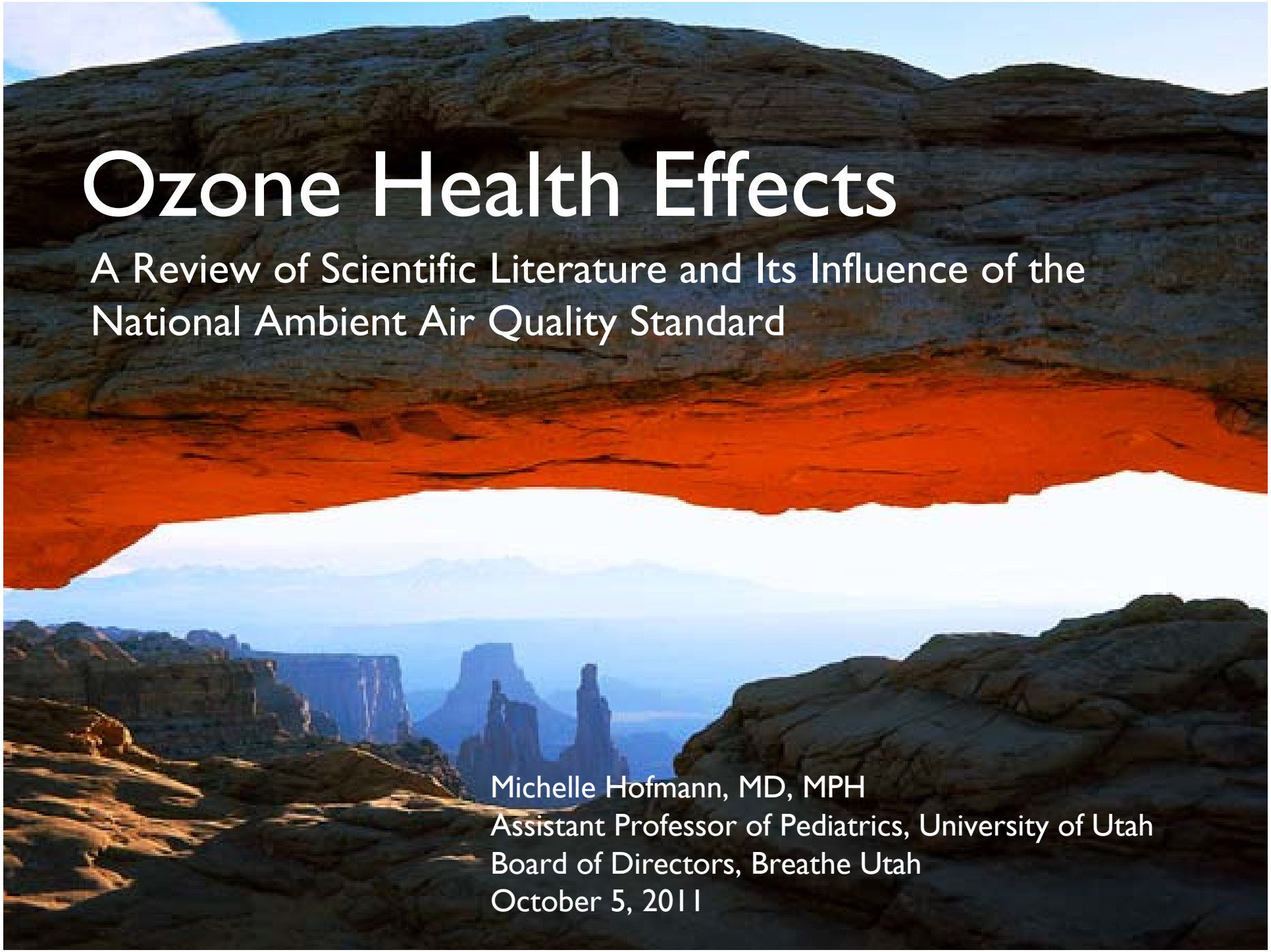

# Ozone Health Effects

## A Review of Scientific Literature and Its Influence of the National Ambient Air Quality Standard

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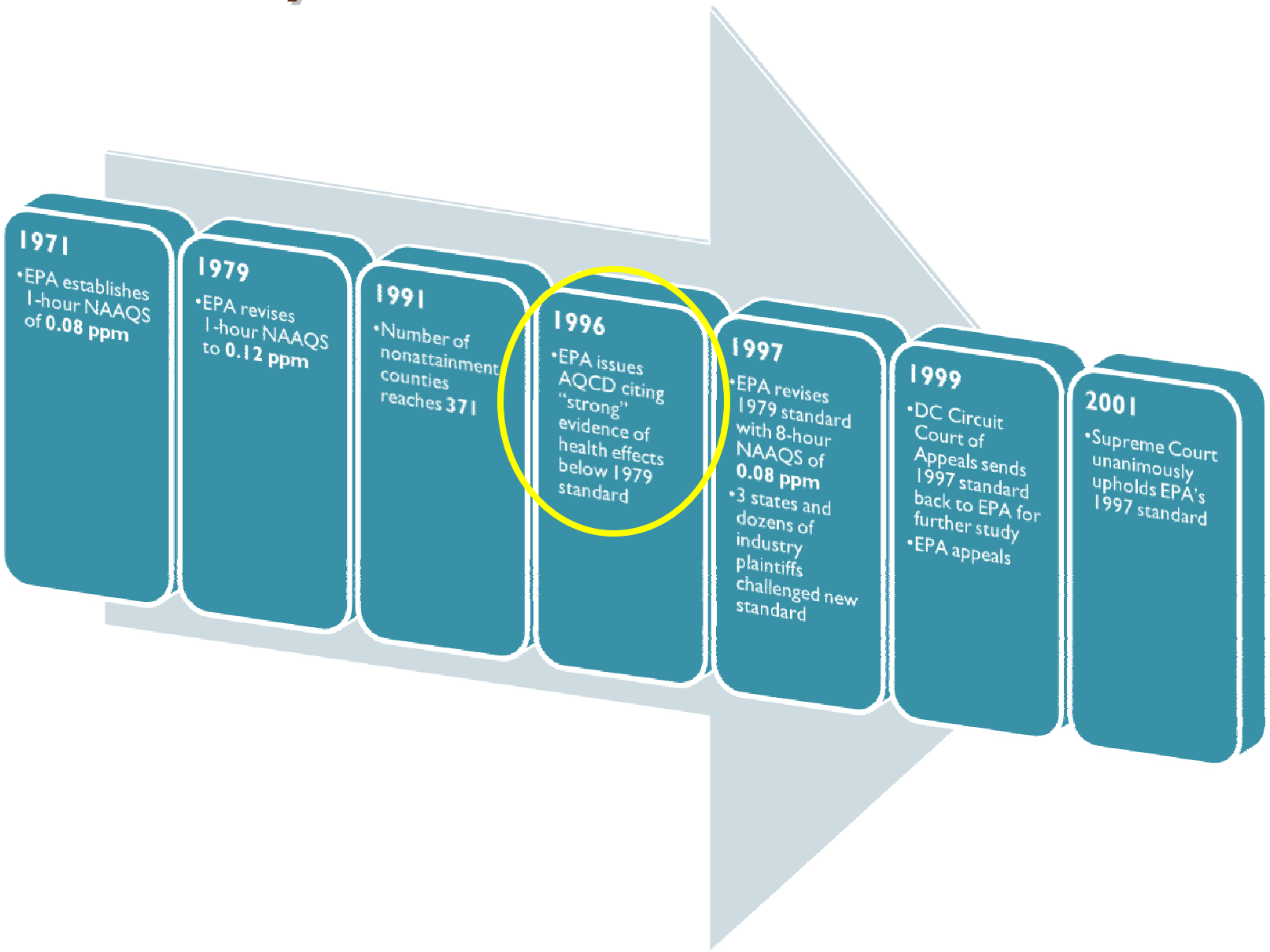
Assistant Professor of Pediatrics, University of Utah
Board of Directors, Breathe Utah
October 5, 2011

# History of the Ozone NAAQS



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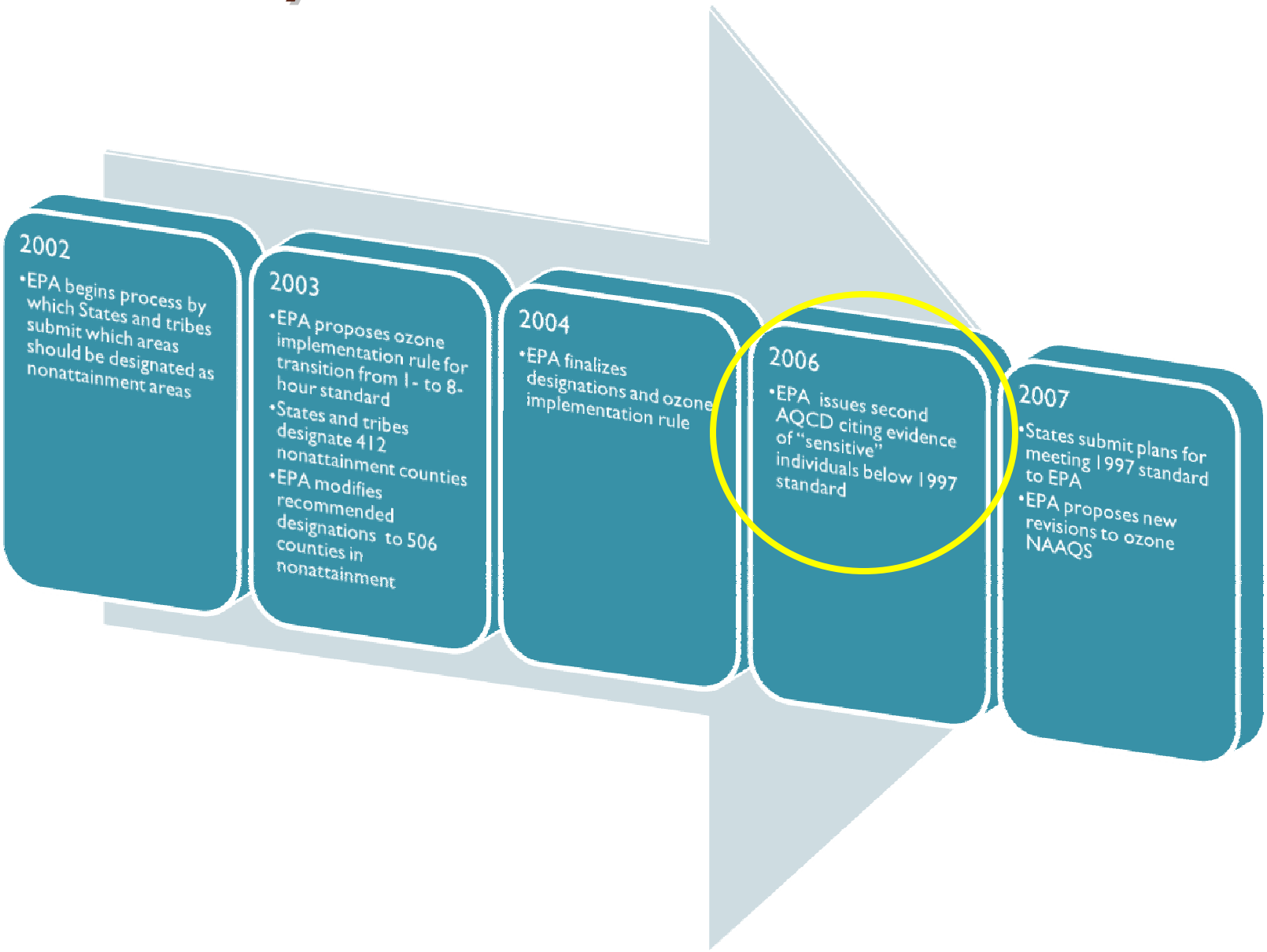

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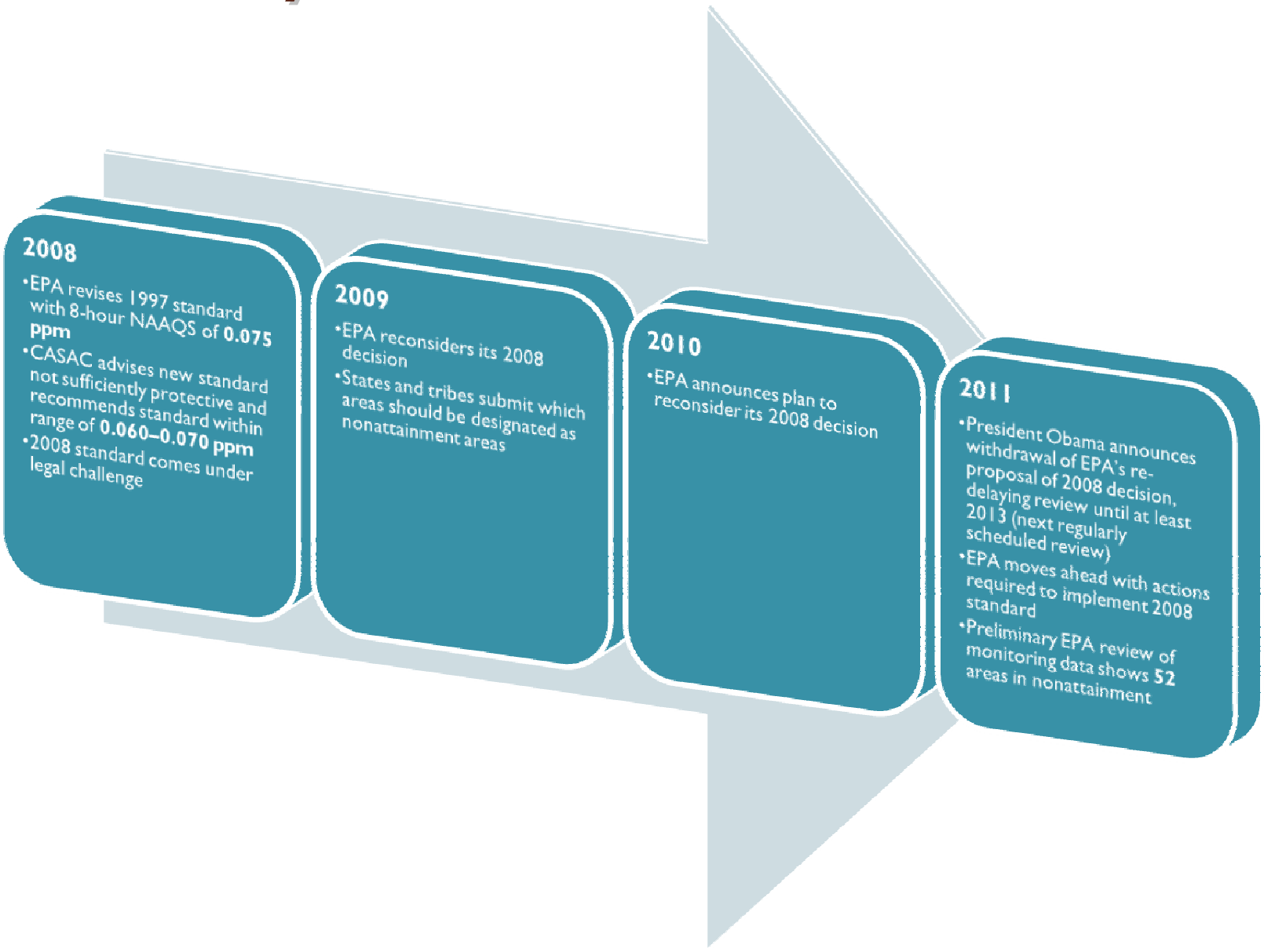
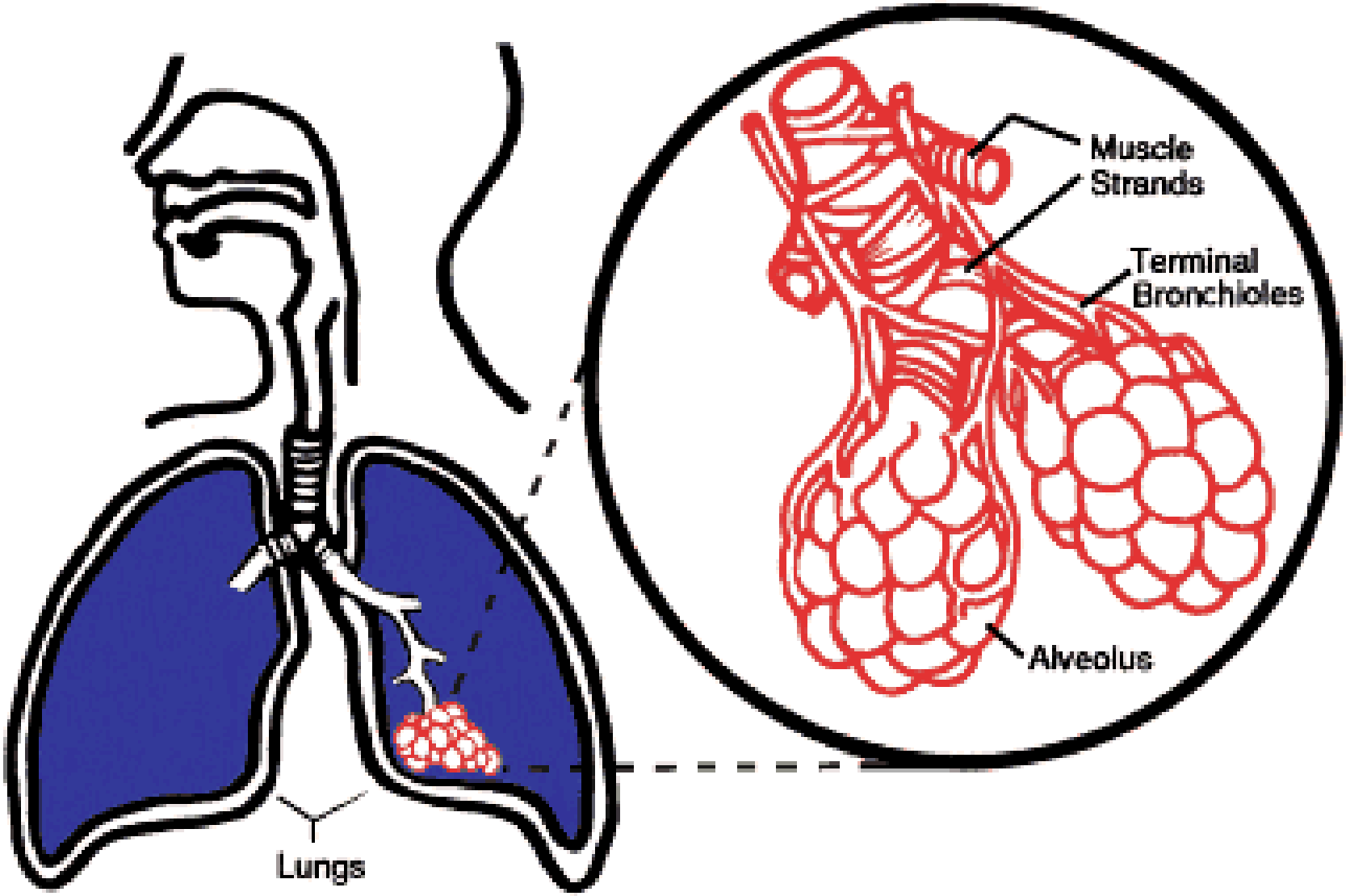


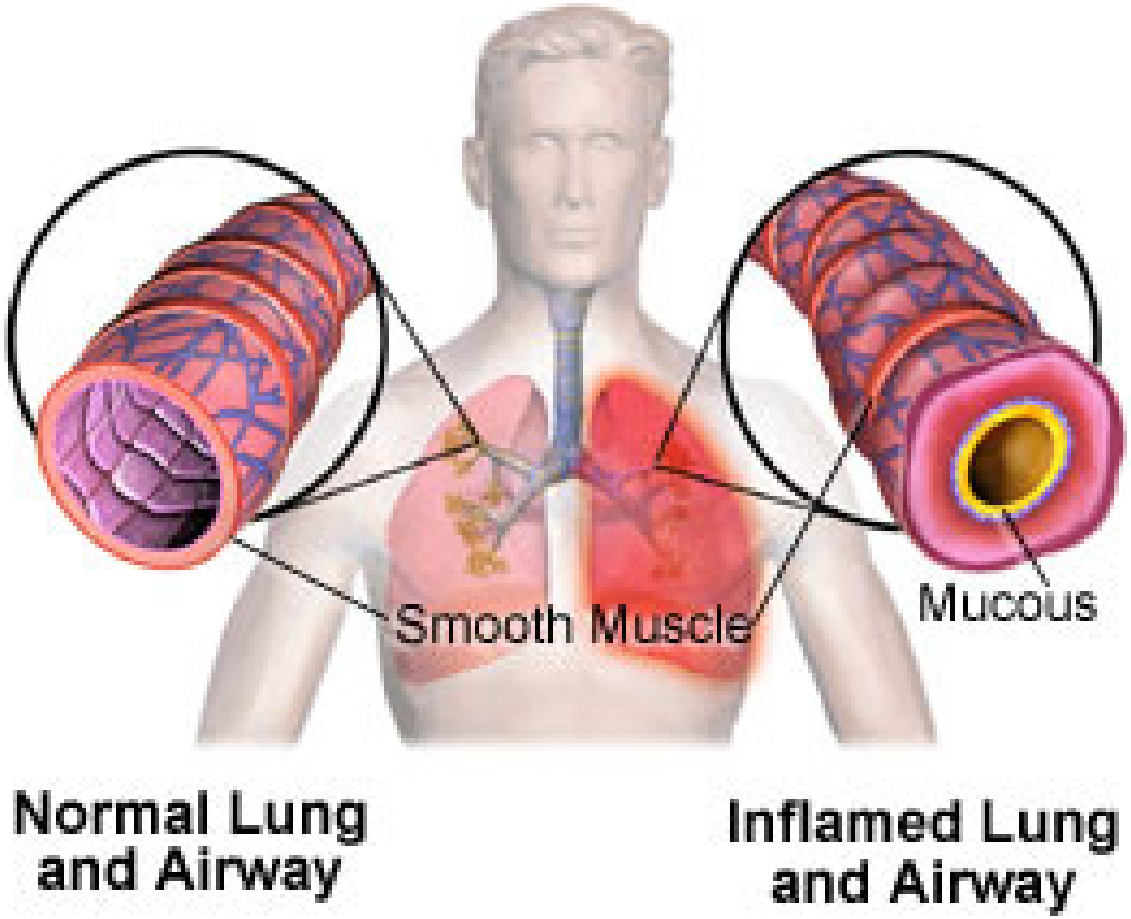
# Ozone Background

- Reactive gas – "Category 1 gas"
- Acute effects – Respiratory irritant
- Chronic effects – Associated with accumulated effects of repeated acute insults

# How are People Exposed to Ozone?



# Ozone causes **inflammation** of the lungs and respiratory airways



# What symptoms does ozone cause?

- Eye, nose and throat irritation
- Coughing or chest tightness
- Difficulty breathing or wheezing
- Increased allergy symptoms
- Increased asthma symptoms

# Types of Studies about Ozone

## Experimental (Animal or Human Chamber)

- Strengths
  - Exposures are controlled
  - Sources of variation minimized
  - Strong evidence of causality
    - Prospective
- Limitations
  - (Usually) Very high dose
  - (Usually) Not humans
  - Restrictive exposure conditions

## Epidemiological (Field/Panel or Population-Based)

- Strengths
  - Direct evidence of human effects
- Limitations
  - Exposures complex and changing
  - Exposures to many chemicals
  - Hard to control for confounders
  - Shows correlation not cause
    - Retrospective
  - Conclusions require weight-of-evidence judgments based on entire body of evidence

# Human Chamber Studies

- Observed effects at near-ambient concentrations for one to several hours
  - Spirometry effects (e.g., ↓ FEV1)
  - Bronchoconstriction
  - Airway hyperresponsiveness
  - Lung inflammation
  - Airway cell damage
  - Shallow/rapid breathing pattern
  - Airway irritation with cough/pain on inspiration

# Summary of Ozone-Induced Respiratory Health Effects from Chamber Studies

| Health Effect | Exercise Level | Prolonged Exposure | Short-term Exposure | Lowest Ozone Effect Level |
|---|---|---|---|---|
| Pulmonary Function Decrements | Moderate | 6.6 hr | | 0.06 ppm |
| | Moderate | 6.6 hr | | 0.08 ppm |
| | Moderate | 4.6 hr | | 0.10 ppm |
| | Moderate | 3.0 hr | | 0.12 ppm |
| | Competitive | | 1 hr | 0.12-0.14 ppm |
| | Very Heavy | | 1-3 hr | 0.16 ppm |
| | Heavy | | 1-3 hr | 0.18 ppm |
| | Moderate | | 1-3 hr | 0.30 ppm |
| | Light | | 1-3 hr | 0.37 ppm |
| | At rest | | 1-3 hr | 0.50 ppm |
| Increased Respiratory Symptoms | Moderate | 6.6 hr | | 0.06 ppm |
| | Moderate | 6.6 hr | | 0.08 ppm |
| | Very Heavy | | 1-3 hr | 0.12 ppm |
| Airway Responsiveness | Moderate | 6.6 hr | | 0.08 ppm |
| | Very Heavy | | 1-3 hr | 0.18 ppm |
| | At rest | | 1-3 hr | 0.40 ppm |
| Respiratory Inflammation | Moderate | 6.6 hr | | 0.08 ppm |
| | Very Heavy | | 1-3 hr | 0.20 ppm |
| Changes in Host Defenses | Moderate | 6.6 hr | | 0.08 ppm |
| Decreased Exercise Performance | Competitive | | 1 hr | 0.18 ppm |

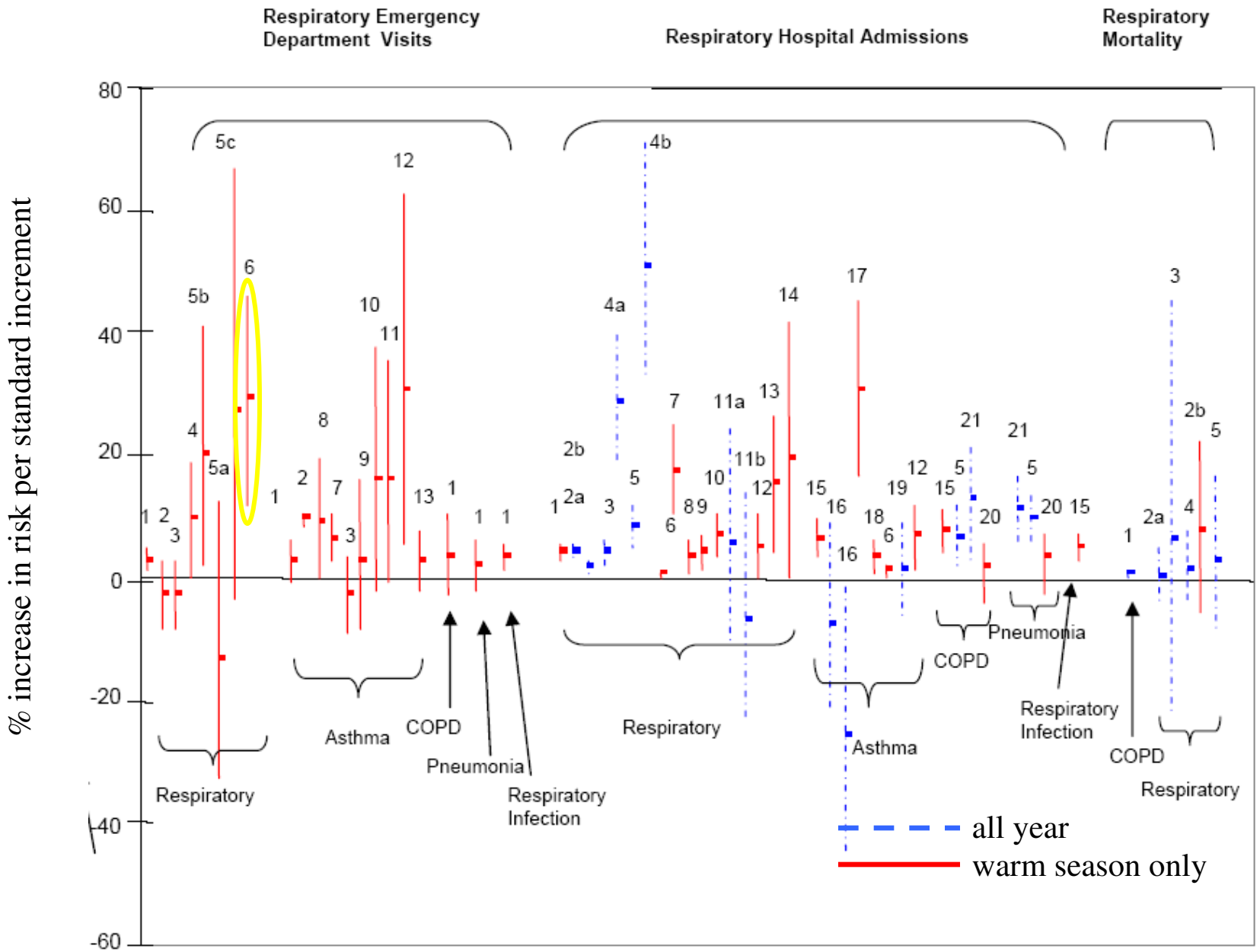
# Field/Panel Studies

- 80's/90's Camp Studies
  - >600 children, mostly healthy, non-asthmatic
  - Multiple measurements per child
  - Significant ↓ FEV1 with increased ozone
  - Ozone predominant ambient pollutant associated with health endpoint
  - Mean levels - 0.053 to 0.123ppm
  - Maximum levels - 0.095 to 0.245 ppm

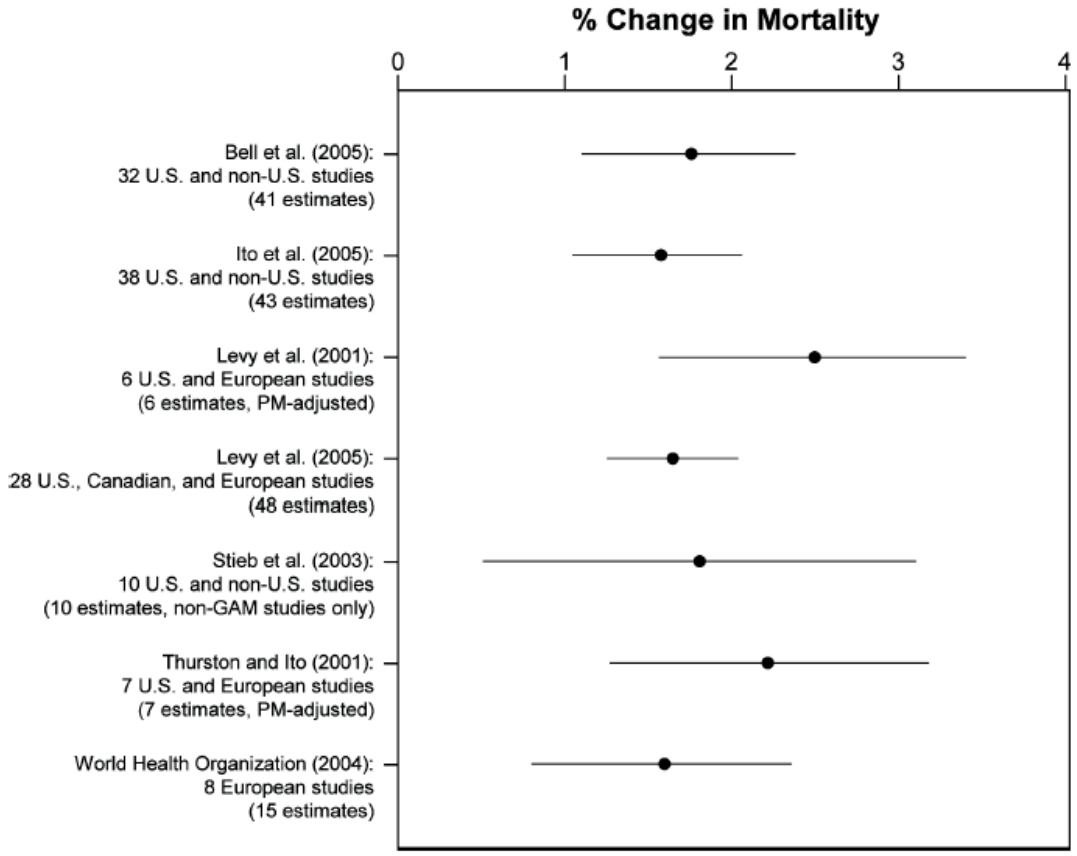
# Population-Based Studies

- Acute (often more severe) endpoints assessed via daily time-series analysis
  - Emergency visits, hospitalizations, death
- Large sample sizes
- Consistent statistical design across studies
- Uses area/regional monitor exposure data
- Confounders are important consideration
  - Temperature, season, co-pollutants, other exposures (e.g., ETS), socioeconomic status

# Summary of Population-Based Studies

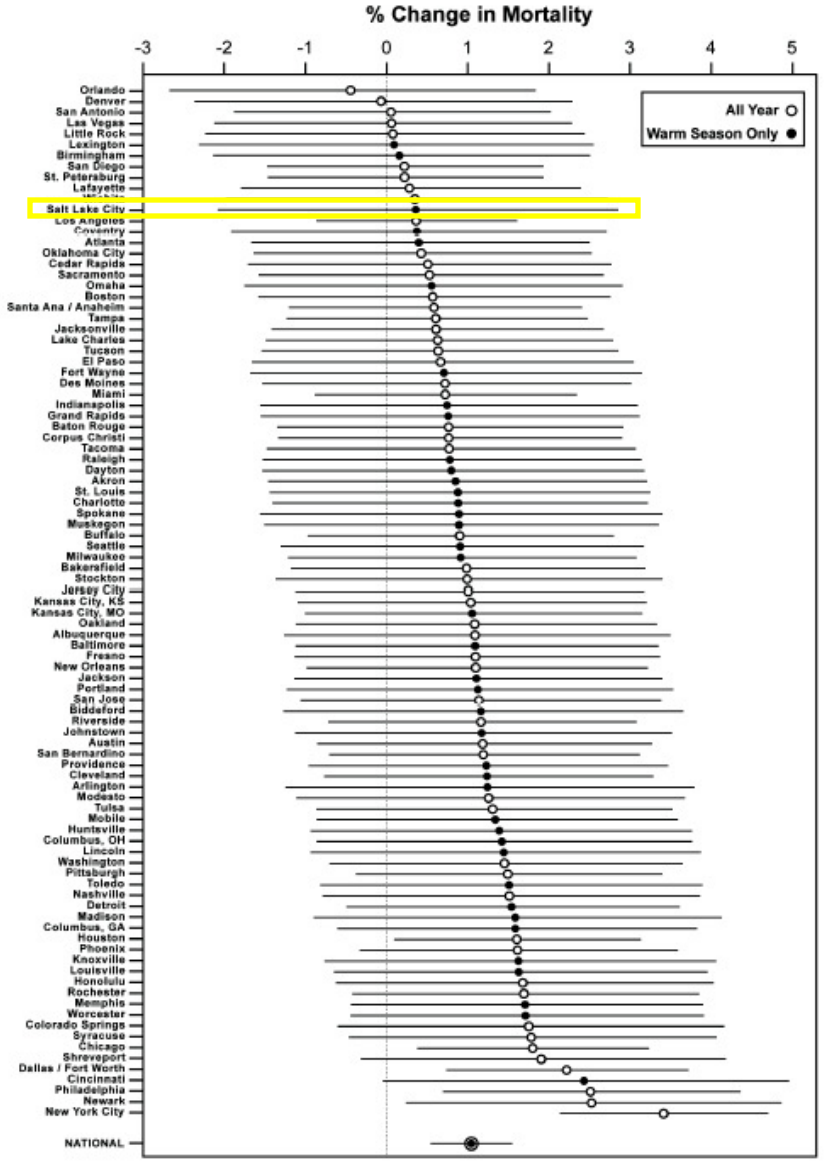


# Daily Mortality Studies




- Population-based times series
- Estimate associations between mortality and daily variations in population average exposures
- Lag time between exposure and death one to several days
- Persistent effect after adjusting for co-pollutants

# Daily Mortality Studies




- Robust association between daily mortality and increased ozone
- Pooled effect estimate robust to PM
- Larger risks in analyses limited to warm season
- Cardiovascular mortality somewhat stronger and more consistent than respiratory

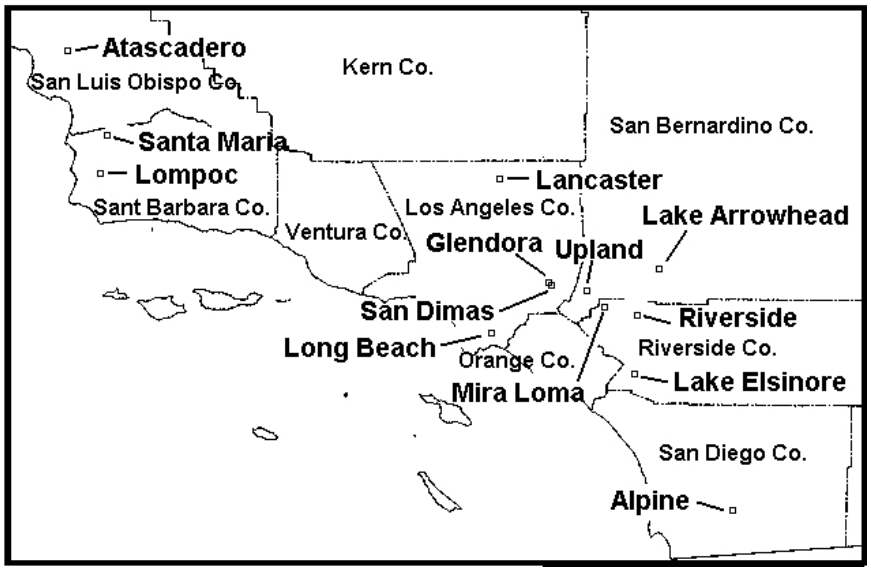
Bell M, Dominici F, McDermott A, et al. Ozone and Mortality in 95 U.S. Cities from 1987 to 2000. Technical Report. 2004, Yale University and Johns Hopkins Bloomberg School of Public Health.

# Chronic Respiratory Effects

- 1996 AQCD
  - Repeated exposure studies in animals show irreversible lung damage
  - Human epidemiology data too limited to conclude whether chronic effects occur
- More recent epidemiology studies focus on asthma development & lung-function growth
  - Lung-function growth in children inversely related to summer ozone concentrations
  - Limited evidence of recovery in lung-function parameters after ozone season

# Children's Health Study

- Long-term cohort from 12 southern CA communities
- Self-reported asthma prevalence, cough, bronchitis and wheeze unrelated to max 1hr ozone
- Reduced baseline lung function in females related to annual average ozone
- Reduced lung function growth related to ozone levels
  - Weaker than $PM_{10}$ effects
- No increased risk of developing asthma high ozone to communities
- Within high ozone RR = 3.3 asthma if sports



# College Freshman Studies

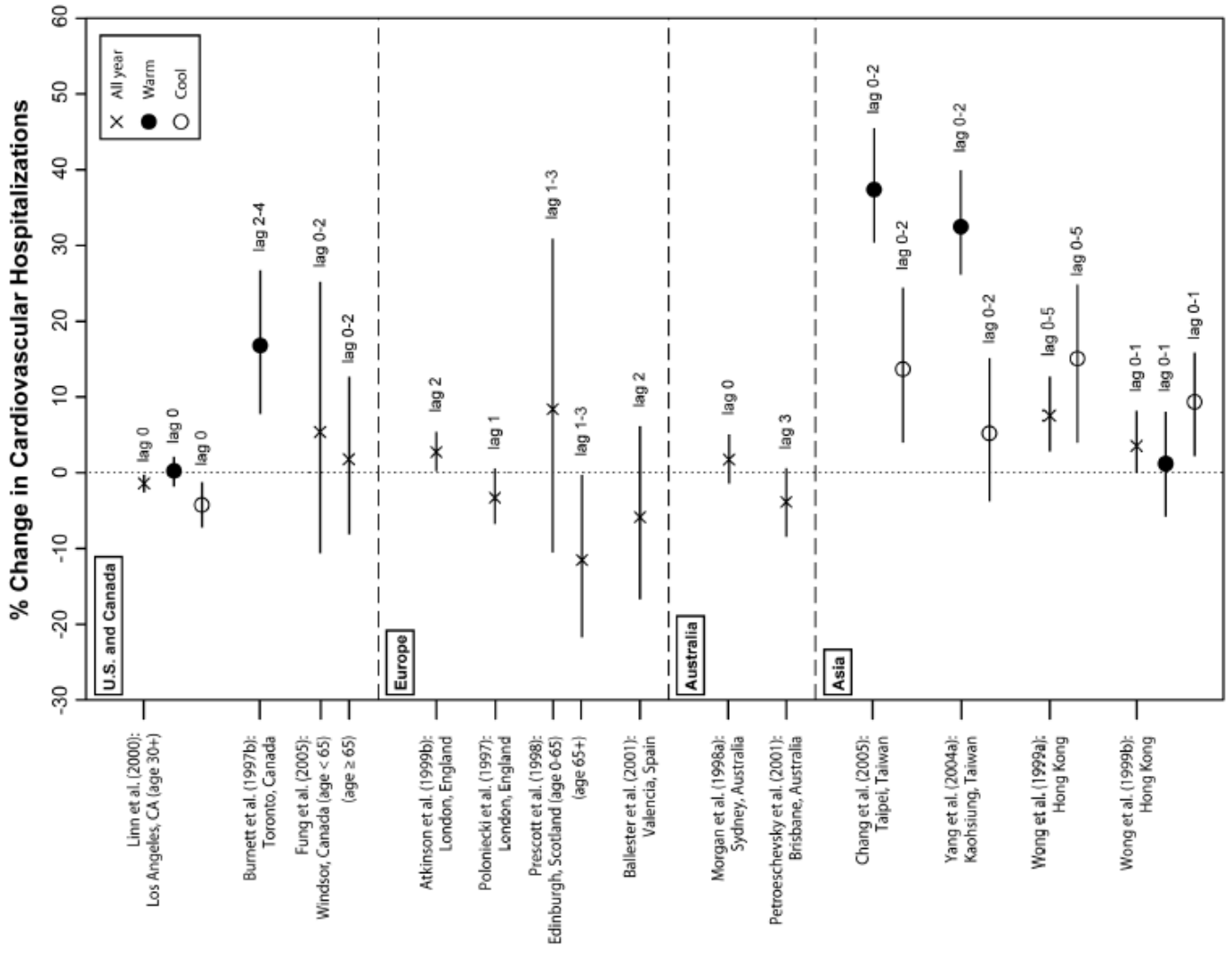
- Yale
  - Reduced lung function in cohort from high vs. low ozone communities
  - Stronger effect in males than females
  - No co-pollutant analysis

- UC Berkeley
  - Reduced lung function comparing students from LA to San Francisco areas
  - Adjusts for intrinsic airway diameter
  - Robust effect in multi-pollutant models

# Panel Studies: Acute Cardiovascular Effects

- Myocardial Infarction – MONICA
  - Current-day ozone associated with acute MI
  - No PM co-pollutant analysis
- Myocardial Infarction – Peters, et al. (2001)
  - Non-significant trend toward increased risk with increased ozone in previous 2 hours
  - PM effects were stronger
- Heart rhythm disturbances – ARIC, NAS, HSPH
  - Ozone associated with reduced heart rate variability and ventricular arrhythmias
  - PM effects on heart rate generally larger and more consistent
  - Ozone effect on arrhythmias robust in two-pollutant models

# Cardiovascular effects – Hospitalizations



## 1996

- Most conclusive evidence
  - Controlled acute human exposures
    - Acute lung function deficits
  - Field/Panel studies
    - Acute lung function deficits
- Highly suggestive evidence
  - Associations with respiratory ED visits and hospitalizations
  - Co-pollutant interactions and chronic effects unclear

## 2006

- Further evidence from controlled exposures
  - Suggestion of sensitive individuals below 0.08 ppm
- Much larger epidemiology database
  - Acute respiratory effects considered causal
  - Strong evidence of association with daily mortality
  - Cardiovascular effects suggestive, but evidence inconclusive
  - Chronic respiratory effects inconclusive
  - Lack of conclusive evidence for several other endpoints (lung cancer, developmental effects)

# EPA's Ozone Air Quality Criteria Document (AQCD)

**March 2011**

- Framework for causal determination offered
- Likely to be causal
  - Daily mortality
  - Acute and long-term respiratory effects
- Suggestive of causal
  - Cardiovascular – acute and long-term effects
  - Central nervous system – acute and long-term effects
  - Reproductive – long-term effects

# EPA's Ozone Integrated Science Assessment (ISA)

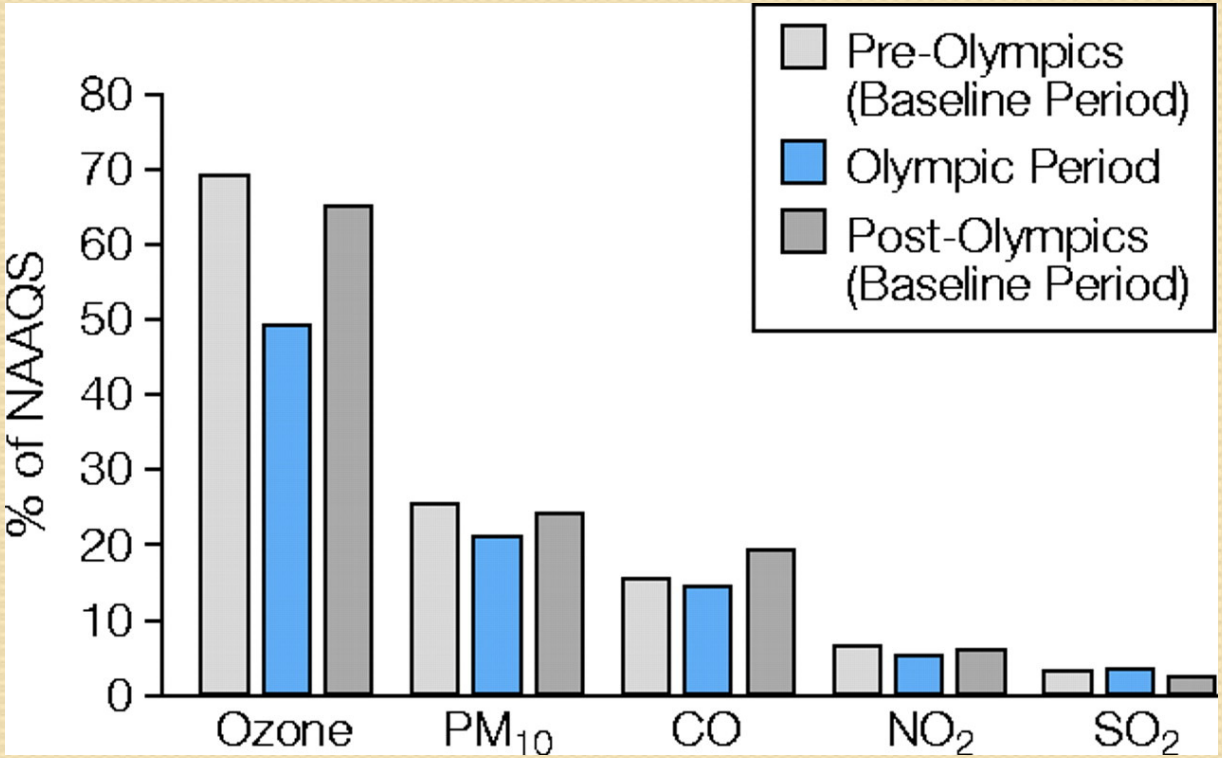
# Air Pollution Mitigation Study: 1996 Atlanta Olympics

- Intervention: around-the-clock public transportation
  - 1,000 buses added
  - Downtown city streets closed to private car
  - Downtown delivery schedules altered
  - Flexible and telecommuting work schedules encouraged

Source: Friedman, M. S. et al. JAMA 2001;285:897-905.

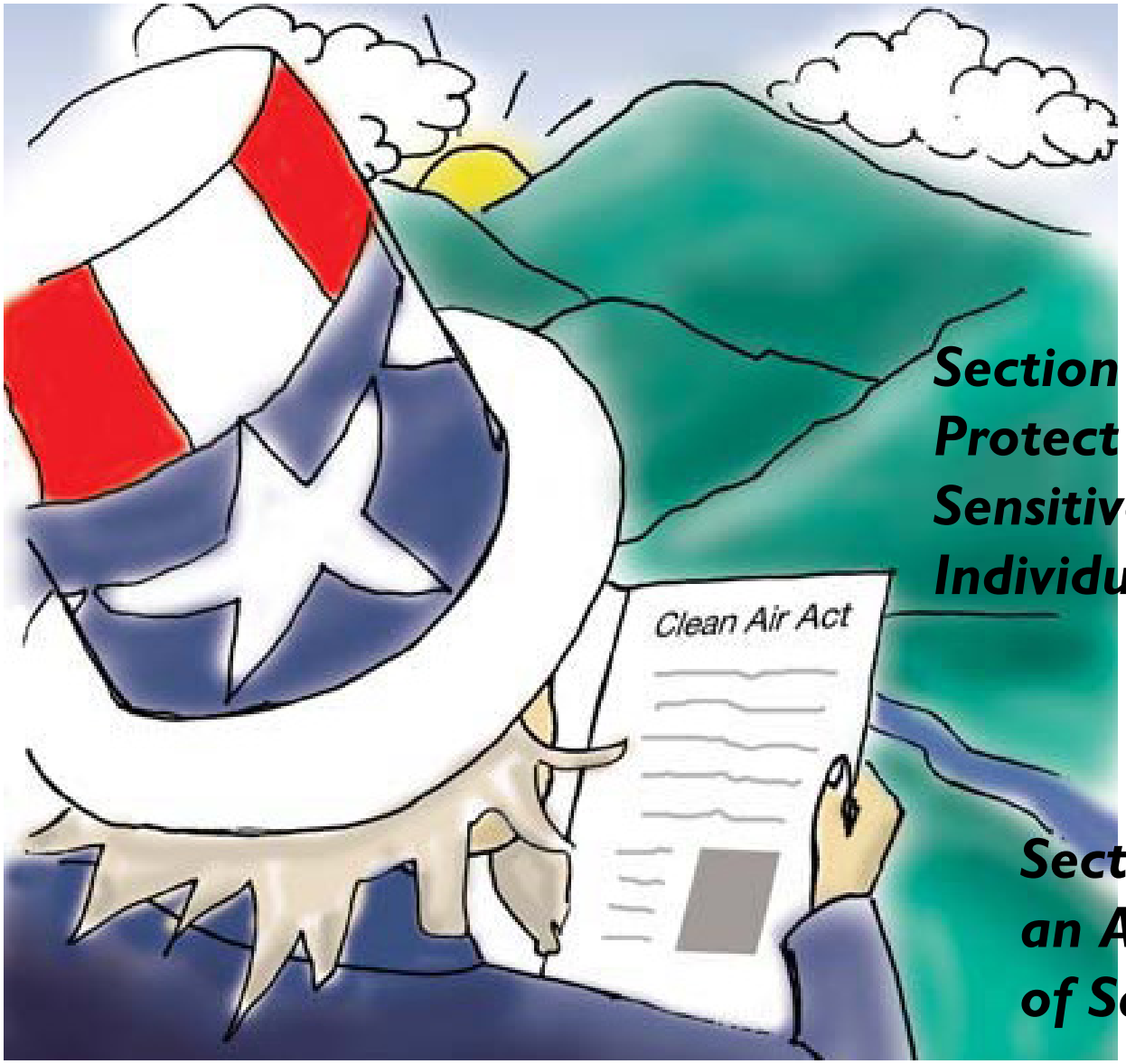
## Mean Levels of Major Pollutants Before, During, and After the 1996 Summer Olympic Games as a Percentage of the NAAQS

- Weekday morning traffic counts dropped 22.5%
- Peak daily ozone concentrations decreased 27.9%



# Reduction in Number of Asthma Claims During 1996 Atlanta Olympics

| Type of claim | % change in mean number of asthma claims/day | % change in mean number of non-asthma claims/day |
|---|---|---|
| Medicaid<br>Hosp and ED Visits | **- 41.6%** | **- 3.1%** |
| HMO<br>ED, Urgent Visit, Hosp | **- 44.1%** | **+ 1.3%** |




***Section 7408…***
***Protect the Health of Sensitive or Susceptible Individuals***

***Section 7409…With an Adequate Margin of Safety***

# QUESTIONS?