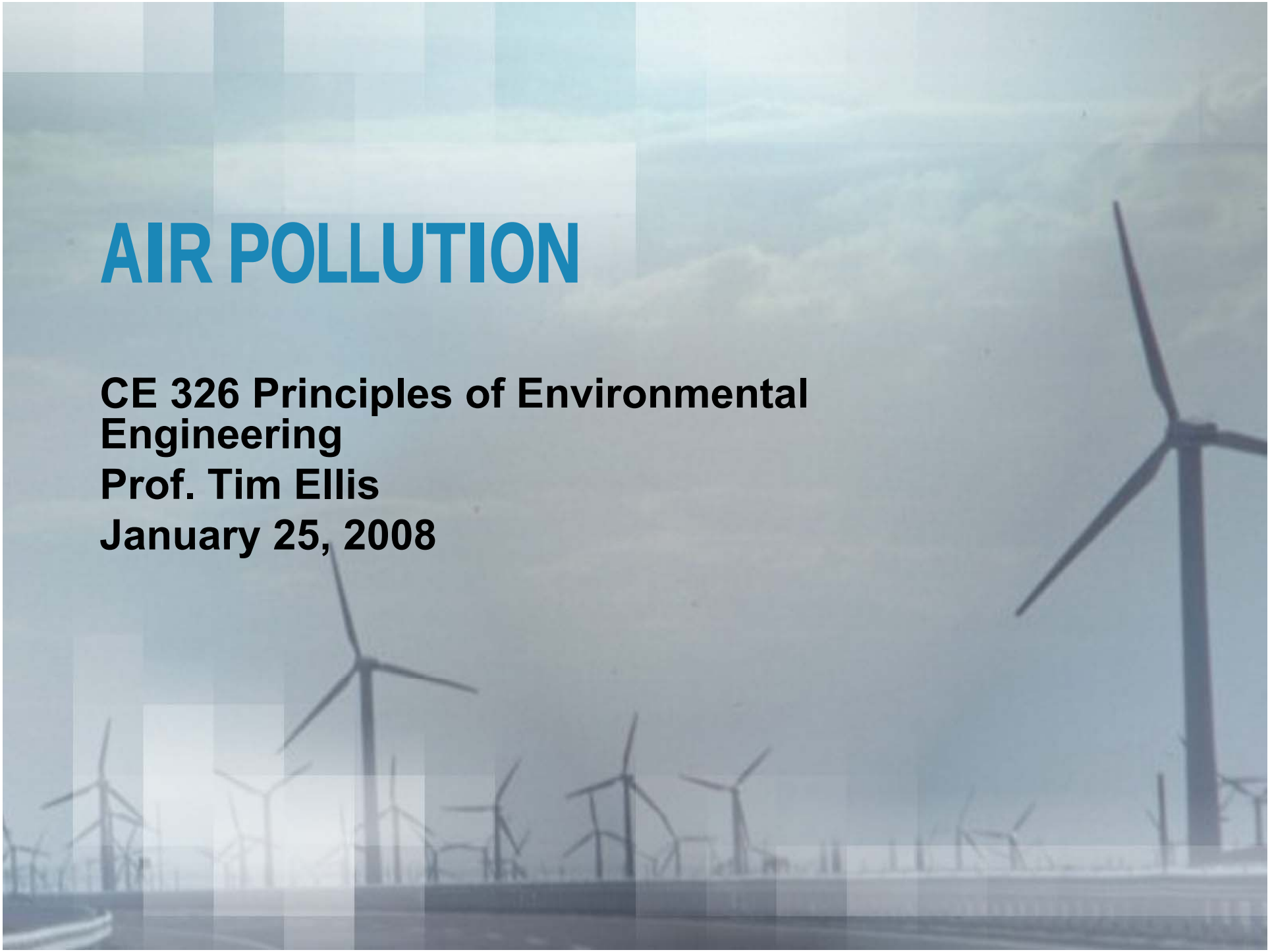

AIR POLLUTION

CE 326 Principles of Environmental Engineering

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January 25, 2008

Seven Major Pollutants of Concern

1. P_____
2. S_____ Oxides (SO_X)
3. O_____
4. N_____ Oxides (NO_X)
5. Carbon M_____ (CO and other hyrdrocarbons)
6. Volatile O_____ Compounds (VOCs)
7. L_____ (& others: mercury, other inorganic metals, radon, HCl)

www.lbl.gov/Education/HGP-images/air_pollution.jpg

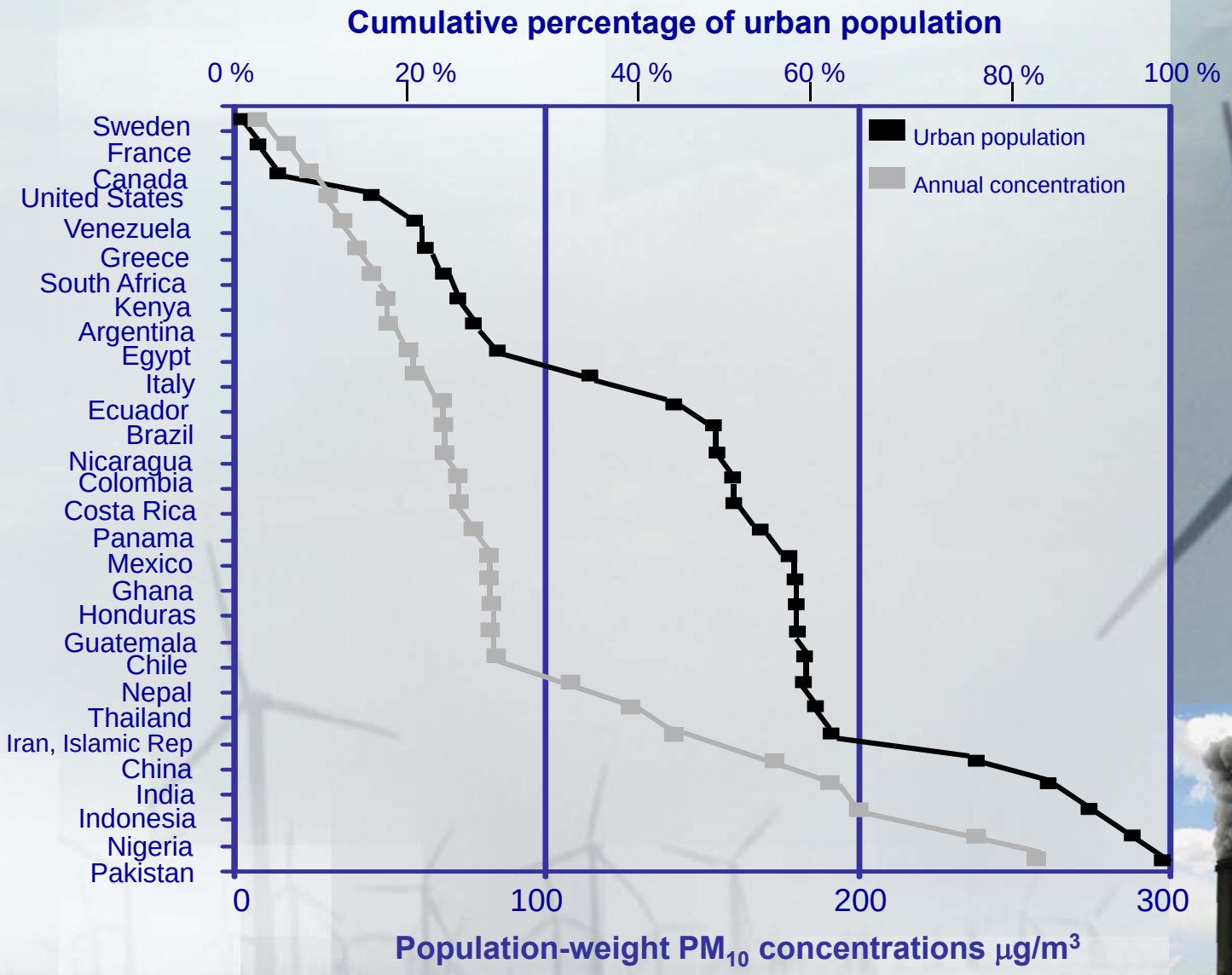
Particulates

- **released d_____ into the air**
- **largely a result of s_____ sources**
- **a nearly u_____ urban pollutant.**

"Although particulate levels in North America and Western Europe rarely exceed 50 micrograms of particulate matter per cubic meter (μg/m^3) of air, levels in many Central and Eastern European cities and in many developing nations are much higher, often exceeding 100 μg/m^3 (http://www.wri.org/wr-98-99/urbanair.htm)."

en.epochtimes.com/news_images/2005-10-14-air-pollution.jpg

Global distribution of urban PM_{10} concentrations



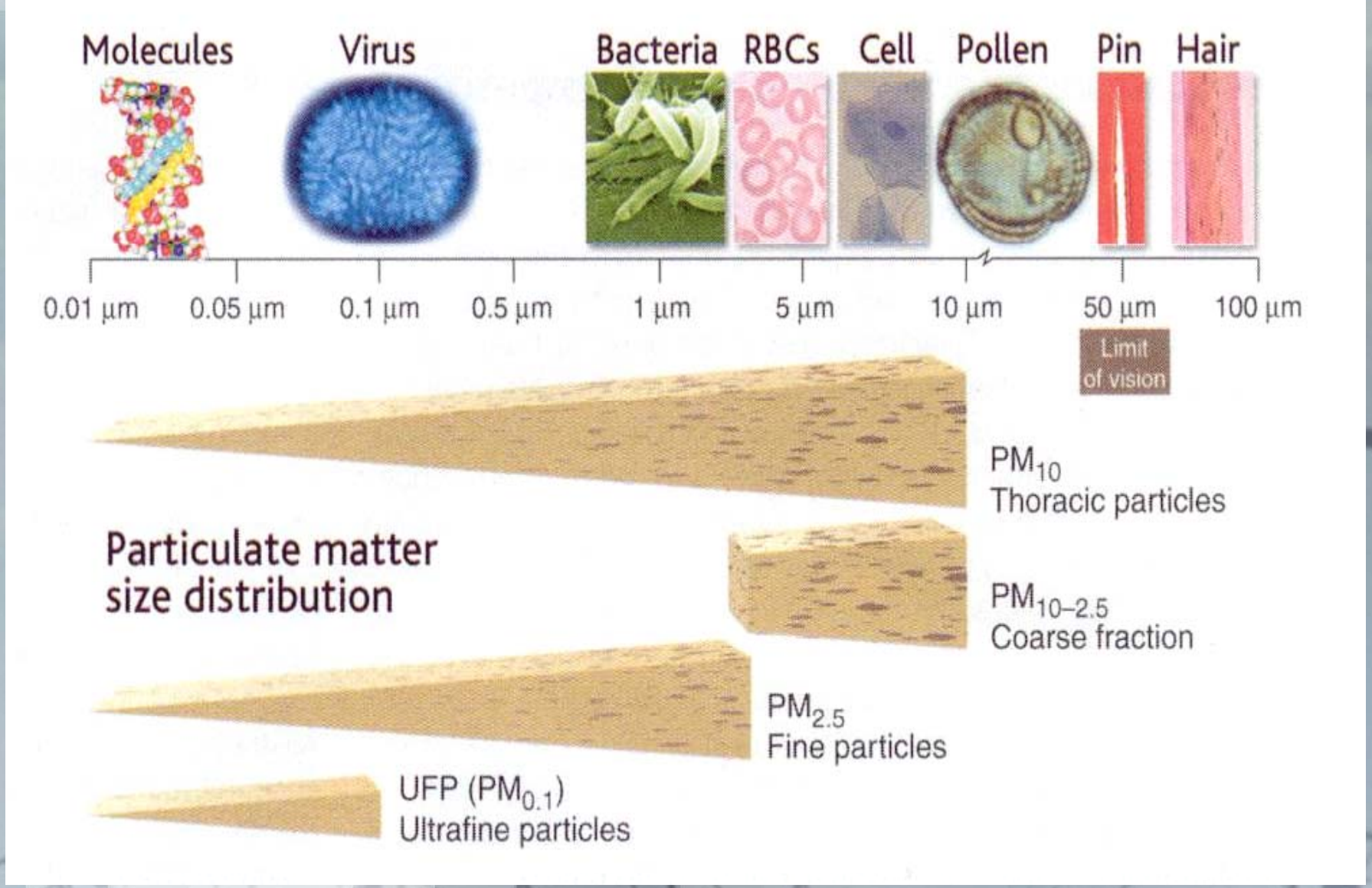
Adapted from Reference

Size of Particulates

- $PM_{2.5\text{-}100}$: 2.5 to 100 μ in diameter, usually comprise s_____ and d_____ from industrial processes, agriculture, c_____ and road traffic, p_____, and other natural sources.
- $PM_{2.5}$: particles less than 2.5 μ in diameter generally come from combustion of f_____ fuels.
- vehicle exhaust s_____, which is often coated with various chemical contaminants
- fine sulfate and nitrate a_____ that form when SO_2 and nitrogen oxides condense in the atmosphere.
- largest source of fine particles is c____-fired power plants, but auto and diesel e_____ are also prime contributors, especially along busy transportation corridors.

Health Effects

- S_____ particulates most damaging ($PM_{2.5}$)
- $PM_{2.5}$ aggravate existing h____ and lung diseases
- changes the body's defenses against i_____ materials, and damages l_____ tissue.
- E_____, children and those with chronic lung or heart disease are most sensitive
- lung impairment can persist for 2-3 weeks after e_____ to high levels of $PM_{2.5}$
- C_____ carried by particulates can also be toxic



Science 307:1857-1861, News Focus, March 2005

Sulfur Oxides

- Sulfur Oxides (SO_X, mainly SO_2)
- emitted largely from burning c____, high-sulfur o___, and d_____ fuel.
- usually found in association with p_____
- SO_2 is the p_____ for fine sulfate particles (separating the health effects of these two pollutants is difficult)
- SO_2 and particulates make up a major portion of the pollutant l_____ in many cities, acting both separately and in c_____ to damage health.
- concentrations are higher by a factor of _____ in a number of cities in Eastern Europe, Asia, and South America, where residential or industrial coal use is still prevalent and diesel traffic is heavy
- major component of a____ r_____

Health Effects

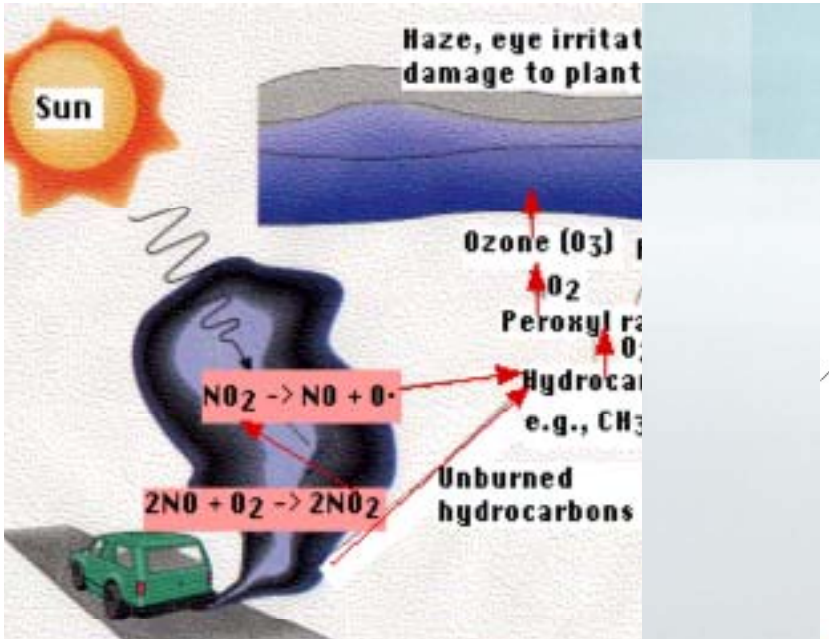
- SO_2 affects people q_____, usually within the first few minutes of e_____
- SO_2 exposure can lead to the kind of a_____ health effects typical of particulate pollution.
- Exposure is linked to an increase in h_____ and deaths from respiratory and cardiovascular causes, especially among a_____ and those with preexisting respiratory diseases
- severity of these effects increases with rising SO_2 levels, and e_____ enhances the severity by increasing the volume of SO_2 inhaled and allowing SO_2 to penetrate deeper into the respiratory tract
- Asthmatics may experience w_____ and other symptoms at much lower SO_2 levels than those without asthma.
- When o_____ is also present, asthmatics become even more sensitive to SO_2 indicating the potential for synergistic effects among pollutants

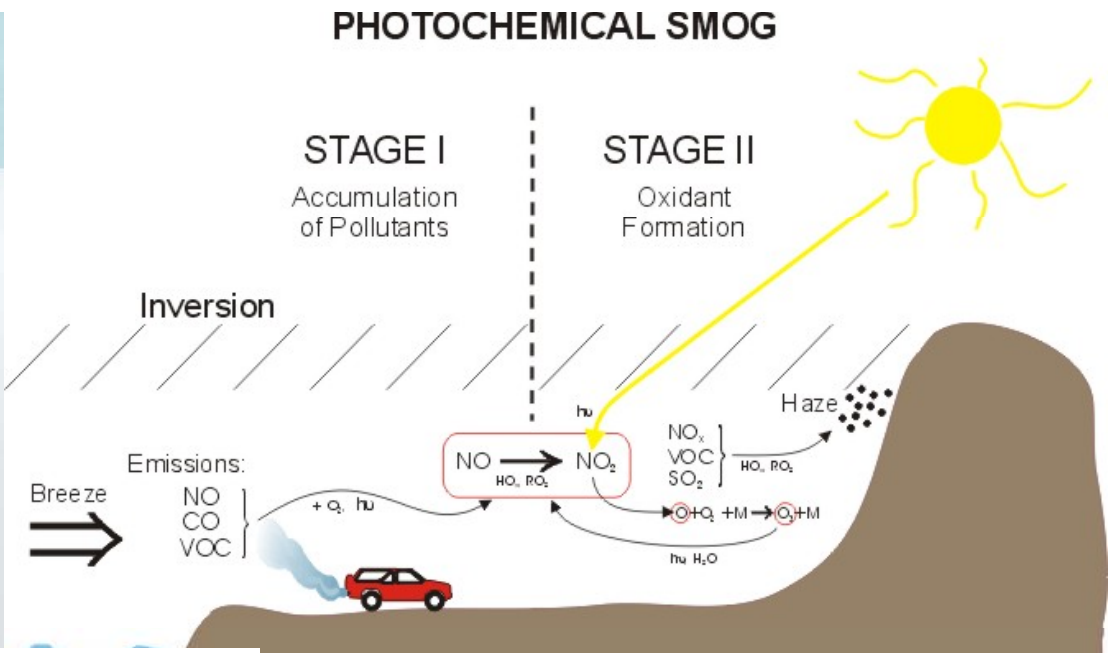
Ozone

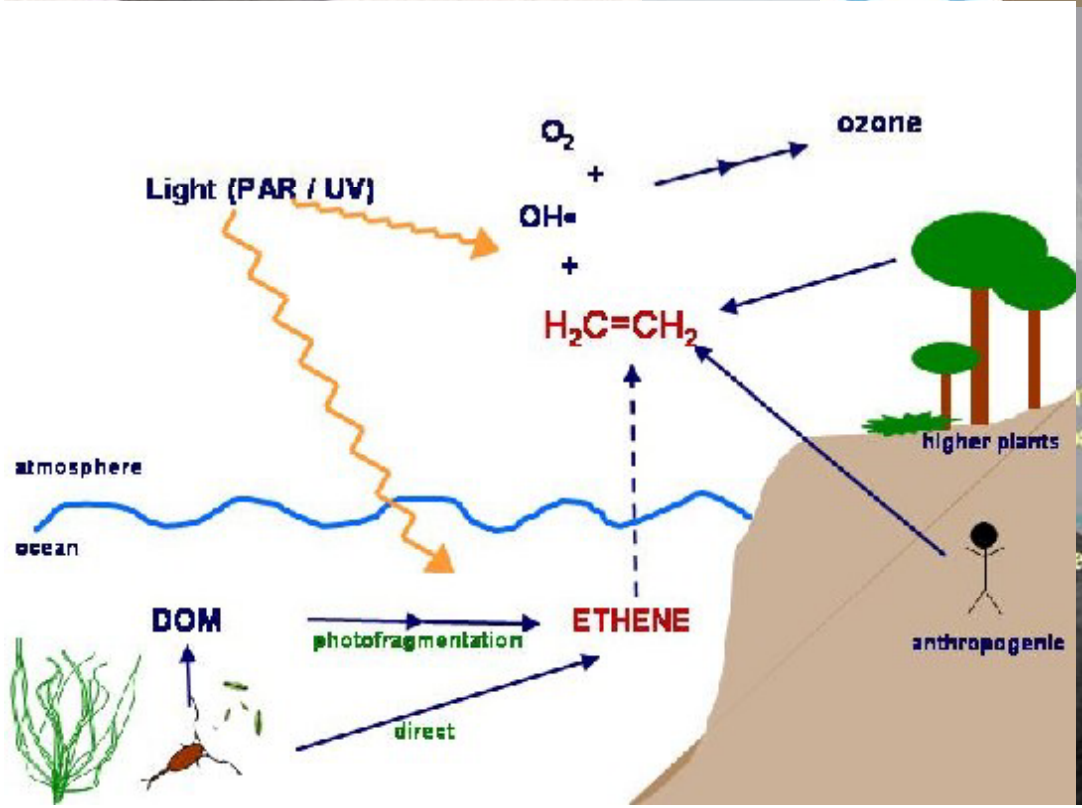
- major component of p_____ smog
- formed when _____ from fuel combustion react with VOCs
- S_____ and heat stimulate ozone formation, peak levels occur in the s_____.
- W_____ in cities in Europe, North America, and Japan as auto and industrial emissions have increased. Many cities in developing countries also suffer from high ozone levels, although few monitoring data exist
- powerful o_____, can react with nearly any biological tissue.

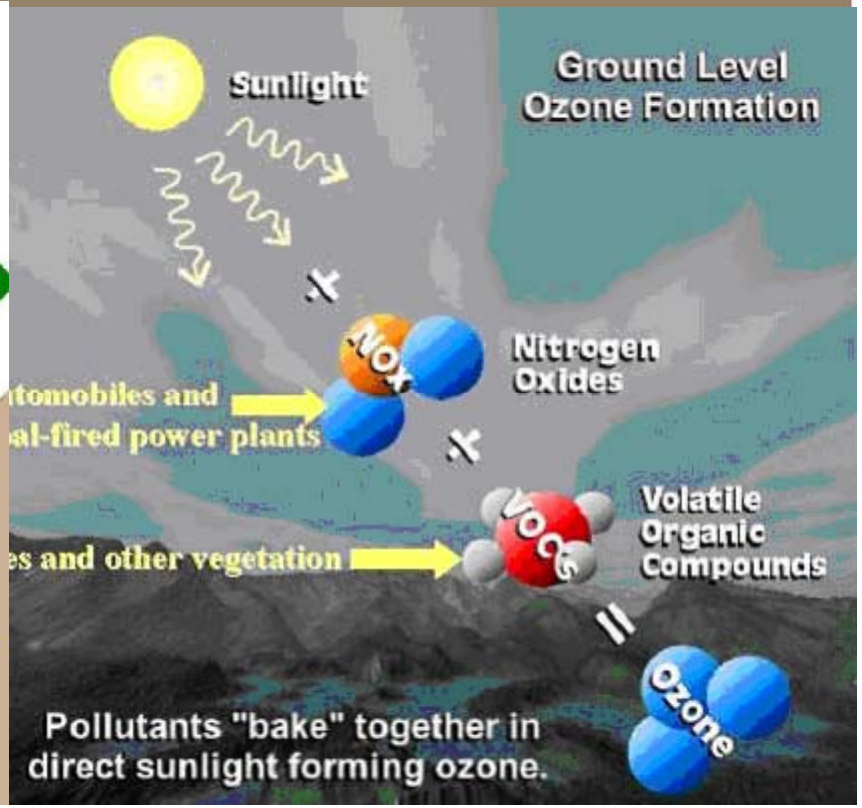
Ozone

- concentrations of 0.012 ppm can irritate the respiratory tract and impair l____ function, causing coughing, shortness of breath, and c_____ pain.
- Exercise increases these effects, and heavy exercise can bring on symptoms even at low ozone levels (0.08 ppm).
- ozone exposure l_____ the body's defenses, increasing susceptibility to respiratory infections
- As ozone levels rise, hospital a_____ and emergency room visits for respiratory illnesses such as asthma also increase.
- hospital admissions rise roughly 7 to 10 percent for a 0.05 ppm increase in ozone levels.
- in 13 cities where ozone levels e_____ U.S. air standards, the American Lung Association estimated that high ozone levels were responsible for approximately 10,000 to 15,000 extra hospital admissions and 30,000 to 50,000 additional emergency room v_____ during the 1993-94 ozone season

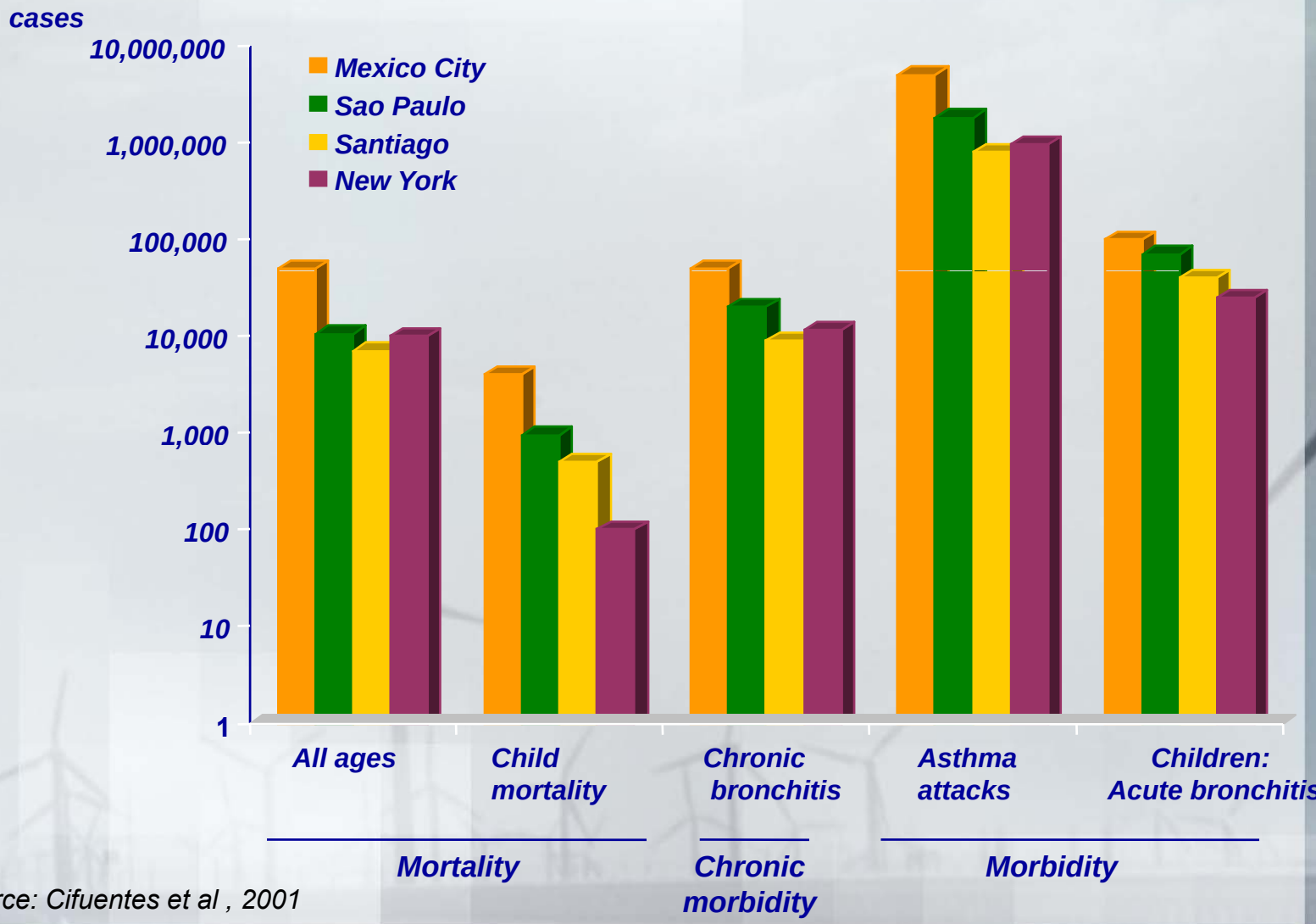

Sun
Haze, eye irritat
damage to plant
Ozone (O3)
O2
Peroxyl ra
Hydrocar
e.g., CH3
NO2 -> NO + O·
2NO + O2 -> 2NO2
Unburned
hydrocarbons


PHOTOCHEMICAL SMOG
STAGE I
Accumulation
of Pollutants
STAGE II
Oxidant
Formation
Inversion
Haze
Emissions:
NO
CO
VOC
Breeze
NO
NO2
HO2, RO2
NOx
VOC
SO2
hu
hu H2O


O2
+
ozone
Light (PAR / UV)
OH·
+
H2C=CH2
atmosphere
ocean
higher plants
DOM
photofragmentation
ETHENE
direct
anthropogenic


Sunlight
Ground Level
Ozone Formation
NOx
Nitrogen
Oxides
tomobiles and
al-fired power plants
VOC
Volatile
Organic
Compounds
es and other vegetation
ozone
Pollutants "bake" together in
direct sunlight forming ozone.

Preventable health effects due to a 10% reduction of environmental levels of PM_{10} and ozone between 2000 and 2020



Source: Cifuentes et al , 2001

Nitrogen Oxides

- principal p_____ component of photochemical smog
- component of a____ rain (NO_X is oxidized to NO_3^- in the atmosphere, NO_3^- reacts with moisture to form nitric acid H_2NO_4)
- formed i_____ due to high temperature of combustion of atmospheric nitrogen

Carbon Monoxide

- H_____ has an affinity for CO that is 200 to 250 times its affinity for oxygen
  - this reduces its affinity for oxygen, disrupts release of oxygen.
- Blood level of 0.4% is maintained by CO produced by b_____.
- Blood is cleared of 50% of CO in 3-4 hours after e_____.
- Global emissions of CO are 350 million tons per year, 20% from mobile sources.
- CO concentration in c_____ smoke is ~400 ppm.
- 24% of emergency room patients complaining of f____-like symptoms in one study showed carbon monoxide poisoning

Carbon Monoxide health effects

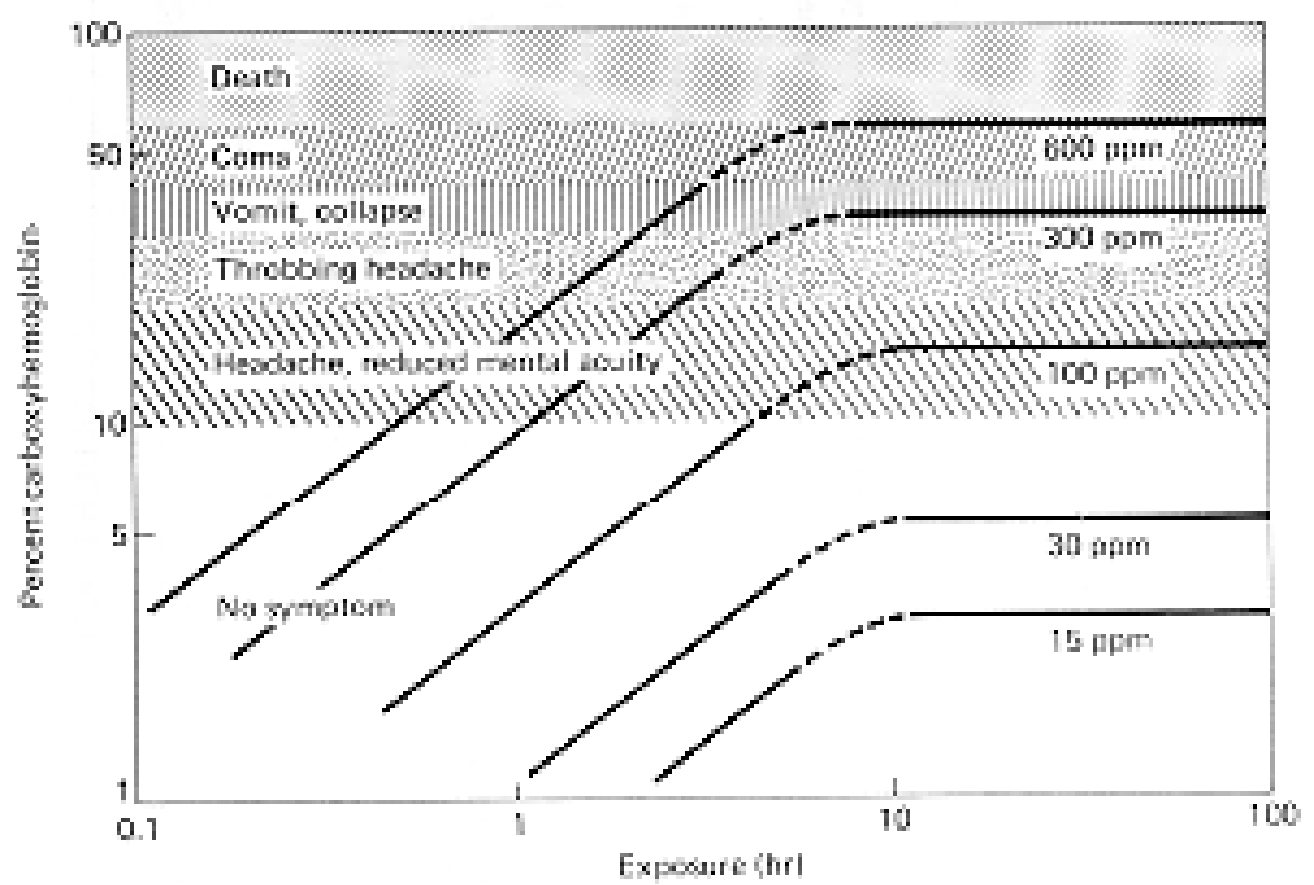


FIGURE 1-4
Effects of exposure to CO on man.

- CO blocks the oxygen transport in your blood.
- CO is 100x better at binding in the oxygen site.
- CO poisoning is like suffocating.

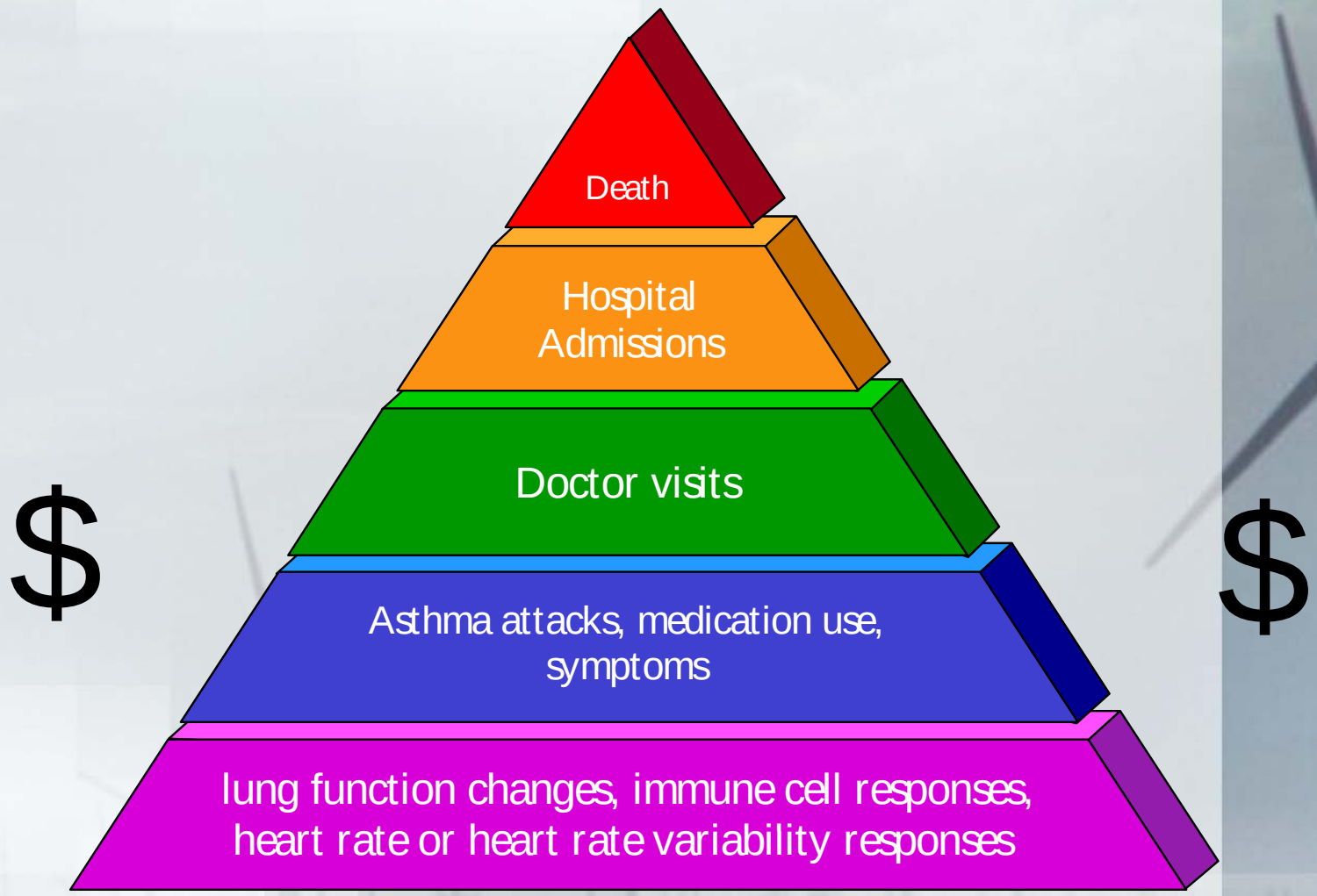
Volatile Organic Compounds (VOCs)

- contribute to o_____ generation
- many are subject to NESHAPS (benzene from gasoline vapors)
- significant i_____ emissions (e.g., perchloroethylene from dry cleaners)
- many are c_____ or suspected carcinogens

Other Air Pollutants

- Lead
- Mercury
- other inorganic metals
- Indoor air pollution
  - Second hand smoke
  - Radon

"Pyramid of Effects"



National Ambient Air Quality Standards (NAAQS)

Criteria Pollutants	Standard Type	Avg. Time	Conc.	Health Risks and Concerns	Anthropogenic Sources	Natural Sources
Carbon monoxide	Primary	8 h 1 h	9 ppm 35 ppm	carboxy-hemoglobin (blood)	incomplete combustion from mobile and stationary sources	intermediate in breakdown of methane by hydroxyl radicals (OH·)
Hydrocarbons (measured as CH_4)	Primary	3 h	240 ppb	photochemical smog	incomplete combustion from mobile and stationary sources	see graph
Lead	Primary	24 h 3 month	18 ppb 6 ppb	CNS	leaded gasoline (obsolete?), smelters and refineries	volcanic activity and soils
Nitrogen dioxide	Primary	annual 1 h	53 ppb 250 ppb	health risks, visibility (NO_2 has a brown color)	high temperature combustion	bacterial processes in soil release nitrous oxide N_2O
Ozone	Primary	1 h 8 h	120 ppb 80 ppb	eye irritation, breathing difficulties	formed in nitrogen oxide photolytic cycle (NO_X + sunlight)	
Sulfur dioxide	Primary	annual 24 h	30 ppb 140 ppb	respiratory disease	sulfur in fuel	sulfur released in biological processes
Sulfur dioxide	Secondary	3 h	500 ppb	plant damage, material damage		
Total suspended particulates (TSP)	Primary	annual 24 h	75 μg/m^3 150 μg/m^3	visibility and respiratory effects	combustion of fossil fuels and industrial activity	soil, sea salt, sand, forest fires, volcanoes
Particulates (PM_{10})	Primary	annual 24 h	50 μg/m^3 365 μg/m^3	visibility and respiratory effects		
Particulates ($PM_{2.5}$)	Primary	24 h	65 μg/m^3	visibility and respiratory effects		