# Overview of Particulate Matter in California

**November 18, 2004**

Air Resources Board

California Environmental Protection Agency

# Outline of Presentation - Part 1

- Particulate matter primer
- Health impacts
- Exposure and toxicity considerations
- Future directions

# Particulate Matter Primer

# What is Particulate Matter?

***A complex mixture that may contain:***

Soot Smoke Metals

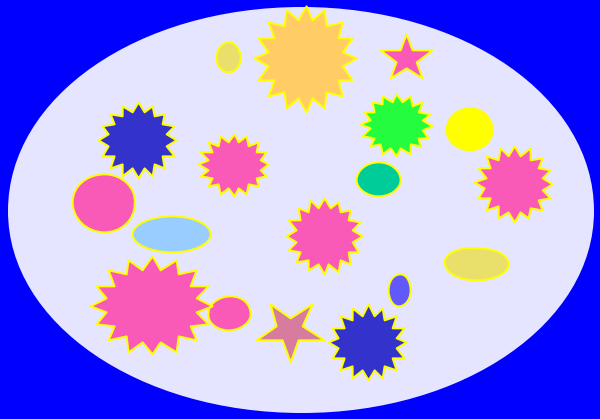
Elemental and Organic Carbon

Nitrates Sulfates Acids

Pollen Vegetation

Dust Water

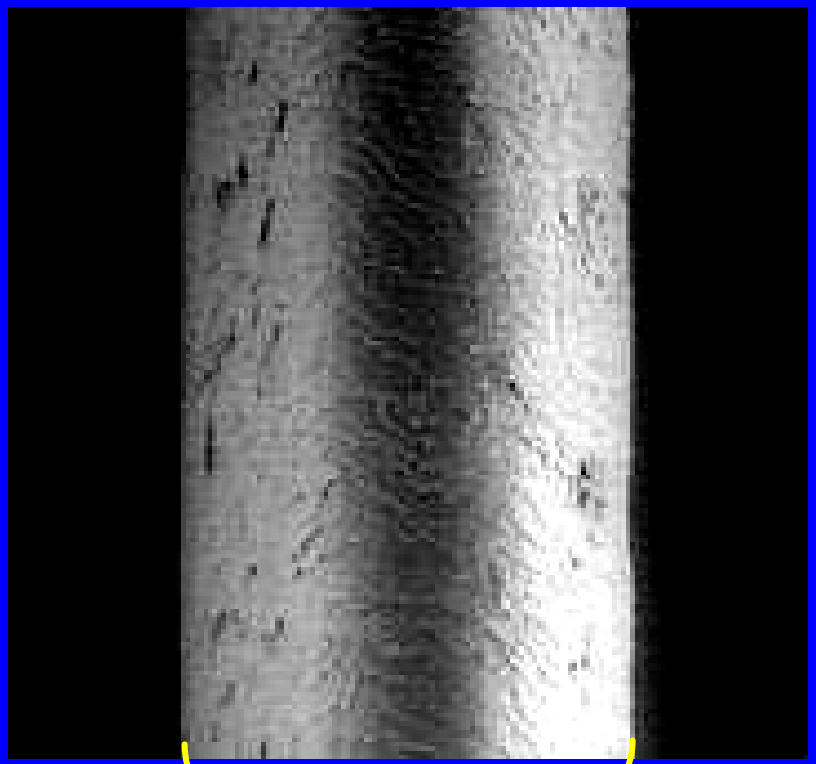
Tire Rubber



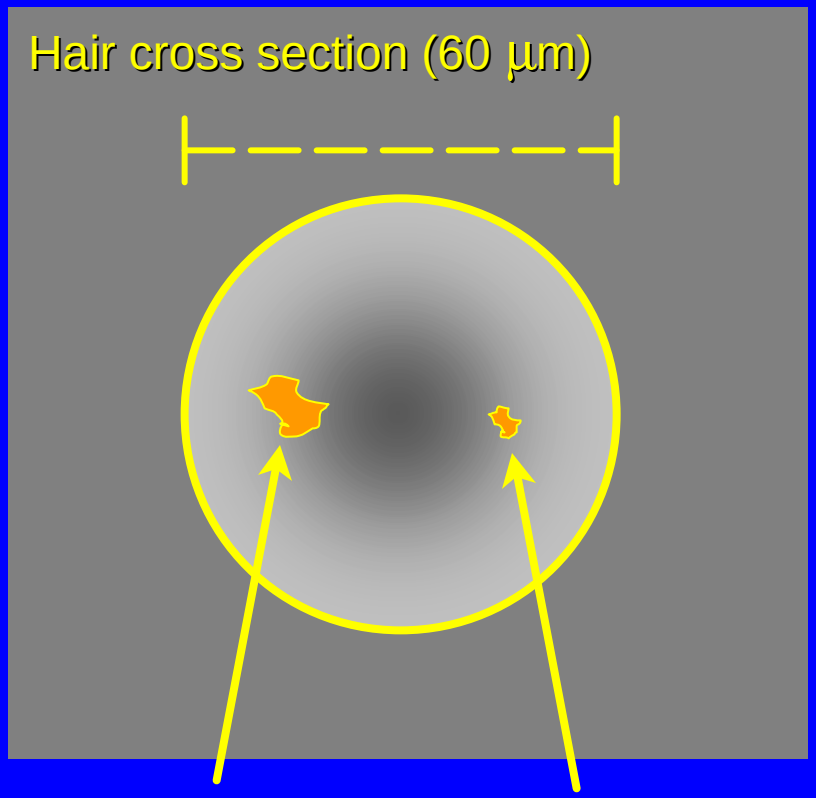
# Common Terms Used in Describing PM

- ***Origin***
  - Primary (directly emitted)
  - Secondary (formed in the atmosphere)
- ***Size Distribution***
  - Coarse (2.5 to 10 μm) (primary)
  - Fine (2.5 μm and less) (primary + secondary)
  - Ultrafine (0.1 μm and less) (primary + secondary)
- ***Measurement***
  - $PM_{10}$ (ultrafine + fine + coarse)
  - $PM_{2.5}$ (ultrafine + fine)
  - $PM_{10-2.5}$ (coarse)

# How Small is PM?



**Human Hair**
**(60 μm diameter)**



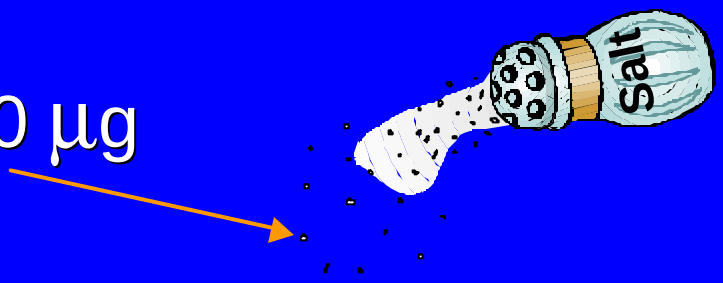

**$PM_{10}$**
**(10 μm)**

**$PM_{2.5}$**
**(2.5 μm)**

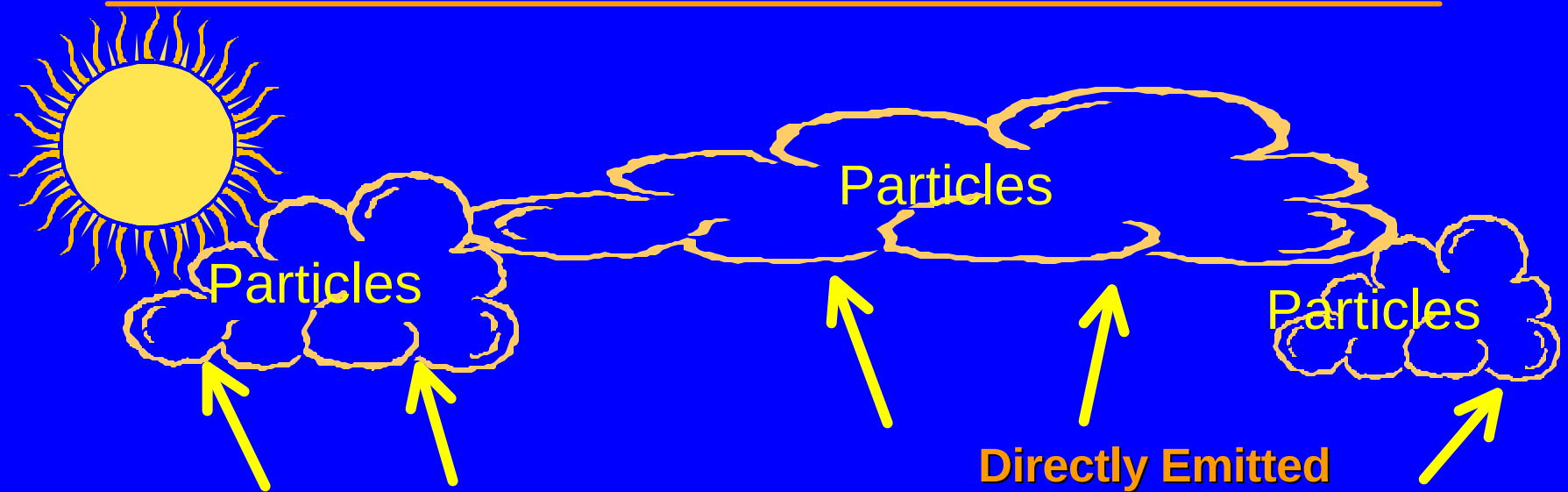
# Measurement of Particulate Matter

- Particles are captured onto a filter
- Mass of PM measured as micrograms per cubic meter ($\mu g/m^3$) of air

One grain = 60 µg



# Sources of Particles




**Gas-to-particle Conversion (Secondary PM)**

fuel combustion
livestock
sewage
biogenic hydrocarbons

**Directly Emitted (Primary PM)**

fuel combustion
mechanical abrasion
(brake wear, tire wear)
road dust (paved, dirt)
agricultural activities
fugitive dust
biological (pollen, fungi)
sea salt
meat cooking

# How is Secondary PM Formed?

***Photochemical Reactions in the Atmosphere***

Ozone Chemistry

$NO_X$ → Nitric acid

or Polluted Fog

Low T, High RH

Nitric acid ⇌ **Nitrate salts**

**ammonium nitrate - ammonia**
**sodium nitrate - sea salt**
**organic nitrate - organic gases**

High RH

$SO_2$ → **Sulfate salts** **ammonium sulfate - ammonia**

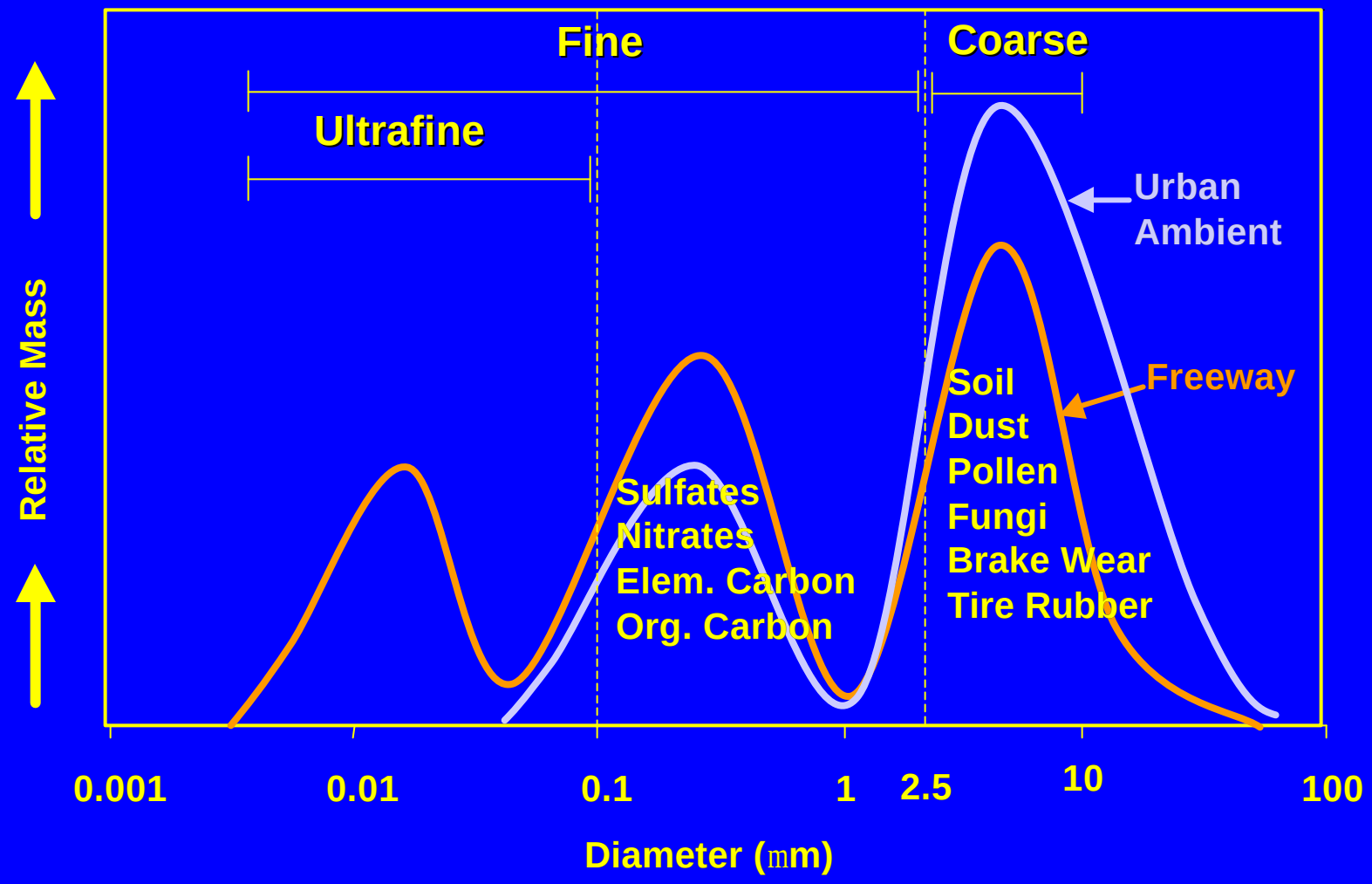
or Ozone Chemistry

Ozone Chemistry

**Organic gases** → **Condensible Organics**

**[aromatics (eg, PAHs), alkenes]**

# Distribution of Mass by Particle Size

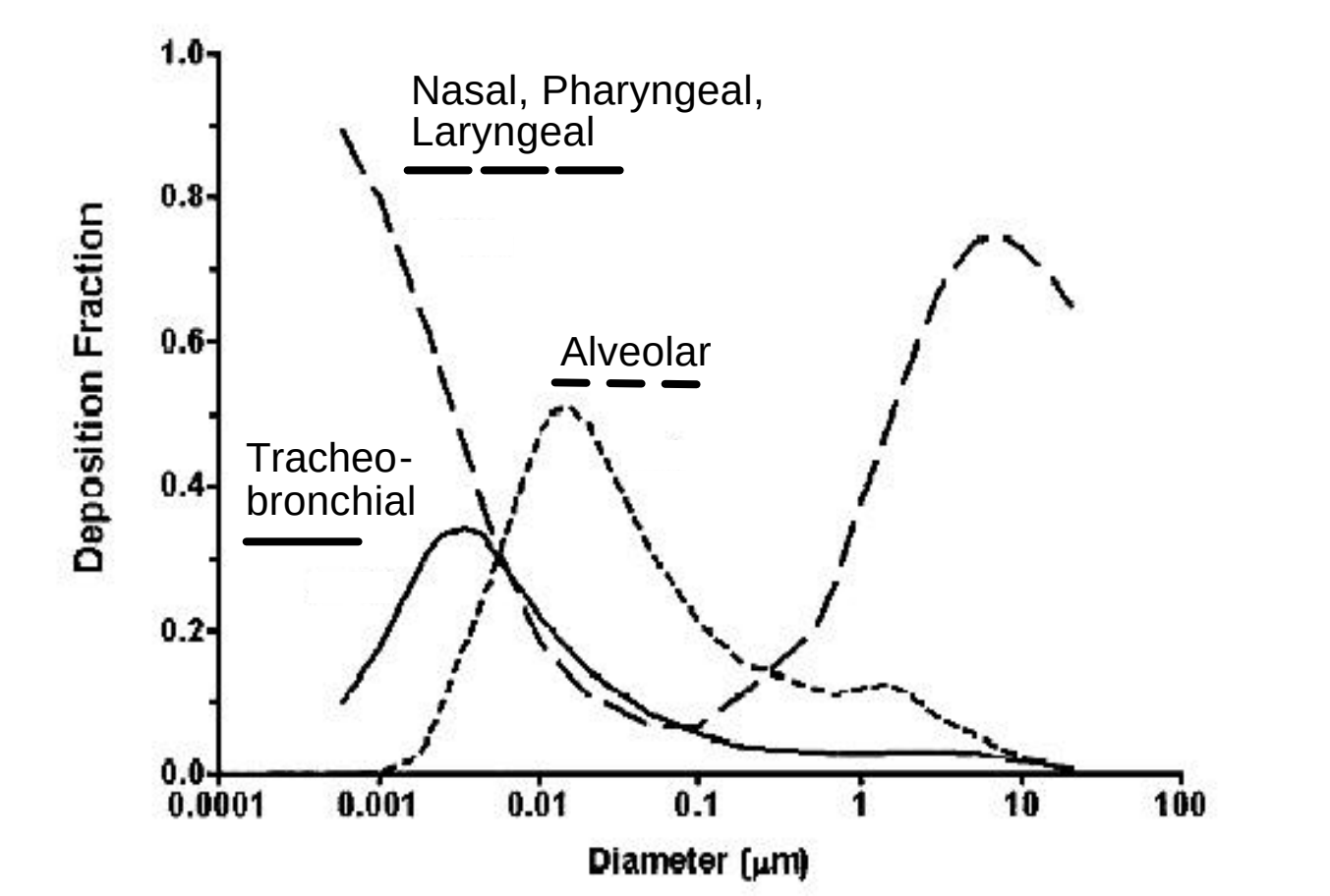


# Health Impacts:

**Particulate matter accounts for most of the serious health effects linked to ambient air pollution**

# Particle Size and Health

## *Respiratory Deposition as a Function of Particle Size*




Coarse PM is mostly deposited in upper respiratory track.
Ultrafine and Fine PM are deposited throughout the respiratory track.

# Types of Health Studies

## Epidemiologic Studies

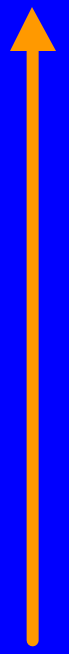
- Investigate responses in populations
- Types:
  - Time-series -- acute effects
  - Longitudinal -- long-term effects
  - Intervention -- effects of control programs

## Mechanistic Studies

- Investigate biological mechanisms or responses
- Types:
  - Cellular
  - Animals
  - Humans

# Vulnerable Populations

| Group | Type of Evidence | | Strength of Evidence |
|---|---|---|---|
| | Epidemiology | Mechanistic | |
| Elderly with heart/lung disease | yes | yes | |
| Asthmatics | yes | emerging | |
| Children | yes | emerging | |
| Infants | yes | emerging | |
| Neonates | yes | emerging | |
| Diabetics | yes | emerging | |



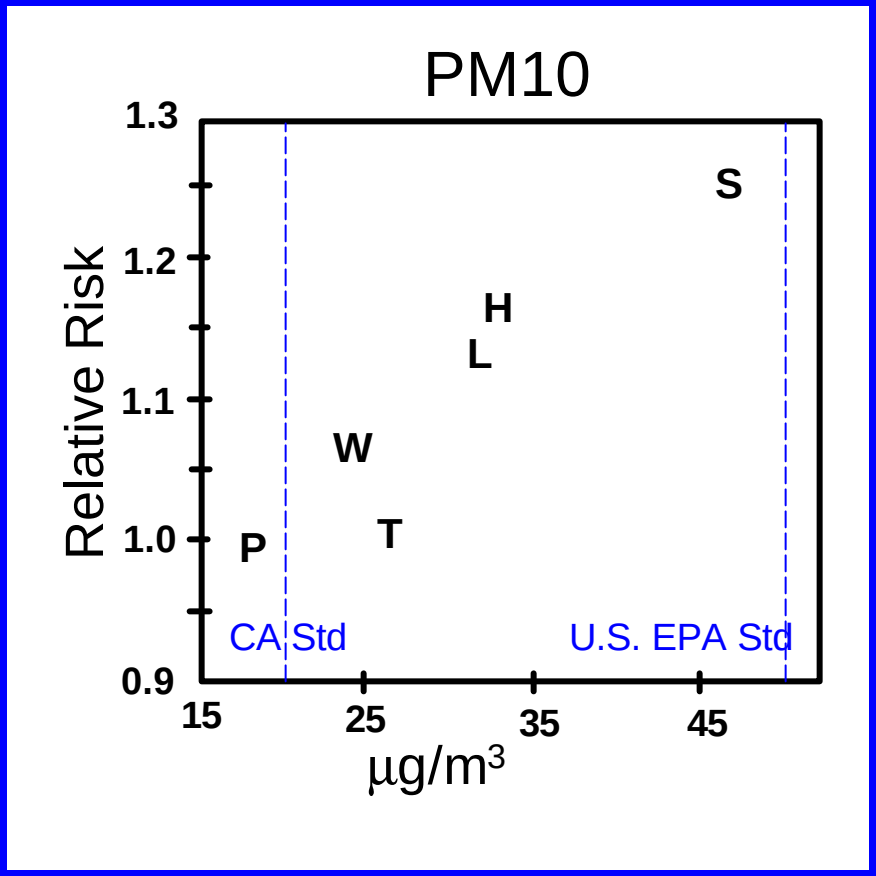
# Effects of Long-term Exposure to PM

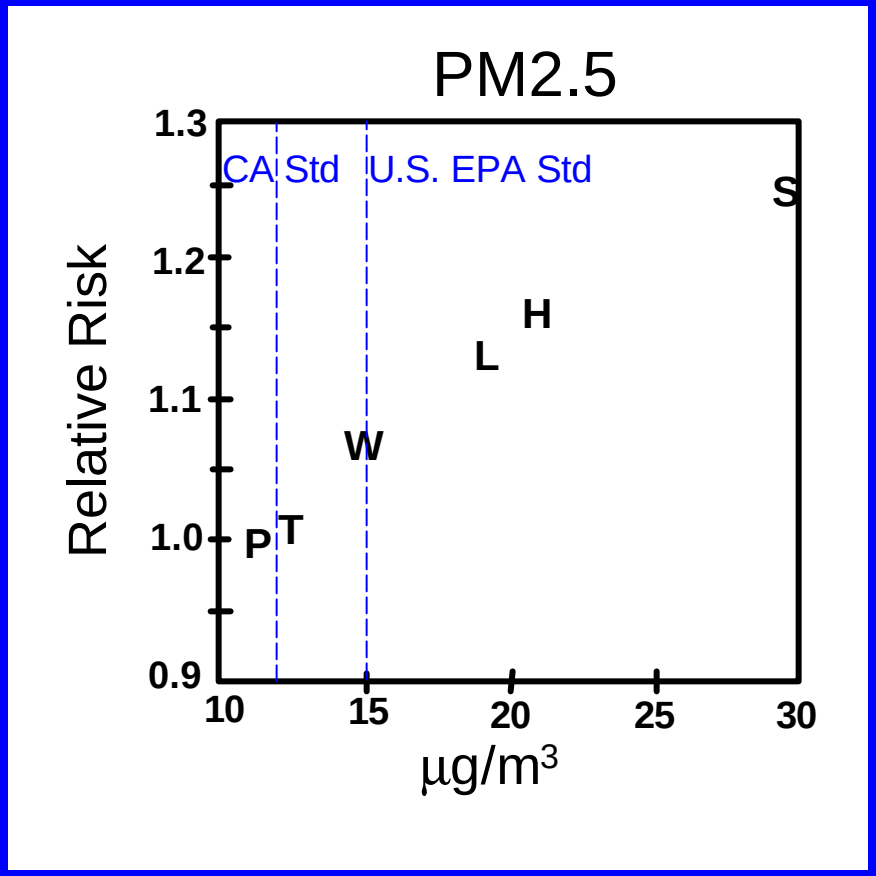
***Long-term $PM_{2.5}$, $PM_{10}$ and sulfate exposure is associated with death in older adults with cardiopulmonary disease***

- **American Cancer Society study (Pope et al., 1995, 2002)**
  - Over 550,000 adults from 151 U.S. cities
  - Followed for 16 years
  - 1.5 year average loss in life expectancy between least and most polluted cities (14 years per premature death)
  - Increased risk of lung cancer mortality
- **Harvard Six-Cities study (Dockery et al., 1993)**
  - Over 8000 adults
  - Followed for 14 to 16 years

# Mortality Risk and Long-term PM

## *Harvard Six-Cities Study*

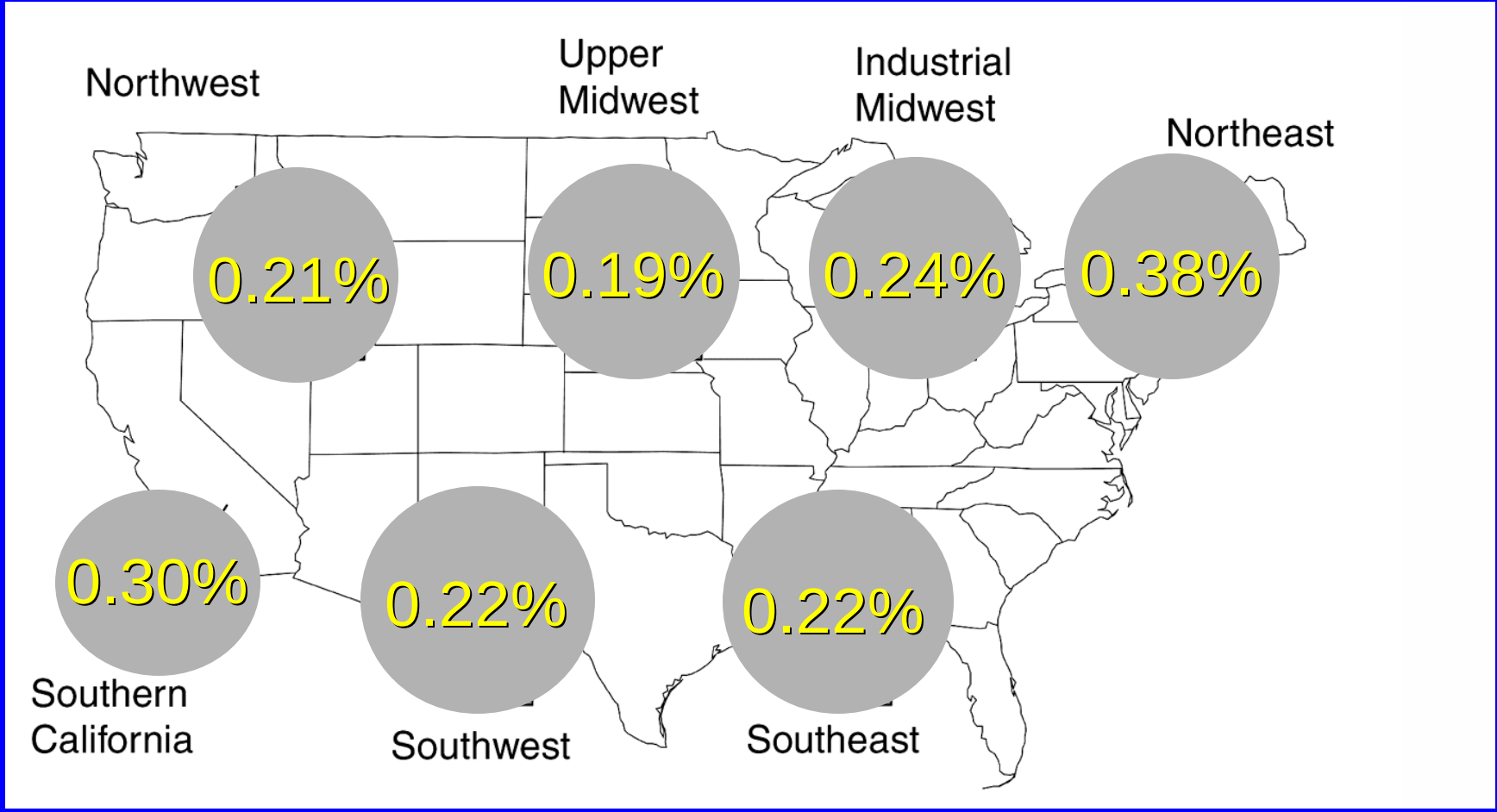



From Dockery et al., 1993

# Death Risk and Short-term PM

Percent Increase in death per 10 µg/m$^3$ PM10
(90 cities, results for day after PM10 event)

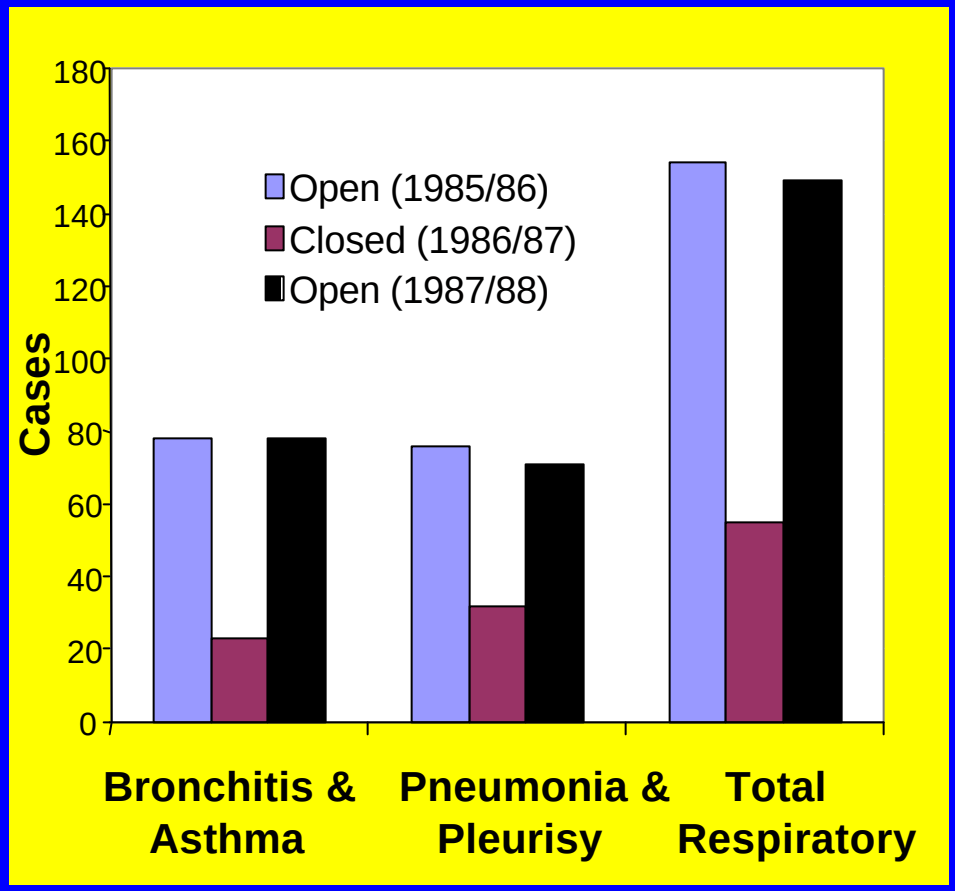



European studies out to 40 days find 2-4 times the death rate.
Analysis of 20 largest cities found no threshold for death from PM10.

# Health Benefits of PM Control

## *Intervention Studies*

**Winter Hospital Admissions for Children**




**Utah Valley Steel Mill Closure**

***Other Interventions***

- CHS relocation (improved lung function growth)
- Dublin coal ban
- Erfurt, Germany reunification
- Hong Kong sulfur reduction

***Ongoing***

- Los Angeles (1980-2000)

***An Opportunity?***

- Diesel retrofits

# Ambient Air Quality Standards
## ($\mu g/m^3$)

| | | Annual | 24-Hour |
|---|---|---|---|
| **California** | $PM_{10}$ | 20 | 50 |
| | $PM_{2.5}$ | 12 | -- |
| **National (current)** | $PM_{10}$ | 50 | 150 |
| | $PM_{2.5}$ | 15 | 65 |
| **National (under review)** | $PM_{10-2.5}$ | 13-30 | 30-75 |
| | $PM_{2.5}$ | 12-15 | 30-50 |

# Selected Examples of Health Benefits from Attaining State PM Standards

***Meeting the California annual standards estimated to prevent, per year, about:***

- 6,500 deaths
- 3,100 cardiovascular and 2,900 respiratory hospitalizations (over 65)
- 1,000 asthma hospitalizations (under 65)
- 389,000 incidences of lower respiratory symptoms (ages 7-14)
- 2,800,000 million lost work days
- Others (ER visits, asthma exacerbation)

Based on 18.5 (PM2.5) and 33.1 (PM10) $\mu g/m^3$ population-weighted annual-average exposure in 2000.

# Adverse Health Effects from Diesel PM Exposure

***(annual number of cases)***

| | |
|---|---|
| Lung Cancer (TAC) | 270 (95% upper limit) |
| Mortality ($PM_{2.5}$) | 2000<br>(or 3000 95% upper limit) |

Based on 1.8 µg/$m^3$ population-weighted annual-average exposure in 2000.
Lung cancer has a 90% mortality rate.

**Particle exposure and toxicity considerations are a logical way to prioritize emission reductions**

# Controlling Ambient Air Impacts: Mass vs. Health

- Current control programs assess emissions reductions
  - "A ton is a ton"
- For health impacts need to consider
  - Human exposure
  - Toxicity of particles

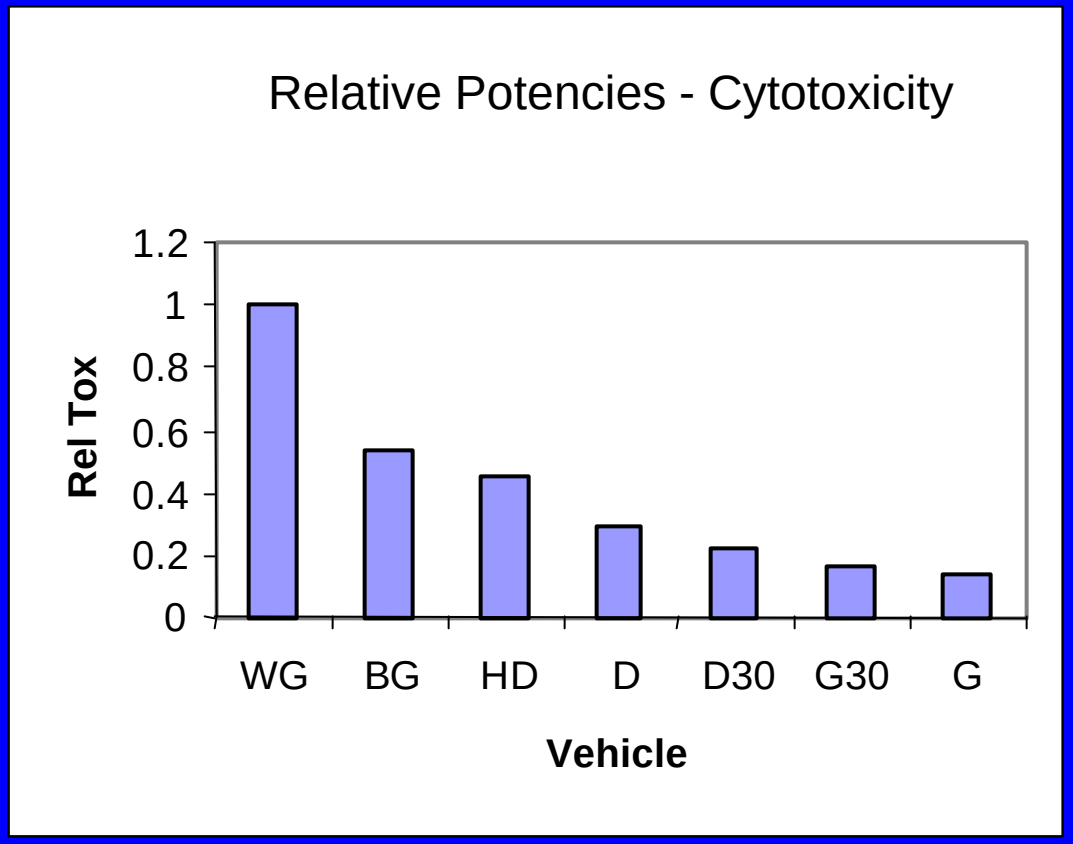
# Exposure

- Total exposure for a population depends on:
  - Total mass emitted
  - Size of particles
  - Meteorology/dilution
  - Proximity effects
  - Population density
  - Ventilation rates
- Exposure impact can vary by 100-fold

# PM Toxicity

- PM toxicity can vary
- Measured as toxic effect per PM mass
- Determined from human, animal, and cell culture studies
- Different animals, protocols makes comparisons difficult

# Diesel and Gasoline Potency




**WG** = White smoke emitter, gasoline (n=1)

**BG** = Black smoke emitter, gasoline (n=1)

**HD** = Diesel black smoke emitter (n=1)

**D** = Diesel (n=3)

30 = tested at 30 deg F

**G**= gasoline (n=5)

Adapted from Seagrave et al. (2002)

# What's on the Horizon?

# Air Pollution Research Directions

- Toxicity ranking of PM sources
  - ARB - traffic, wood smoke
  - HEI/USEPA - systematic protocols
  - HEI - Advanced Collaborative Emissions Study
- Mechanisms of PM toxicity
  - NIEHS/USEPA - neonates, diabetics
  - ARB - ultrafine PM

# Ultrafine PM in Ambient Air

- Definition -- PM up to 0.1 μm
- Sources
  - Diesel- and gasoline-powered vehicles
  - Meat cooking and wood/biomass combustion
  - Secondary formation from heavy hydrocarbons
- High levels near sources
- Health findings
  - May be associated with death and disease
  - Pass into the circulatory system
  - Induce cellular damage

# Health Effects Summary

- PM responsible for most of the serious health effects known from exposure to ambient air pollutants
- Annual-average standards most important to attain
  - U.S. EPA standards not health-protective
- Exposure and toxicity of particles appear to vary
- Future research includes health effects of ultrafine particles