London Killer Smog

- European environment hit hard by Industrial Revolution 250 years ago
- Smelters, factories, powerplants released large amount of pollution into atmosphere
- Thick smog of sulfuric acid (from burning of soft coal), soot, CO, VOC, and NOx caused respiratory problems resulting in death.
- London, 1952, 4000 die from air pollution during a single weekend; another 8,000 die in following weeks
- Loss of wildlife not documented

Natural Sources of Air Pollution

- Biological
  - Pollen
  - Spores
  - Isoprene, methane, terpenes, and other VOC
  - Baterial, algal, and viral particles
  - H_2S, SO_2, N_2O
  - Acetic and formic acids
- Geological
  - Dust
  - Volcanic ash
  - Sulfur dioxide
  - Sea sprays

Anthropogenic Sources of Air Pollution

- "Criteria", or conventional pollutants
  - Sulfur compounds - second only to smoking to air pollution-related human health problems
  - Nitrogen compounds
  - Carbon oxides - including CO_2 and global warming
  - Metals and halogens
  - Particulate material - solids and liquids
  - VOC
  - Photochemical oxidants

Anthropogenic Sources of Air Pollution

- Unconventional/ "Other" pollutants - especially toxic
  - Asbestos
  - Benzene
  - Beryllium
  - Mercury
  - Polychlorinated biphenyls (PCBs)
  - Vinyl chloride
  - Biocides

Anthropogenic vs. Natural Sources

TABLE 18.1 Estimated Fluxes of Pollutants and Trace Gases to the Atmosphere

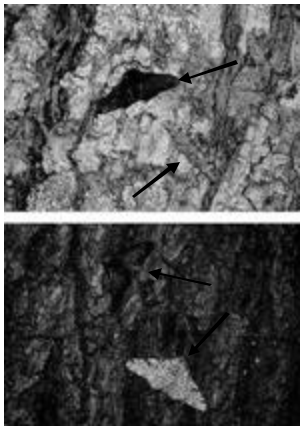
SPECIES	SOURCES	APPROXIMATE ANNUAL FLUX	
		NATURAL (MILLIONS OF METRIC TONS/YR)	ANTHROPOGENIC
CO_2 (carbon dioxide)	Respiration, fossil fuel burning, land clearing, industrial processes	370,000	23,900[a]
CH_4 (methane)	Rice paddies and wetlands, gas drilling, landfills, animals, termites	155	350
CO (carbon monoxide)	Incomplete combustion, CH_4 oxidation, biomass burning, plant metabolism	1580	930
NMHC (nonmethane hydrocarbons)	Fossil fuels, industrial uses, plant isoprenes and other biogenics	860	92
NO_x (nitrogen oxides)	Fossil fuel burning, lightning, biomass burning, soil microbes	90	140
SO_x (sulfur oxides)	Fossil fuel burning, industry, biomass burning, volcanoes, oceans	35	79
SPM (suspended particulate materials)	Biomass burning, dust, sea salt, biogenic aerosols, gas to particle conversion	583	362

[a] About half of this is taken up again by plant photosynthesis while the rest accumulates in the atmosphere.

Source: Data from Joyce E. Penner, "Atmospheric Chemistry and Air Quality" in W. B. Meyer and B. L. Turner (eds.), *Changes in Land Use and Land Cover: A Global Perspective*, 1994, Cambridge University Press and UNEP 1999.

Air Pollutant Health Standards

Pollutant	Major Source	Comments
Carbon monoxide (CO)	Motor-vehicle exhaust; some industrial processes	Health standard: 10 mg/m3 (9 ppm) over 8 hr; 40 mg/m3 over 1 hr (35 ppm)
Sulfur dioxide (SO2)	Heat and power generation facilities that use oil or coal containing sulfur; sulfuric acid plants	Health standard: 80 µg/m3 (0.03 ppm) over a year; 365 µg/m3 over 24 hr (0.14 ppm)
Particulate matter	Motor-vehicle exhaust; industrial processes; refuse incineration; heat and power generation; reaction of pollution gases in the atmosphere	Health standard: 50 µg/m3 over a year; 150 µg/m3 over 24 hr; composed of carbon, nitrates, sulfates, and many metals including lead, copper, iron, and zinc
Lead (Pb)	Motor-vehicle exhaust; lead smelters; battery plants	Health standard: 1.5 µg/m3 over 3 months
Nitrogen dioxide (NO2)	Motor-vehicle exhaust; heat and power generation; nitric acid; explosives; fertilizer plants	Health standard: 100 µg/m3 (0.05 ppm) over a year; reacts with hydrocarbons and sunlight to form photochemical oxidants
Ozone (O3)	Formed in the atmosphere by reaction of nitrogen oxides, hydrocarbons, and sunlight	Health standard: 235 µg/m3 (0.12 ppm) over 1 hr



Industrial Melanism

•Change in the frequency of a trait within a population of moth due to natural selection by predators

•trees turned black b/c covered by soot and lichens died

•Evolution cannot predict the future or create adaptations to match an environmental change. It acts on existing variation - black form already existed.

Proportion of black and white pepper moths in England

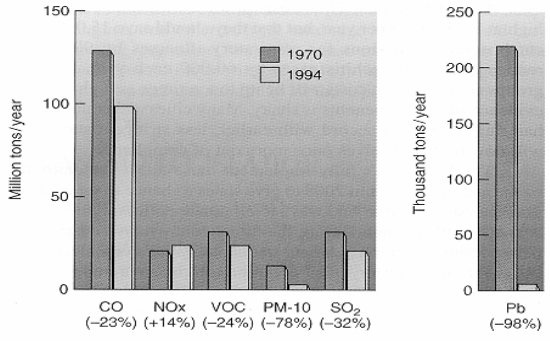
Transport of Air Pollution

- Though they originate in industrial centers, air currents carry pollutants to all reaches of the earth, affecting ecosystems everywhere.
- In fact, it was initially difficult to convince people to stop air pollution b/c it wasn t affecting them directly (old solution: tall smoke stacks)
- Circumpolar winds concentrate air pollution in the arctic and antarctic
- Inuit people have very high concentrations of PCBs, because of long-distance transport of pollutants

Government Steps In

- In 1970, Congress passed the Clean Air Act, establishing a national policy to preserve, protect, and enhance air quality.
- Congress amended the Act in 1977, at which time it designated all national parks greater than 6,000 acres, and wilderness areas greater than 5,000 acres, that were in existence as of August 7, 1977, as mandatory class I areas.
- There are currently 48 units of the National Park System, 21 units of the National Wildlife Refuge System, and 89 units of the National Forest System with this designation.
- Class I areas are afforded the greatest degree of air quality protection under the Act. The 1977 amendments required that air quality related values (including flora, fauna, soil, water, visibility, and historical structures) in class I areas are not adversely affected by air pollutants.

Clean Air Act has been somewhat successful



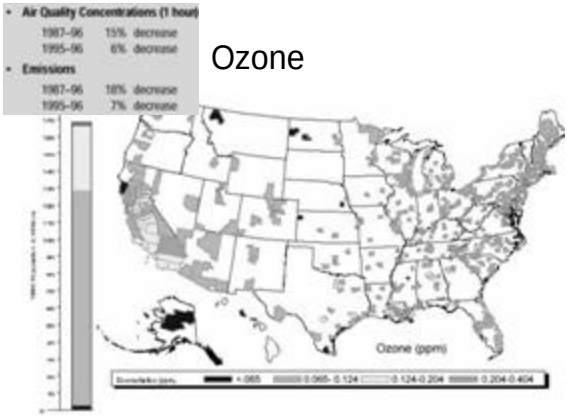
Exposure and Response to Air Pollution

1) inhalation of gases or small particles

2) ingestion of particles suspended in food or water

3) absorption of gases through the skin.

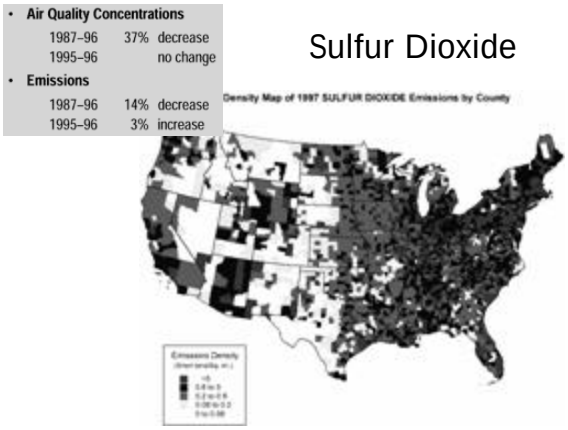
- In general, only softbodied invertebrates (e.g. earthworms), or animals with thin, moist skin (e.g. amphibians) are affected by the absorption of pollutants.
- An individual's response to a pollutant varies greatly and depends on (1) type of pollutant involved, (2) duration and time of exposure, and (3) amount taken up by the animal.
- Factors such as the individual's age, sex, health, and reproductive condition also play a role in its response.
- There is also a great deal of variability between animal classes, species, and even genotypes, in terms of the level of tolerance to a particular pollutant.



Ozone

- Stratospheric ozone is good, however…..
- Ground-level ozone interferes with the ability of plants to produce and store food, which makes them more susceptible to disease, insects, other pollutants, and harsh weather.
- Ozone damages the leaves of trees and other plants, ruining the appearance of cities, national parks, and recreation areas.
- Ozone reduces crop and forest yields and increases plant vulnerability to disease, pests, and harsh weather.

Fig. 22.7



Sulfur Dioxide

Effects of SO_2 and O_3 on Plants

- direct, physiological damage
- interferes with photosynthesis
- chambers with charcoal filtered air shows that soybean production is reduced by as much as 50% by current levels of oxidants in the air
- Some agriculturist believe that ozone and oxidants account for 90% of lost forests, crops, and ornamentals to air pollution

Effects of SO_2 and NOx

- Directly toxic to plants
- Nitrate causes blue-baby syndrome
- Nitrates directly toxic to amphibians
- Irritate mucous membranes
- Stresses and even kills forests
- Especially high altitude forests, which are bathed in acidic clouds for extended periods.
- Affects mycorrhyzal association in roots
- And they contribute to acid rain

Effects of Acid Rain

- Acidified ground water leaches larger amounts of toxic metals
- Acidifies lakes, especially ones with low alkalinity
- Most fish stop reproducing successfully at pH 5
- Toxic metals are leached from rock and soil
- Bones dissolve; Gills destroyed
- $CaCO_3$ precipitation hindered
- Affects sensitive algae and invertebrates too
- Acid rain may be becoming more of a problem despite improved technology and cleaner fuels because the buffering capacity of the atmosphere has been depleted
- Half of the high altitude lakes in Adirondacks lack fish

ELA Study: Effects on Trout

A starving lake trout captured in acidified Lake 223 when the pH was 5.1.
Most of the trout's food supply had been killed off by the acid.

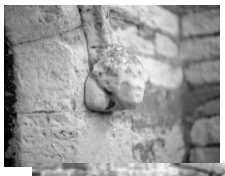
A healthy lake trout captured in recovering Lake 223 when the pH had risen back above 5.4.
Young white suckers were again plentiful in the lake, serving as food for the trout.

evidence so far:

- declining populations occur in areas w/ granitic soils (Rocky Mountain National Park/St. Vrain)
- growing populations where there is access to road salts (Georgetown)
- lambs die before 1 yo of white muscle disease
  - a common cause of this is micronutrient deficiency, particularly selenium
- St. Vrain sheep had very low levels of copper and selenium, especially a radio-collared one found within 6 hours of death
- populations recovering after their diet was supplemented with a mineral block containing micronutrients

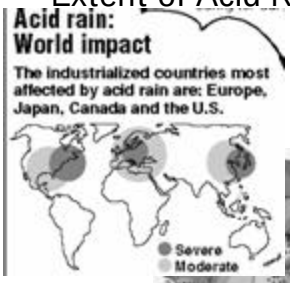
General Effects of Acid Rain

- Corrosion of limestone
  - cathedrals, gargoyles, statues
- $61 million in U.S.
  - acid-resistant paint on new vehicles
- Increasing incidence of lung diseases
  - cancer, bronchitis, emphysema, asthma



(Photo: Westfaliches Amt fur Denkmalpfledge)

Extent of Acid Rain Problems



A Lesser-known Air Pollutant: Fluoride

- Fluoride poisoning, or fluorosis, causes gross malformations of bones and teeth.
- Plants take up gaseous fluoride and store it in their tissues, and fluoride in particulate form is deposited on leaf surfaces and stays there until washed off.
- Herbivores are best known for exhibiting symptoms of fluoride poisoning.
- However, earthworms and other soil invertebrates also accumulate fluoride, which is, in turn, passed on to the animals that eat them. Therefore, fluorosis can be a problem for carnivores as well.