

# Overview of Particulate Matter in California

November 18, 2004



Air Resources Board

# Outline of Presentation - Part 1

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

A yellow L-shaped graphic consisting of a vertical line on the left and a horizontal line at the bottom, intersecting at the origin.

# Particulate Matter Primer

# What is Particulate Matter?

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*A complex mixture that may contain:*

Soot      Smoke      Metals

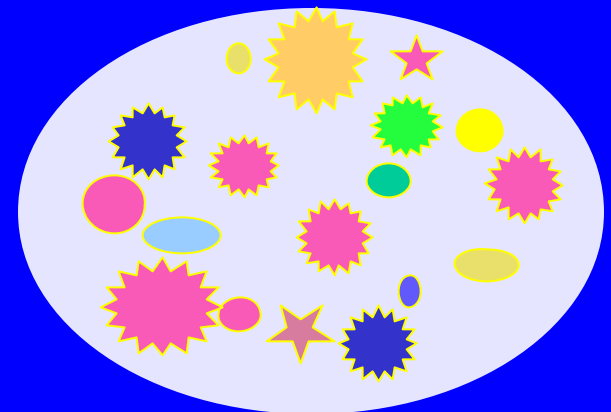
Elemental and Organic Carbon

Nitrates      Sulfates      Acids

Pollen      Vegetation

Dust      Water

Tire Rubber



# Common Terms Used in Describing PM

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- **Origin**

- Primary (directly emitted)
- Secondary (formed in the atmosphere)

- **Size Distribution**

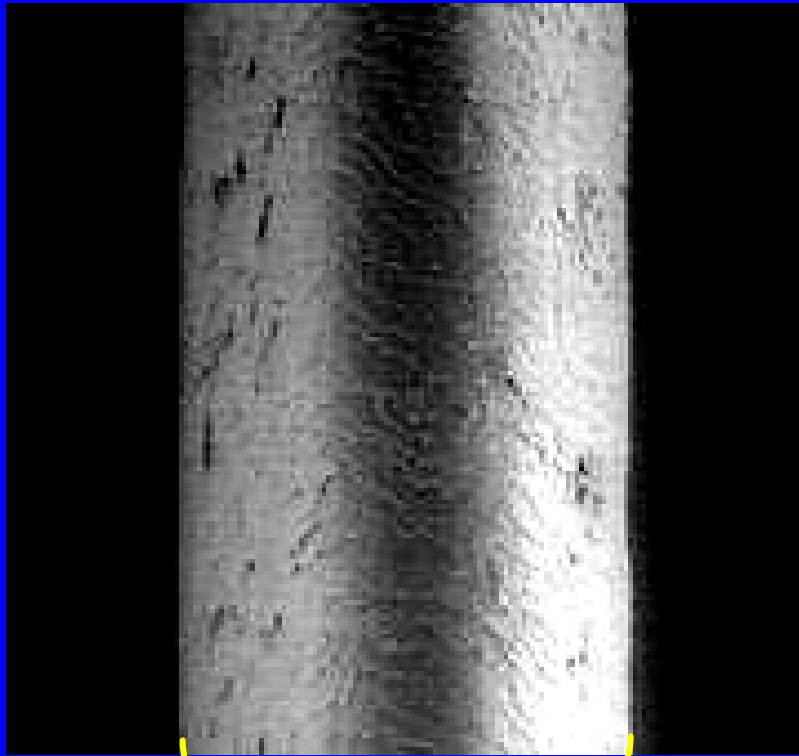
- Coarse (2.5 to 10  $\mu\text{m}$ ) (primary)
- Fine (2.5  $\mu\text{m}$  and less) (primary + secondary)
- Ultrafine (0.1  $\mu\text{m}$  and less) (primary + secondary)

- **Measurement**

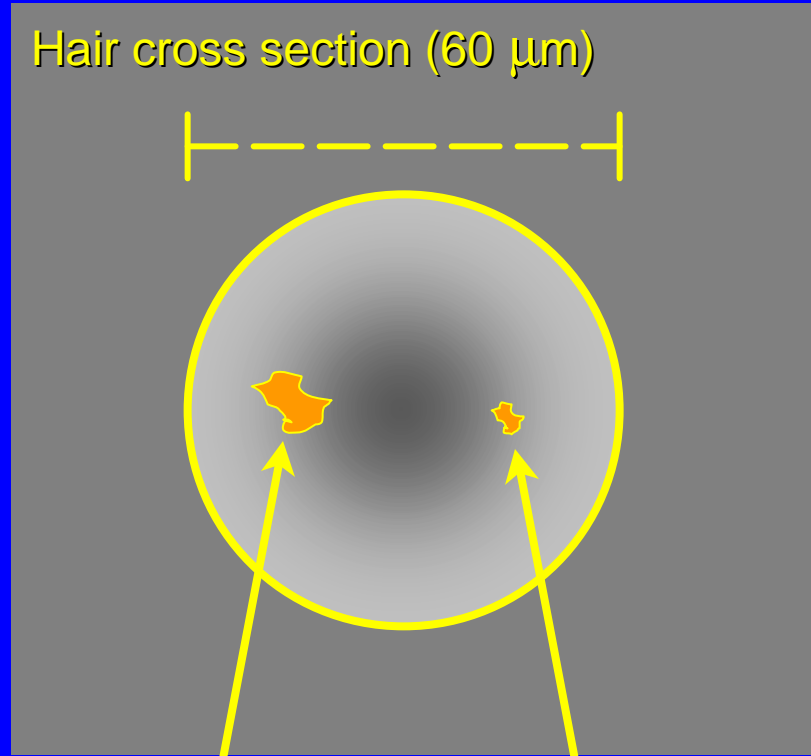
- $\text{PM}_{10}$  (ultrafine + fine + coarse)
- $\text{PM}_{2.5}$  (ultrafine + fine)
- $\text{PM}_{10-2.5}$  (coarse)

# How Small is PM?

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**Human Hair**  
(60  $\mu\text{m}$  diameter)



**PM<sub>10</sub>**  
(10  $\mu\text{m}$ )

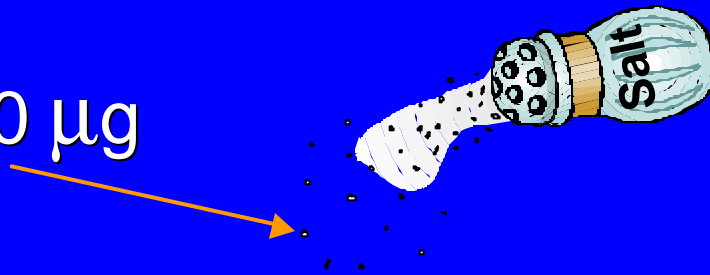
**PM<sub>2.5</sub>**  
(2.5  $\mu\text{m}$ )

# Measurement of Particulate Matter

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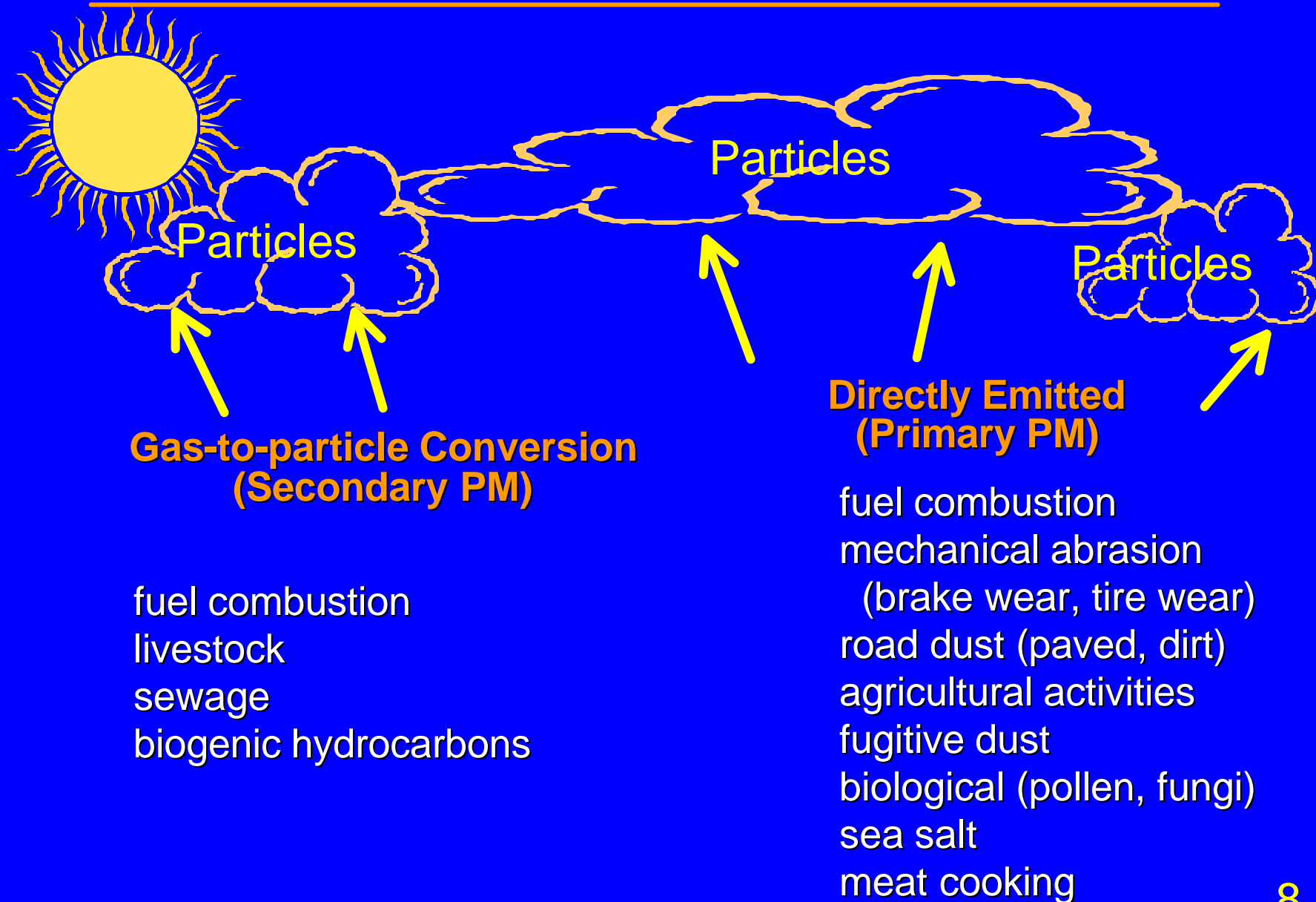
- Particles are captured onto a filter
- Mass of PM measured as micrograms per cubic meter ( $\mu\text{g}/\text{m}^3$ ) of air

One grain = 60  $\mu\text{g}$



# Sources of Particles

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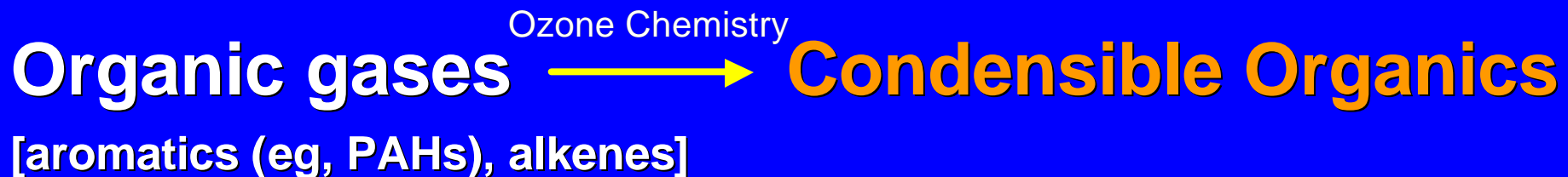
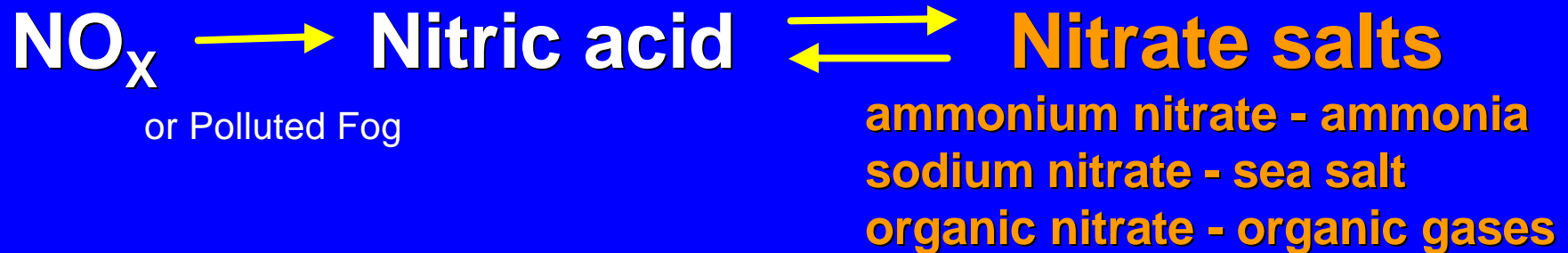
# How is Secondary PM Formed?

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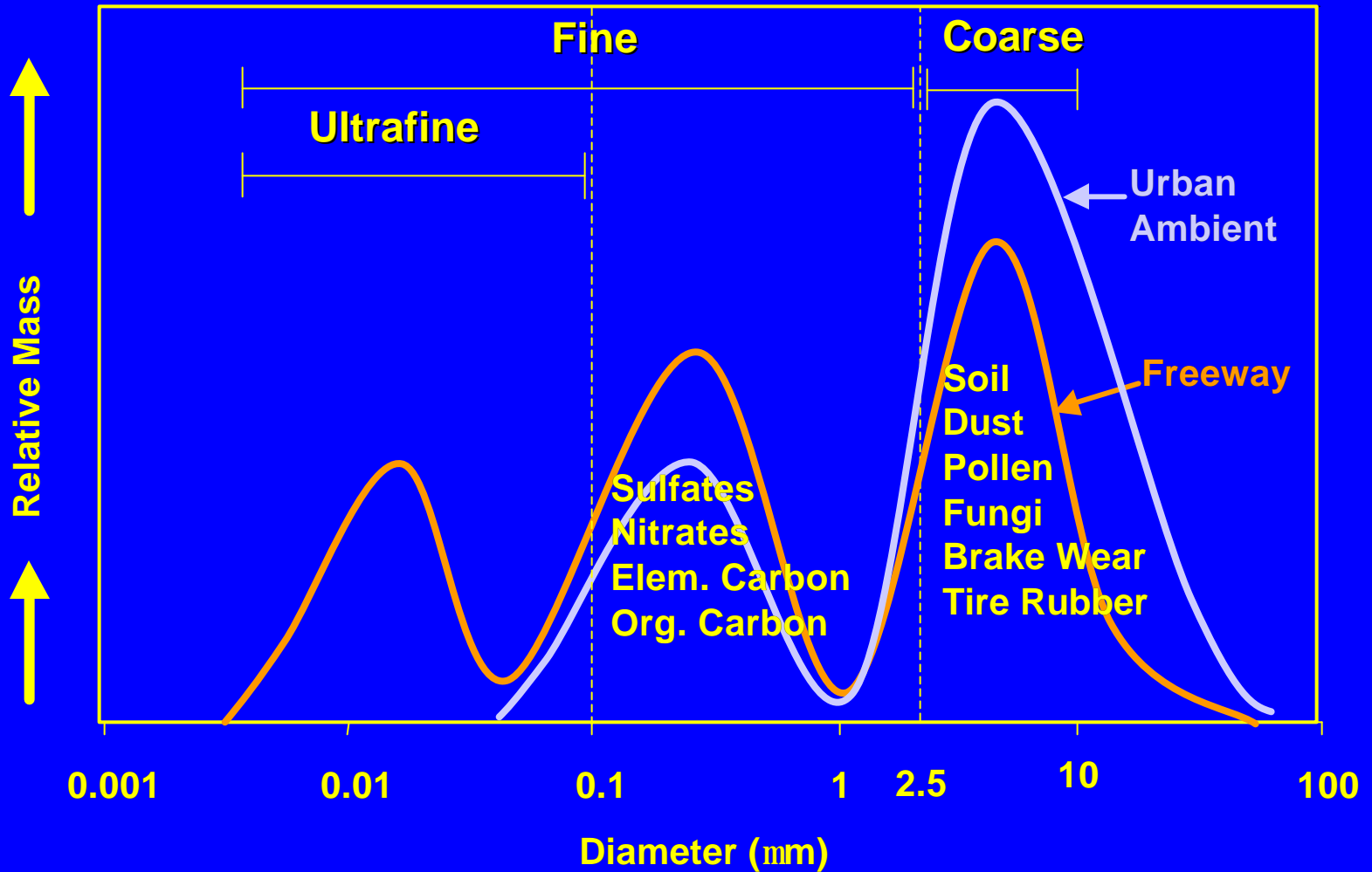
## *Photochemical Reactions in the Atmosphere*

Ozone Chemistry

Low T, High RH



# Distribution of Mass by Particle Size





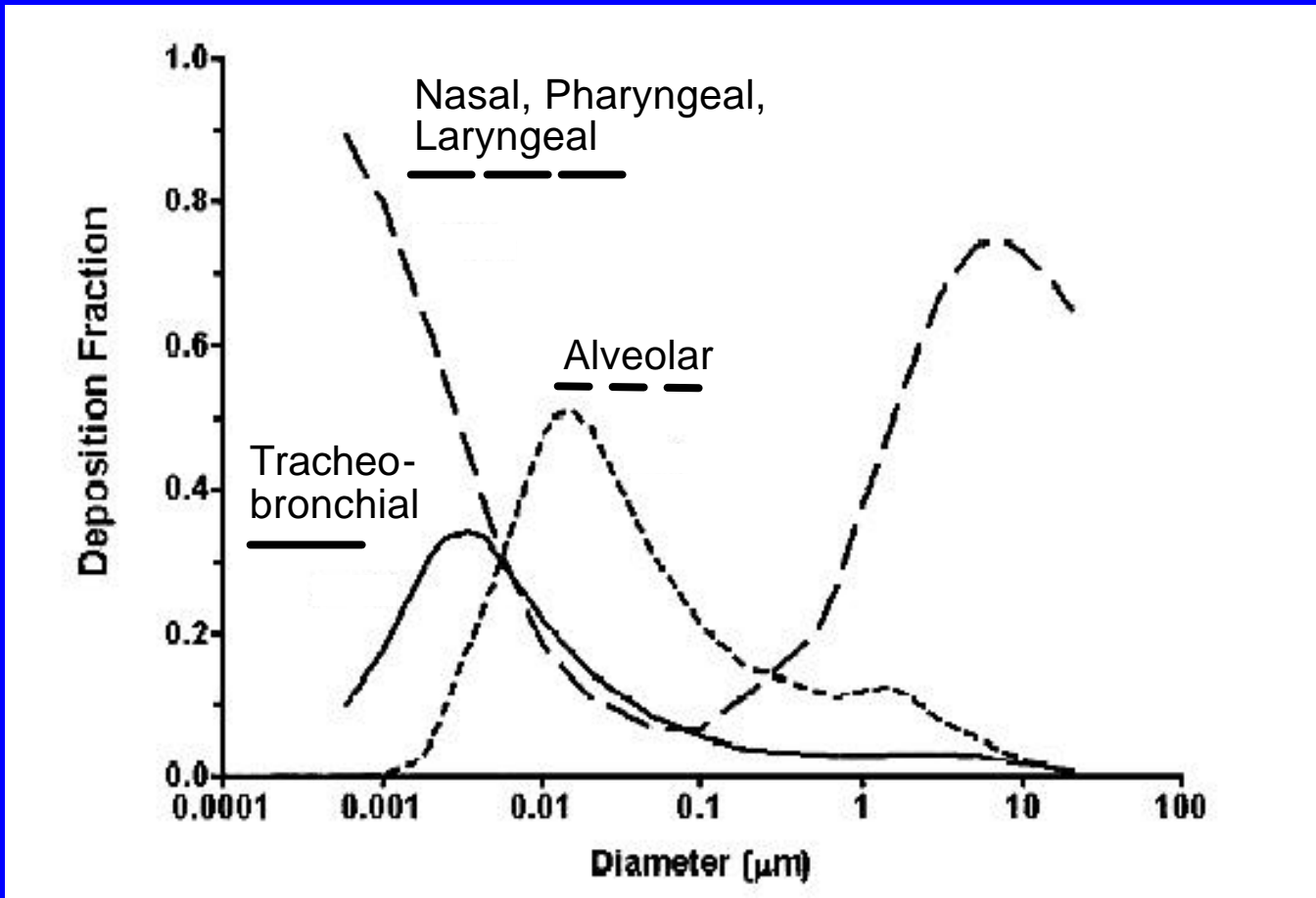
# **Health Impacts:**

**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*

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Coarse PM is mostly deposited in upper respiratory track.

Ultrafine and Fine PM are deposited throughout the respiratory track. 12

# Types of Health Studies

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## 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

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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

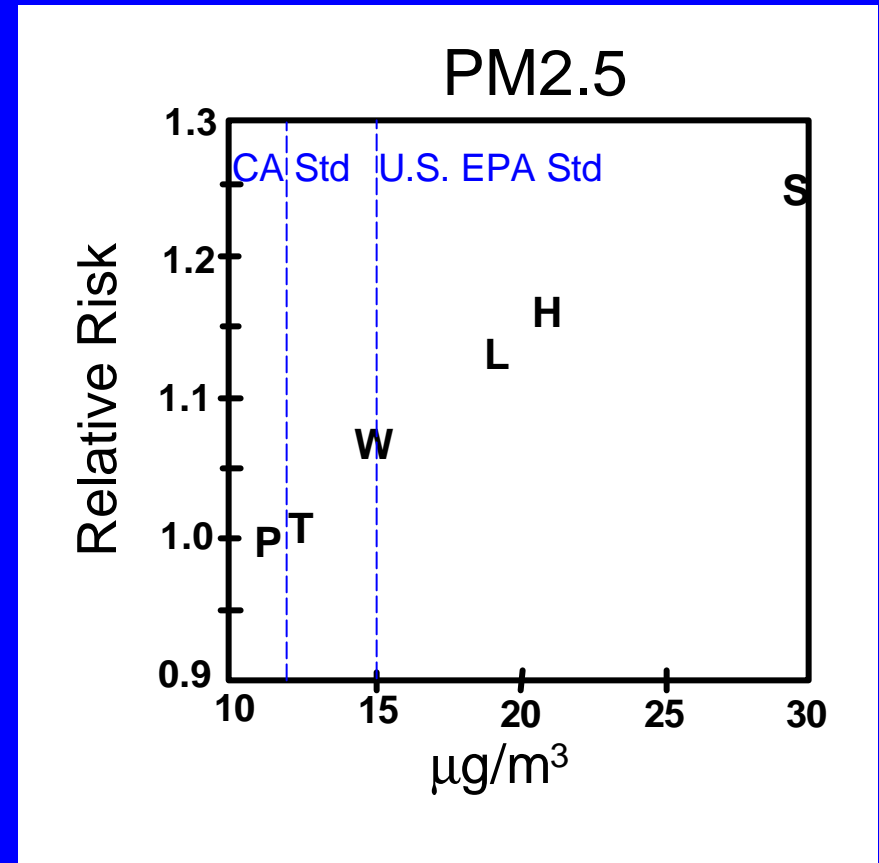
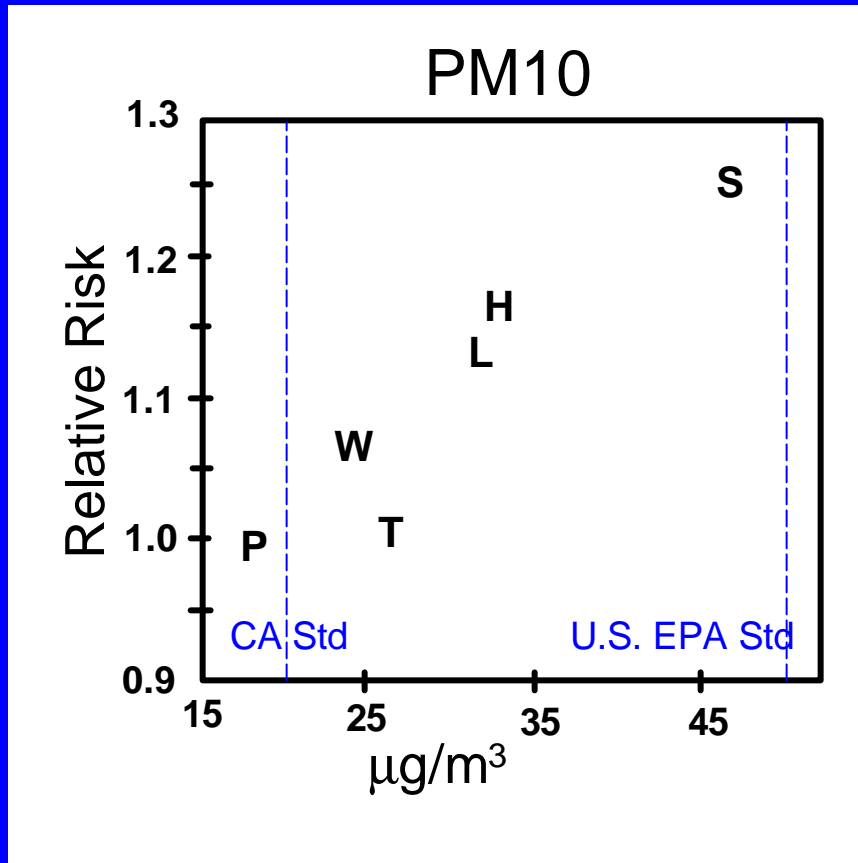
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*Long-term PM<sub>2.5</sub>, PM<sub>10</sub> and sulfate exposure is associated with death in older adults with cardiopulmonary disease*

- **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

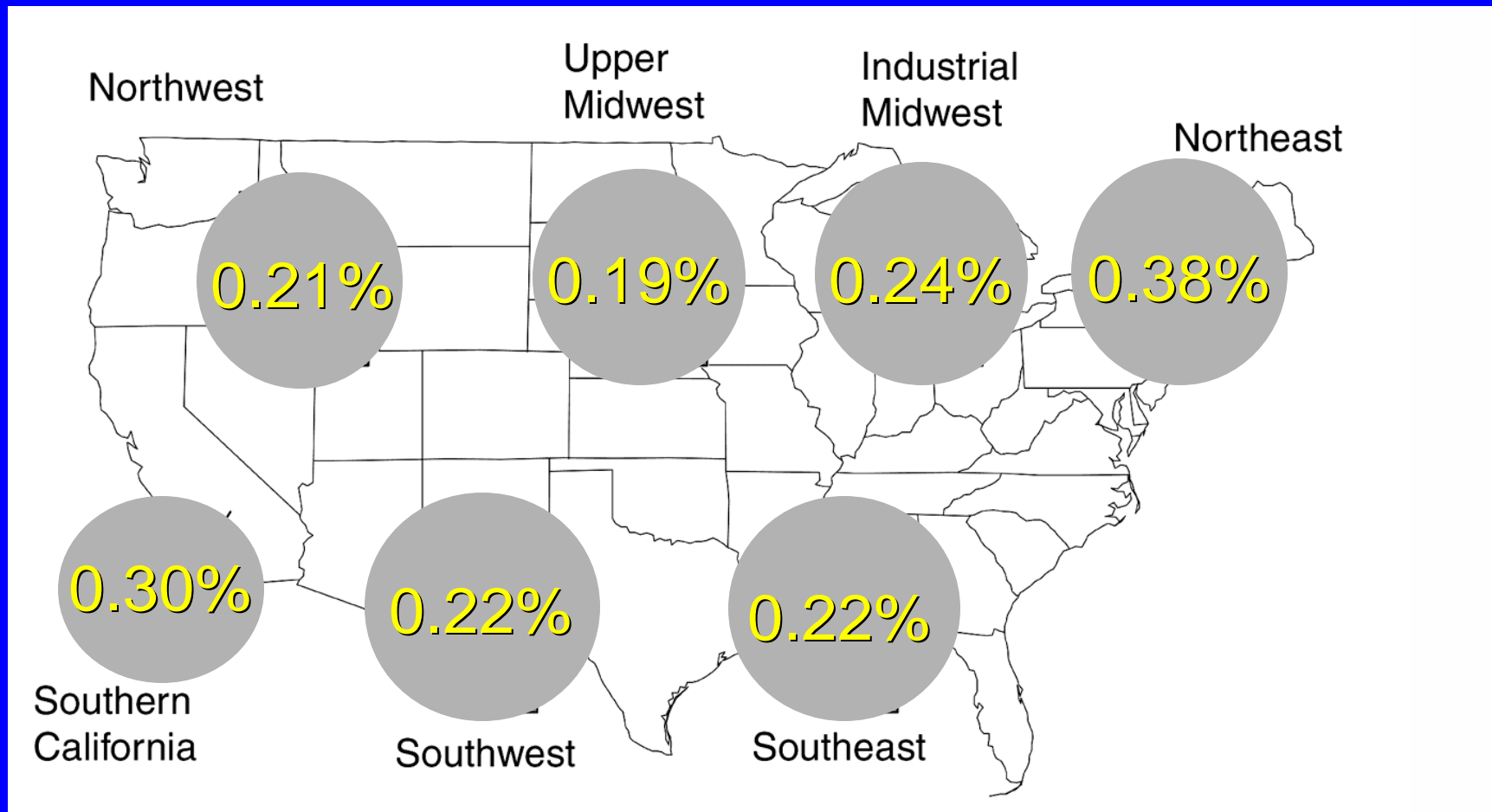


From Dockery et al., 1993



# Death Risk and Short-term PM

Percent Increase in death per 10  $\mu\text{g}/\text{m}^3$  PM10  
(90 cities, results for day after PM10 event)

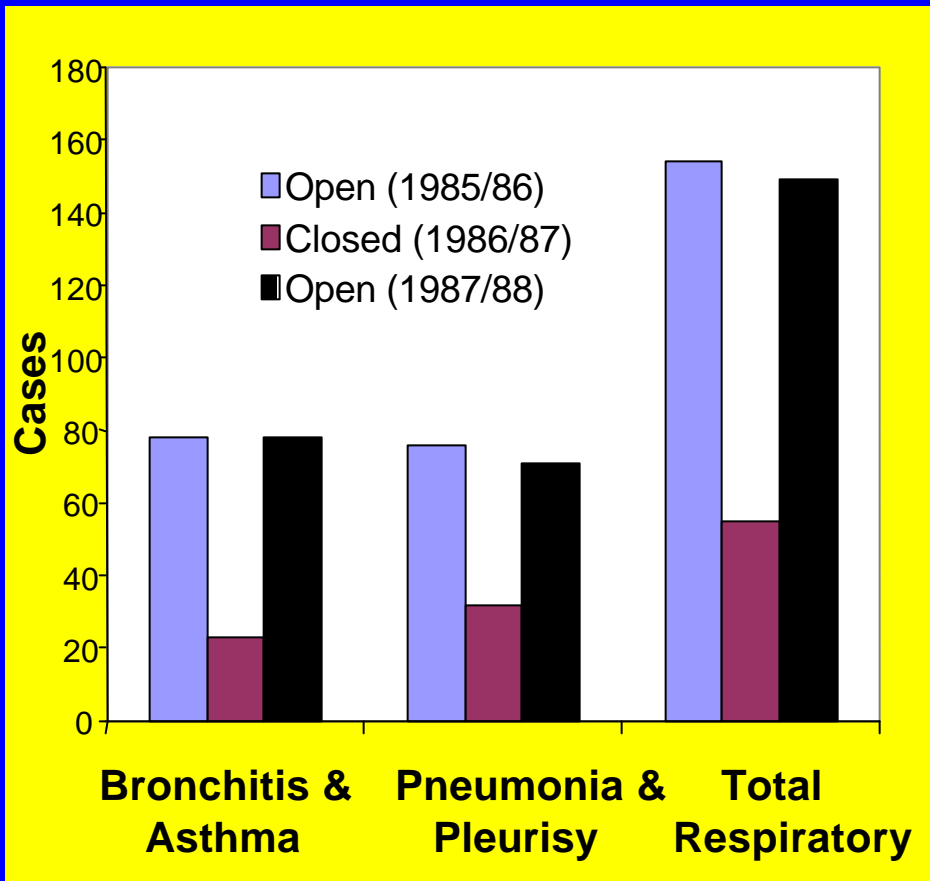


European studies out to 40 days find 2-4 times the death rate.

Analysis of 20 largest cities found no threshold for death from PM10. 17

# 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 (*mg/m<sup>3</sup>*)

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		<b>Annual</b>	<b>24-Hour</b>
<b>California</b>	PM <sub>10</sub>	20	50
	PM <sub>2.5</sub>	12	--
<b>National (current)</b>	PM <sub>10</sub>	50	150
	PM <sub>2.5</sub>	15	65
<b>National (under review)</b>	PM <sub>10-2.5</sub>	13-30	30-75
	PM <sub>2.5</sub>	12-15	30-50

# Selected Examples of Health Benefits from Attaining State PM Standards

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*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 (PM<sub>2.5</sub>) and 33.1 (PM<sub>10</sub>)  $\mu\text{g}/\text{m}^3$  population-weighted annual-average exposure in 2000.

# Adverse Health Effects from Diesel PM Exposure

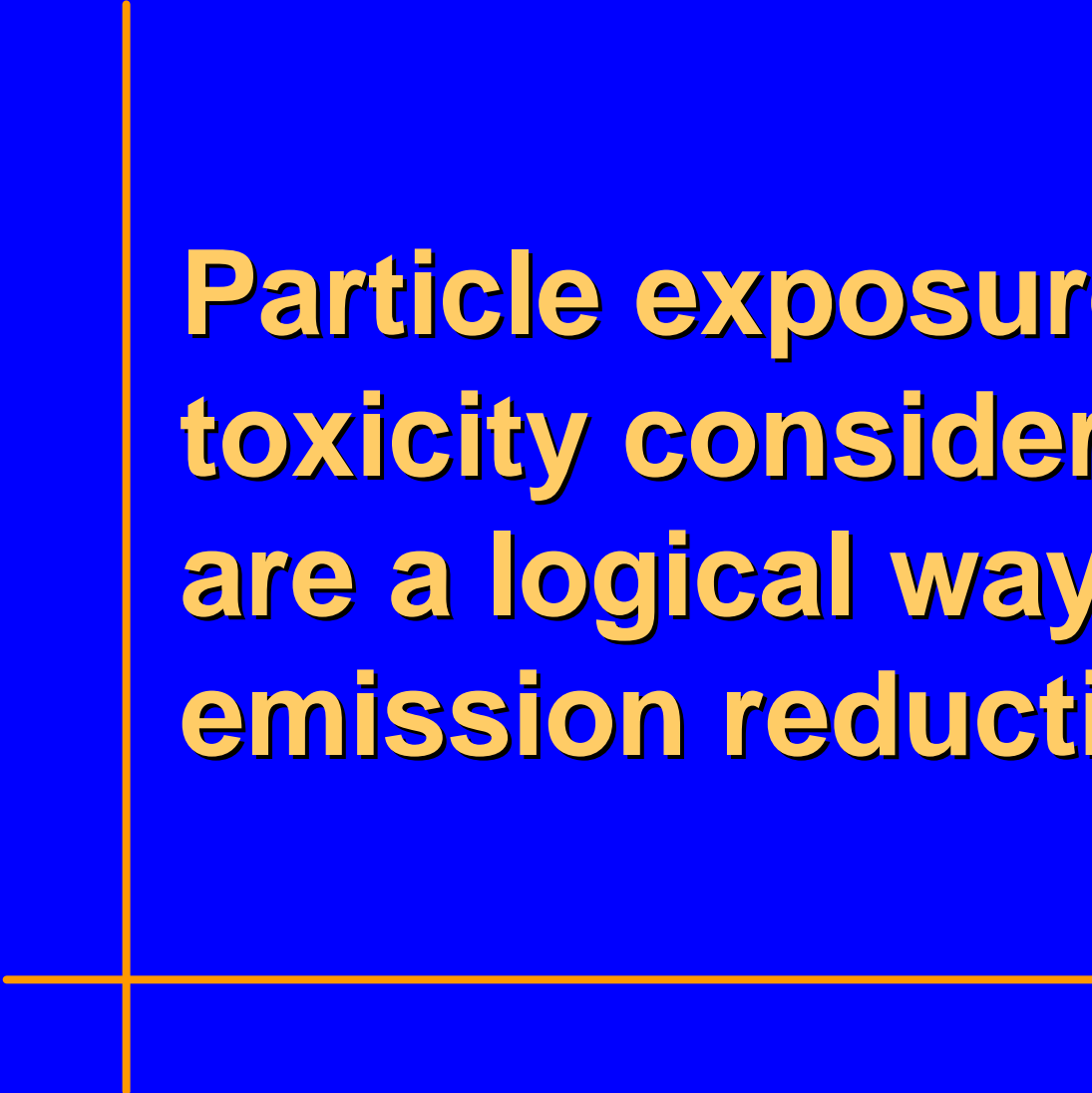
*(annual number of cases)*

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Lung Cancer (TAC)	270 (95% upper limit)
Mortality (PM <sub>2.5</sub> )	2000 (or 3000 95% upper limit)

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

A yellow L-shaped graphic element consisting of a vertical line on the left and a horizontal line at the bottom, intersecting at the origin of the text.

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

# Controlling Ambient Air Impacts: Mass vs. Health

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

# Exposure

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- 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

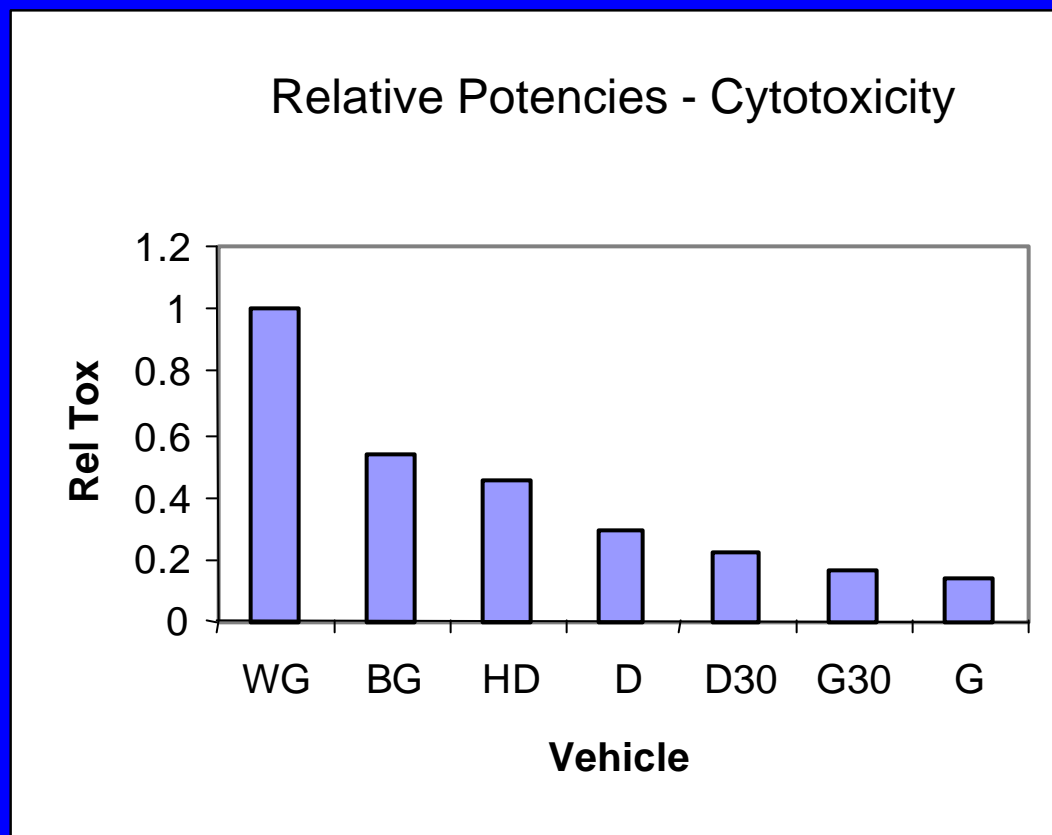


# PM Toxicity

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- 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

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- 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

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- Definition -- PM up to 0.1  $\mu\text{m}$
- 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

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- 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