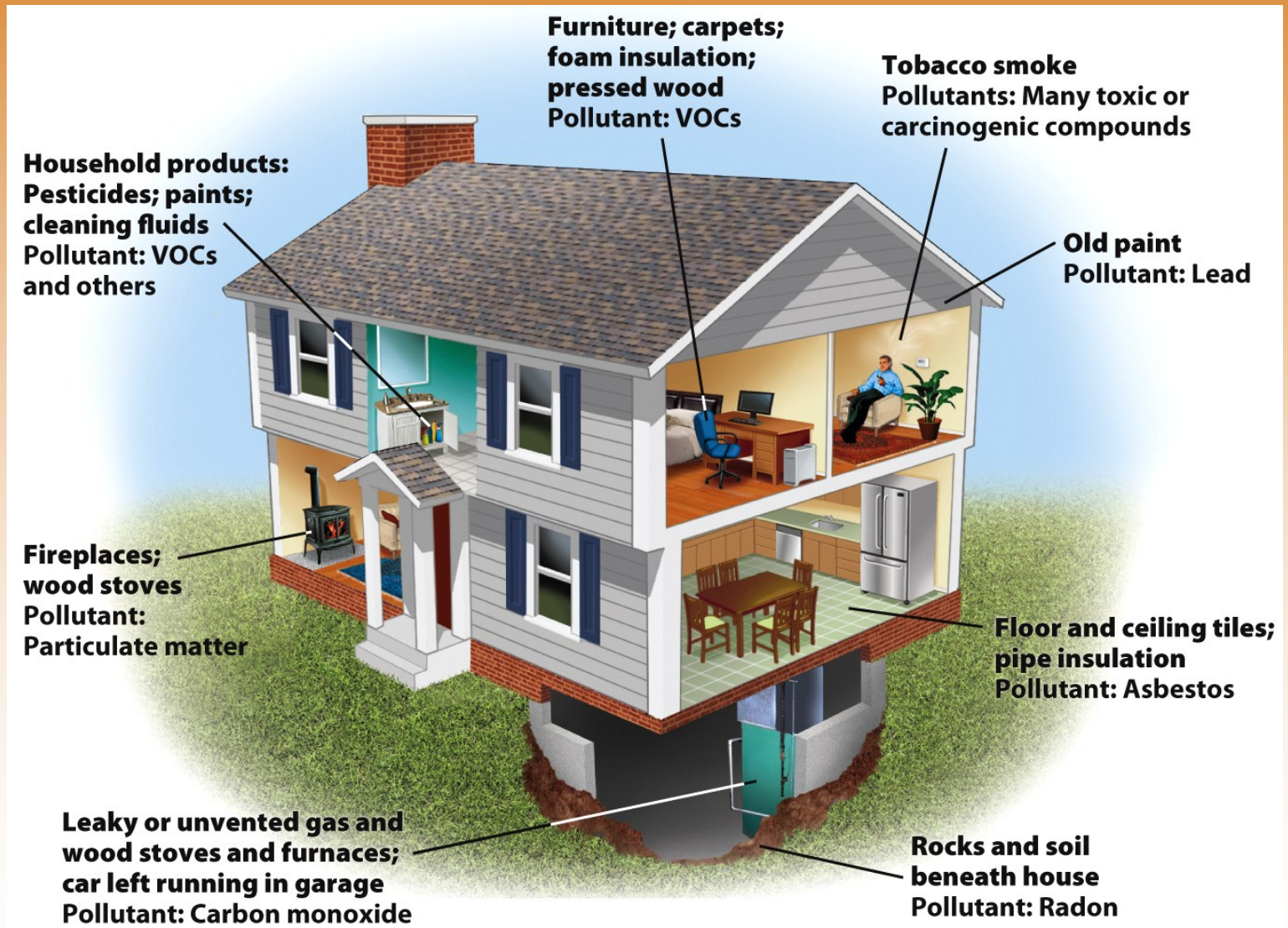

Figure 15.16
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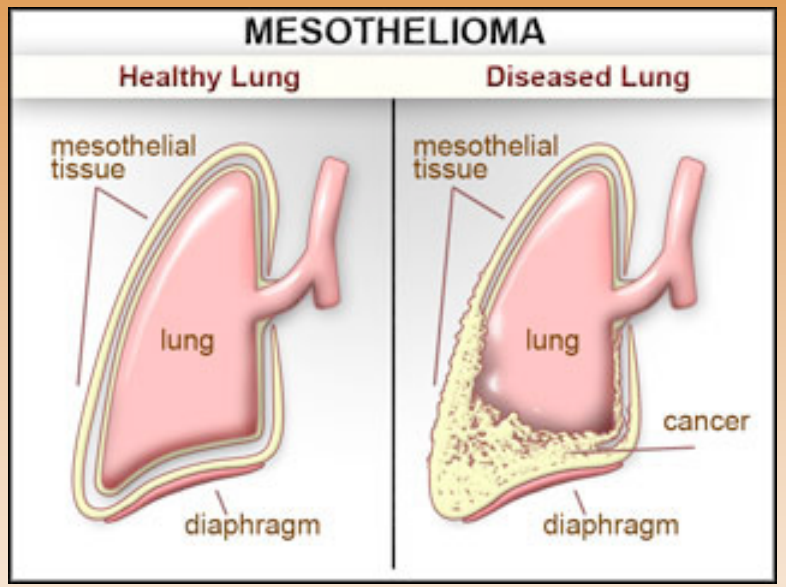
Indoor Pollutants
Asbestos and Mesothelioma



- Fibrous mineral
- Small particles
- Insulation, tiles
- Respiratory illness

Radon-222

- Radioactive gas
- Seeps from rock into homes
- Lung cancer
- Increase ventilation, fill cracks

VOCs

- Building mat'l, furniture, glues, paints
- Ex) Formeldehyde
- Good ventilation, air out new homes, stuff

Sick Building Syndrome and Multiple Chemical Sensitivity

- Inadequate ventilation
- VOCs from copiers, glues, carpet, furniture, cleaning agents
- Biological – molds and pollen