Air Pollution and Health: A Quick Tour of the Scientific Evidence

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Sponsored by: Utah Moms for Clean Air
Presented at: Westminster College
June 19, 2007

What are we breathing?

- Pure Air--nitrogen (78%),Oxygen (21%), Argon, CO_2. . .

+

- Various gaseous pollutants including:
  - SO_2, NO_2, CO, O_3 . . .

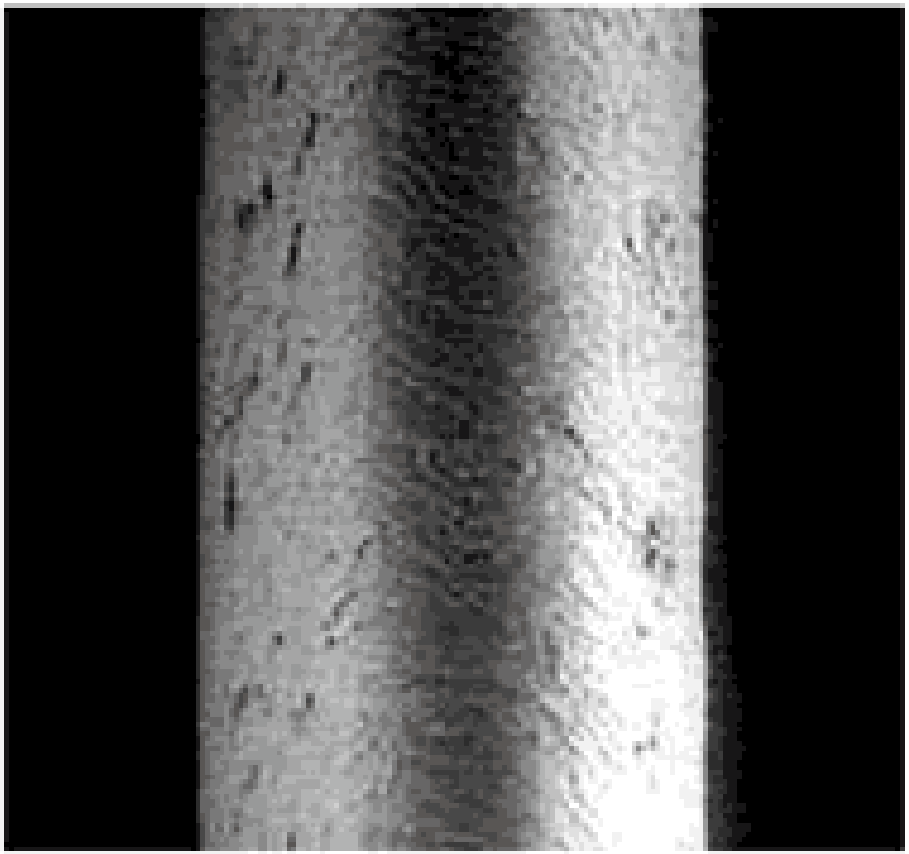
+

- **Particulate matter:**
  - Course particles (> 2.5 μm in diameter)
  - **Fine particles** (< 2.5 μm in diameter)

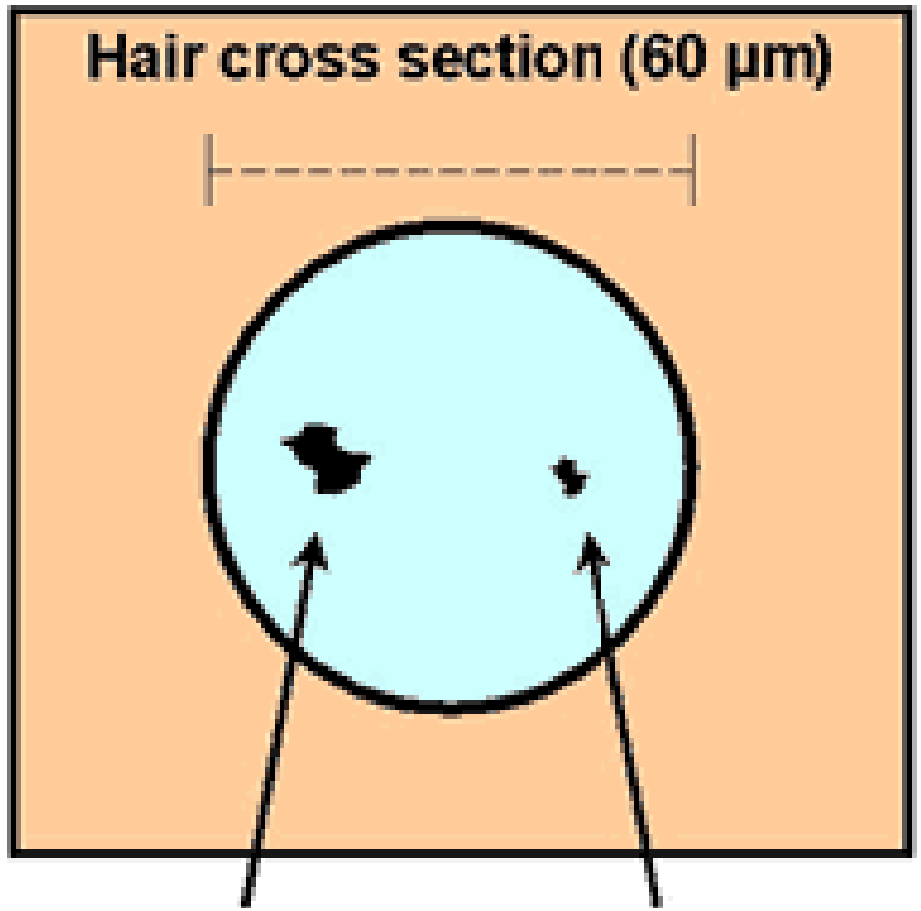
+

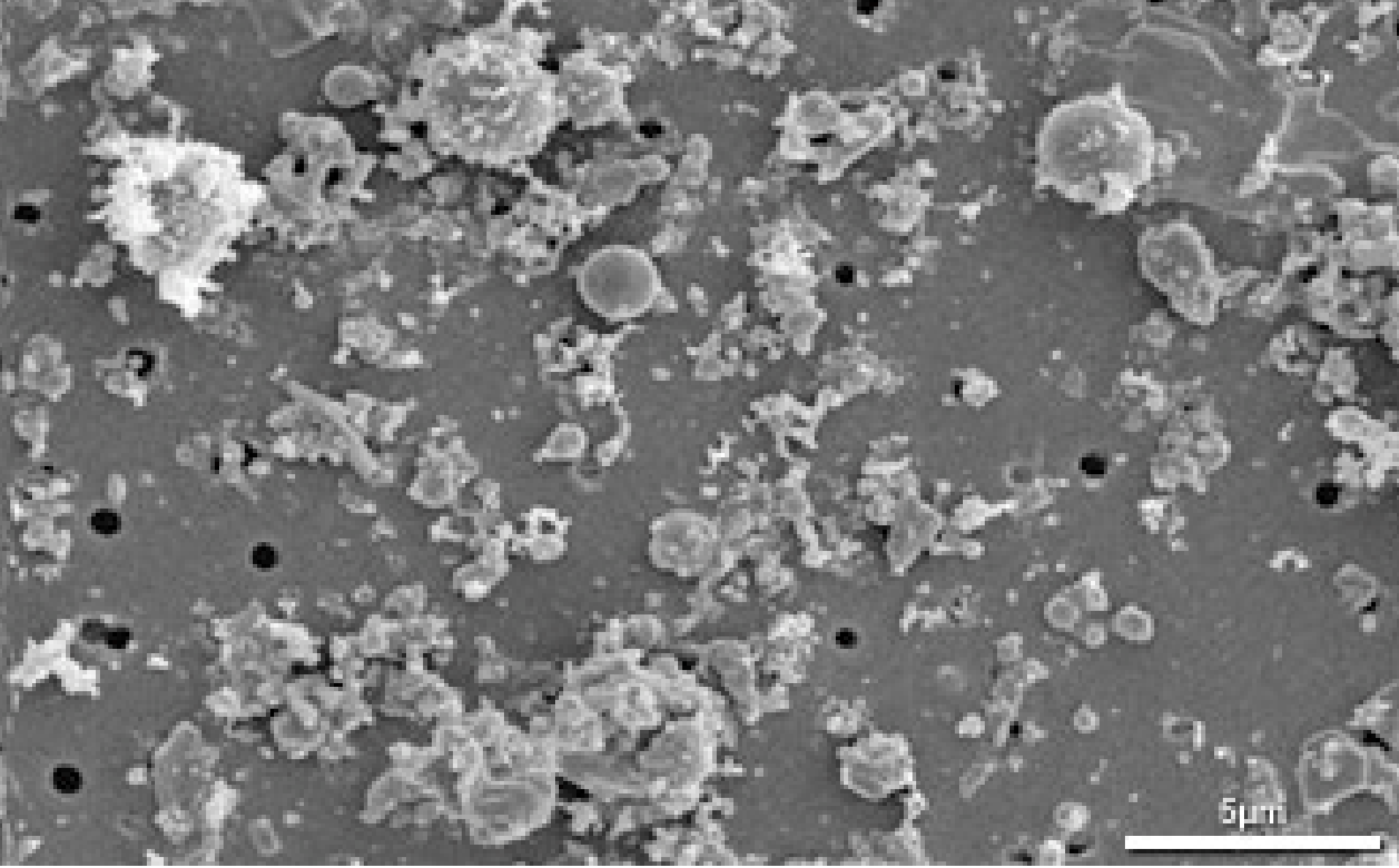
- Other air toxics

How small are fine particles?



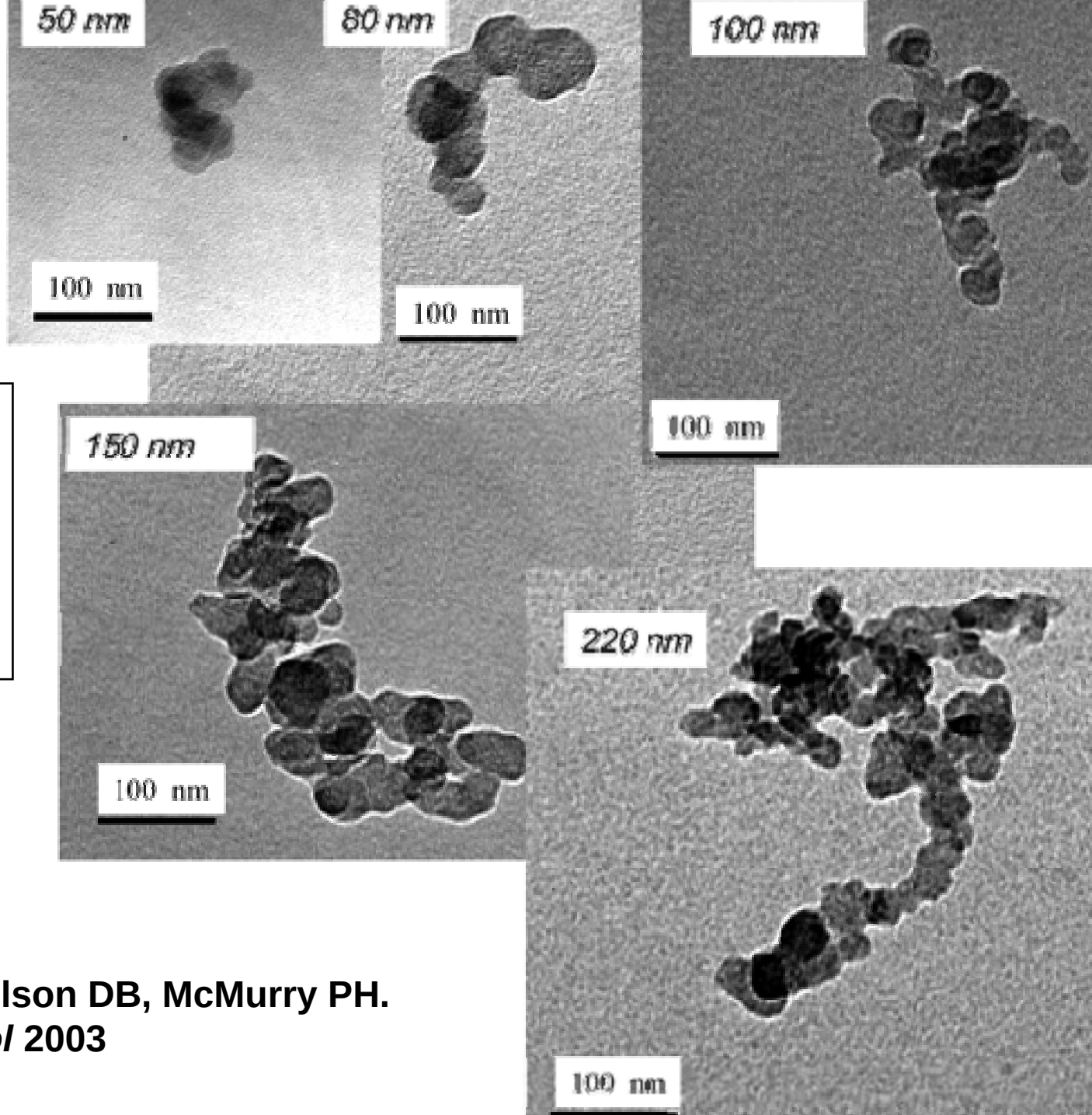
Human Hair
(60 μm diameter)





Magnified ambient particles (www.nasa.gov/vision/earth/environment)

Electron Microscope images of soot particles



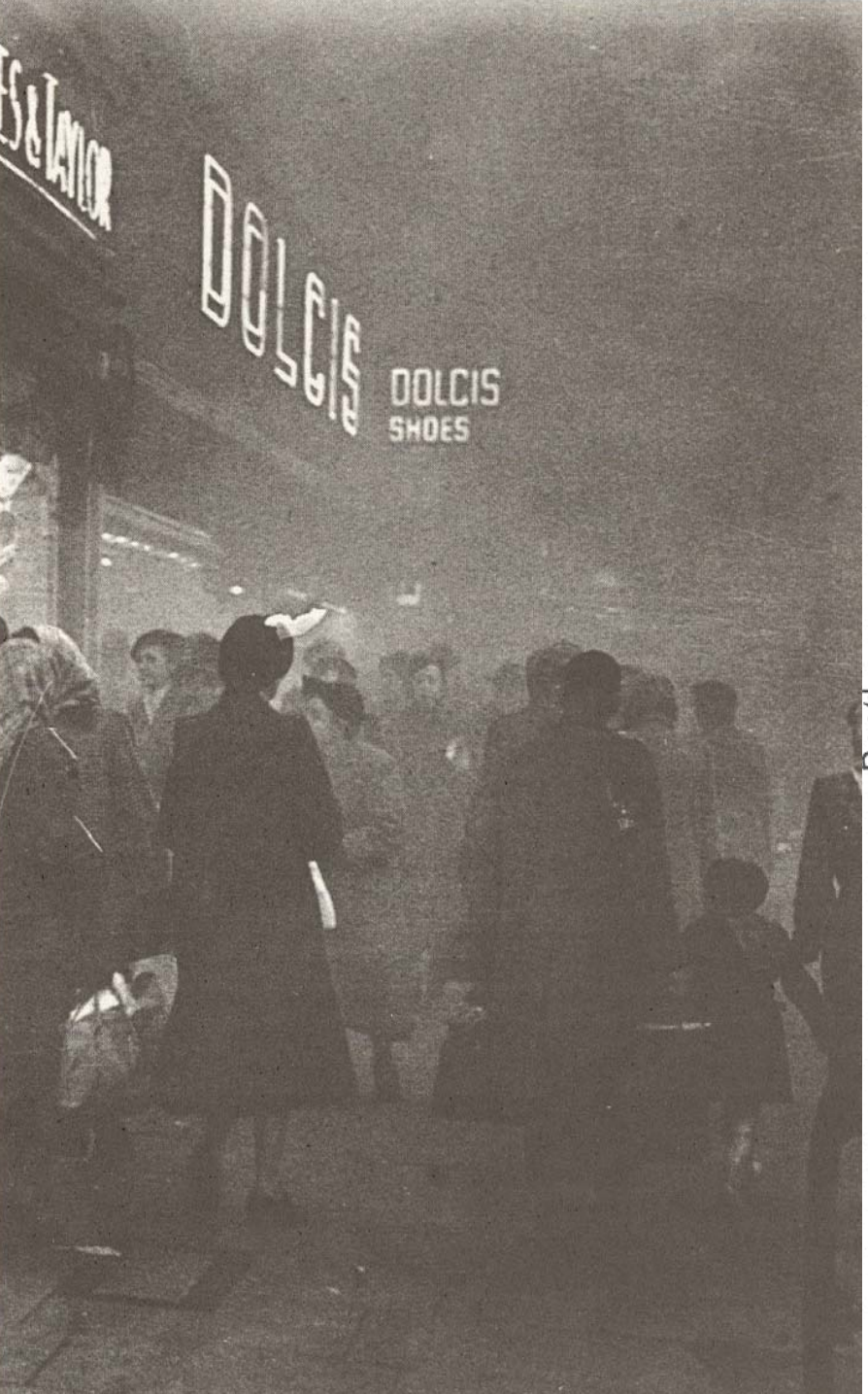
From:
Park K, Cao F, Kittelson DB, McMurry PH.
Environ Sci Technol 2003

Air pollution over SLC, UT

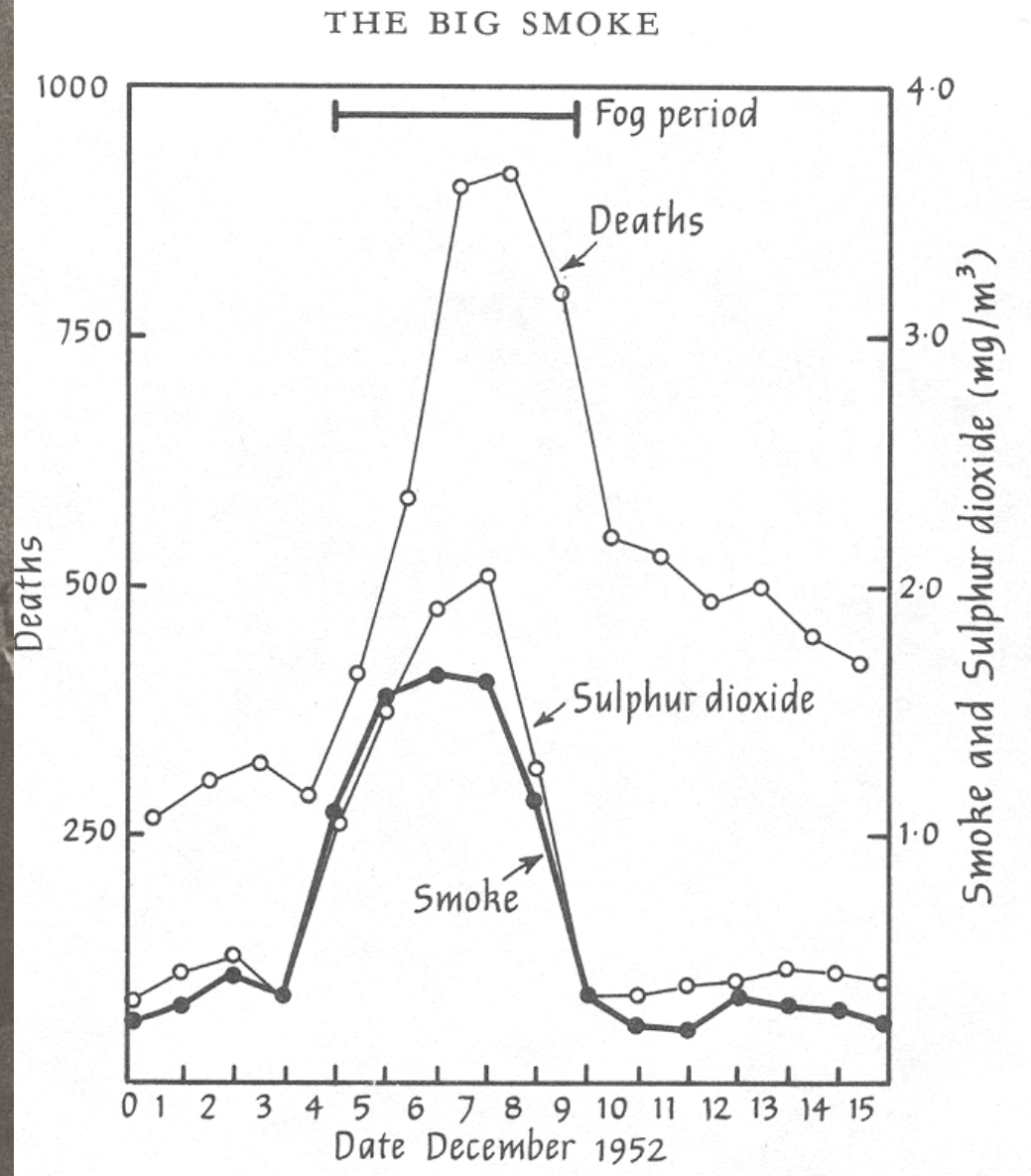
Donora, PA 1948

From, Public Health Service,
Bulletin No. 306, 1949

Danora, PA. Noon, Oct 29, 1948.



London Fog Episode, Dec. 1952



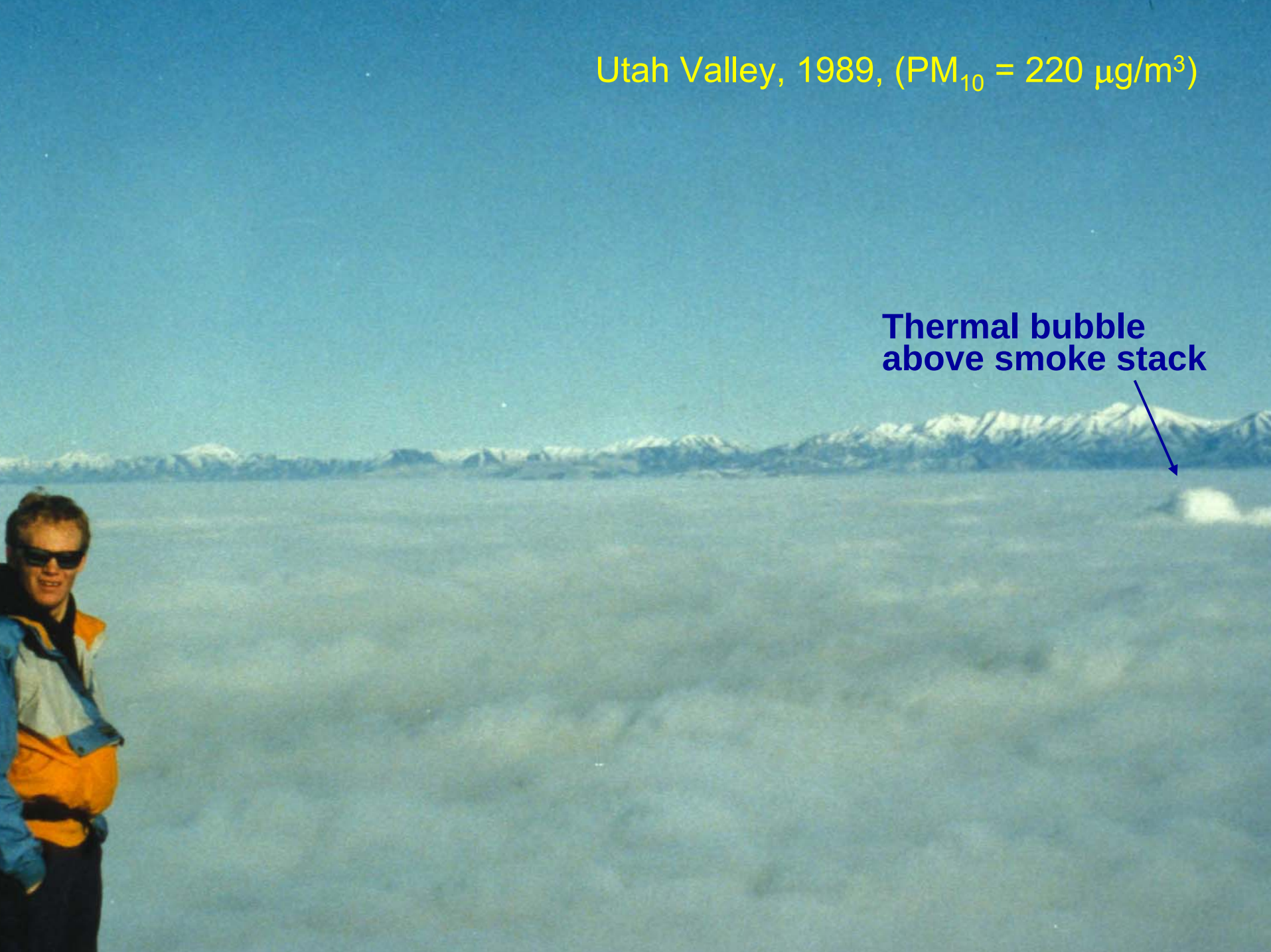
From: Brimblecombe P. The Big Smoke, Methuen 1987

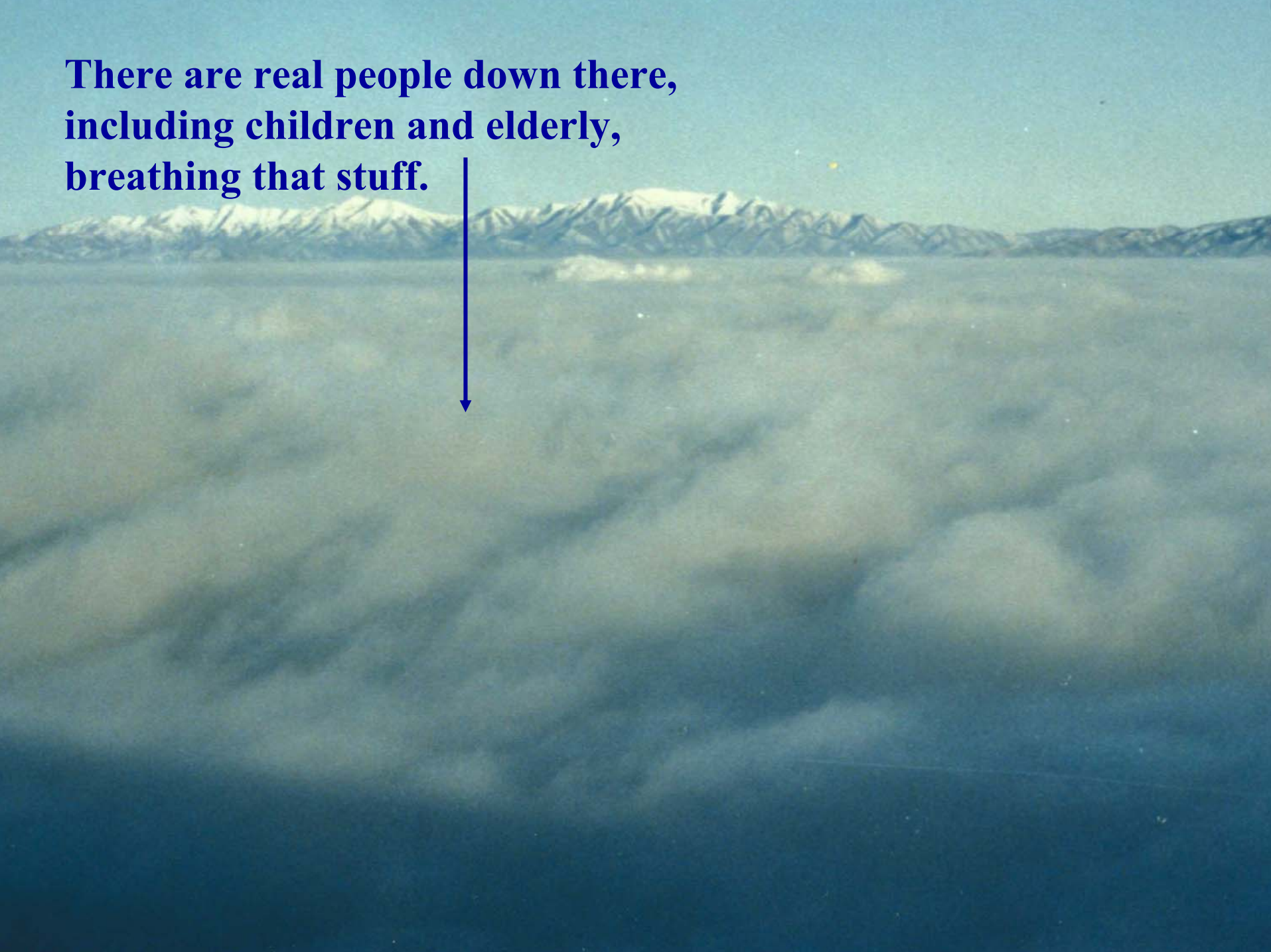
Utah Valley

- **Winter inversions trap local pollution**
- **Natural test chamber**


Local Steel Mill, Utah Valley, 1989 (PM_{10} = 150 μg/m^3)

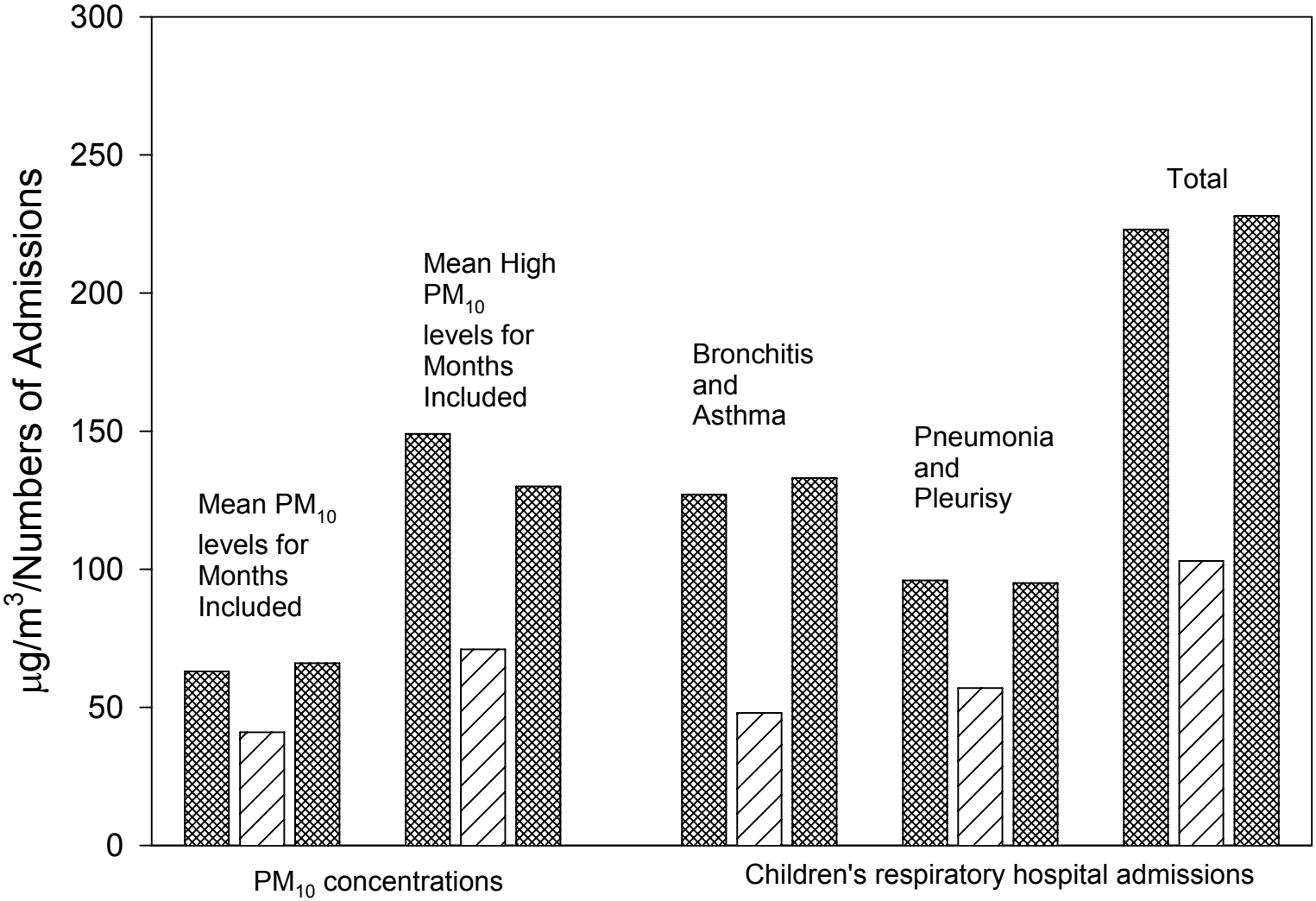

Utah Valley, 1989, (PM_{10} = 50 μg/m^3)
11 11'89


Utah Valley, 1989, (PM_{10} = 220 μg/m^3)
Thermal bubble above smoke stack


There are real people down there,
including children and elderly,
breathing that stuff.

Children's Respiratory Hospital Admissions

Fall and Winter Months, Utah Valley



Sources: Pope. Am J Pub Health.1989; Pope. Arch Environ Health. 1991

Series of panel and related studies

Basic Questions asked: Are day-to-day changes in air pollution in Utah's Wasatch Front associated with changes in lung function, respiratory symptoms, medication use and/or school absences?

Collaborators:
Dockery DW et al. (Harvard)
Kanner RE (UofU)
Ransom MR (BYU)

Sources:

Pope, et al. *Am Rev Resp Dis*.1991
Pope and Dockery. *Am Rev Resp Dis*.1992
Pope and Kanner. *Am Rev Resp Dis*. 1993
Ransom and Pope. *Environ Research*. 1992

Panel studies of asthmatics and non-asthmatics

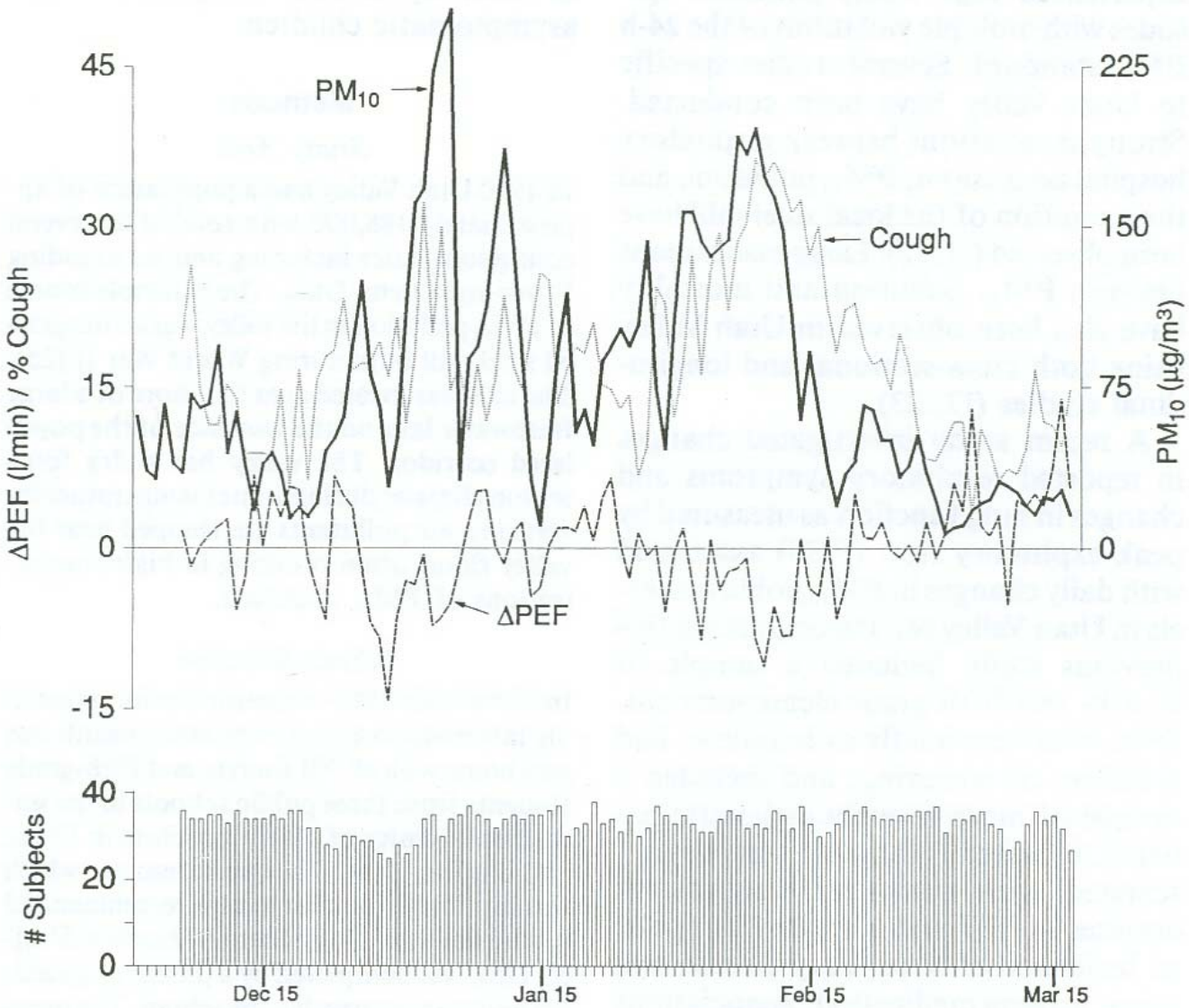
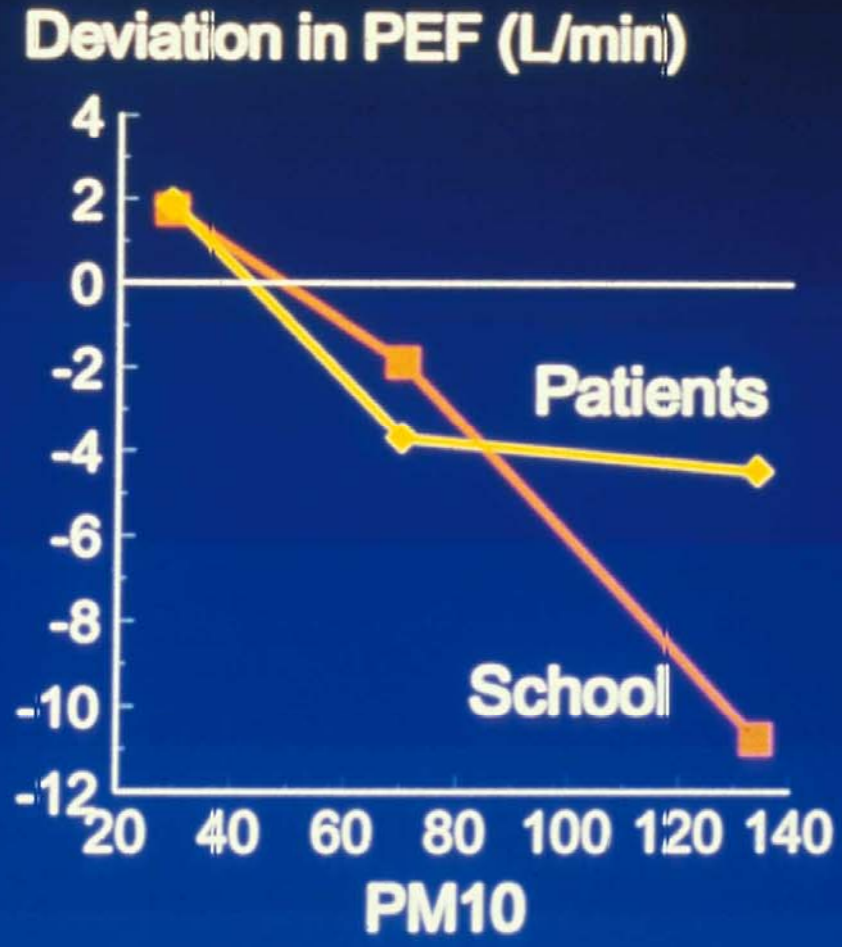


Fig. 1. Daily PM_{10} levels, mean peak expiratory flow deviations (ΔPEF), percentage who reported cough, and number of participants for the symptomatic sample.

Peak Flow and PM_{10}

Pope et al, ARRD 1991

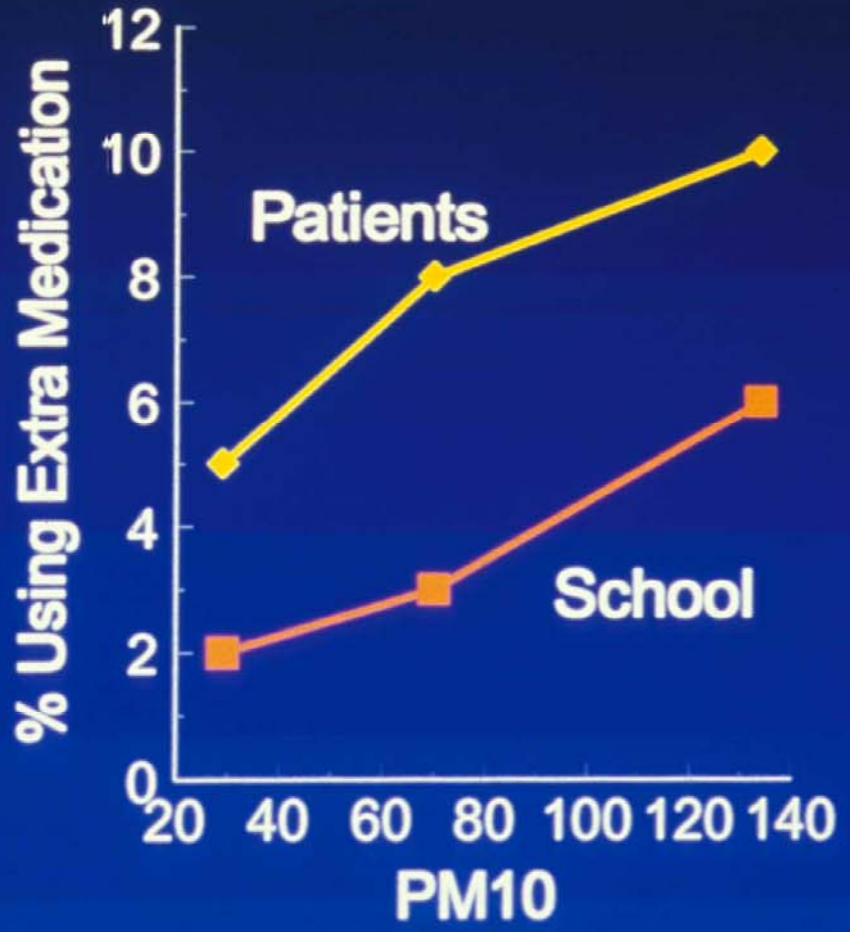
- Panel study
  - 34 School Children
  - 21 Asthma Patients
- Daily Peak Flow Measures (Evening)
  - Deviations from subject's mean
- Daily PM10 measurements
  - Max 195 ug/m3



Asthma Medication & PM10

Pope et al, ARRD 1991

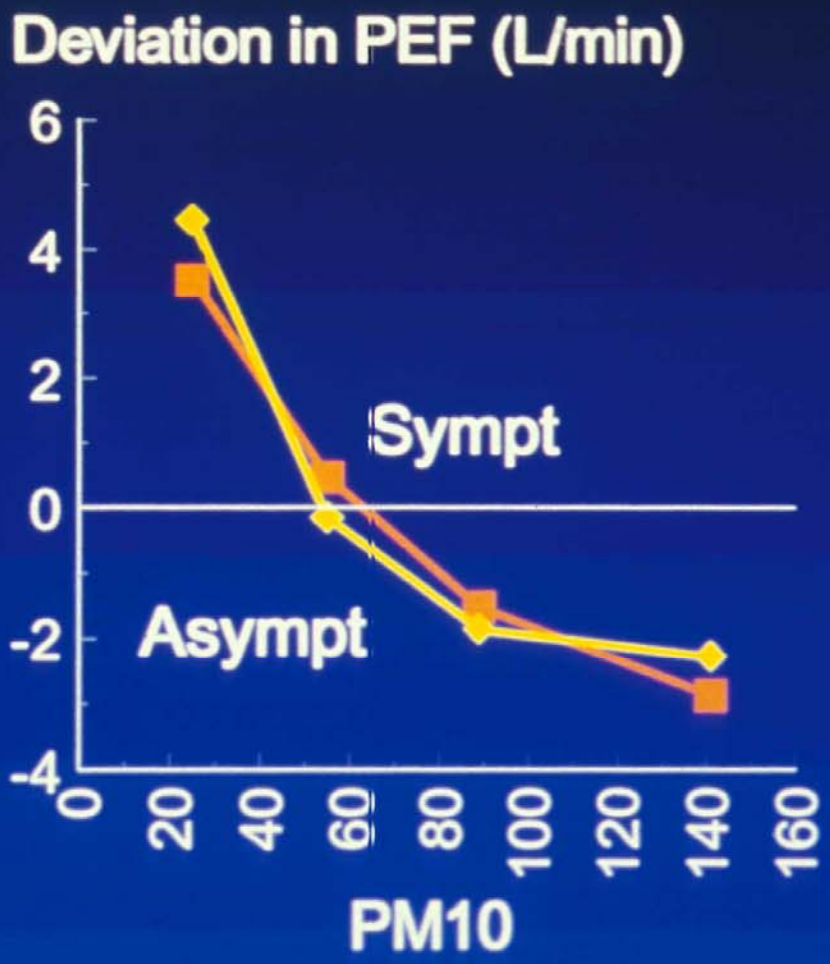
- Panel study
  - 34 School Children
  - 21 Asthma Patients
- Daily Reports of Extra Asthma Medications
- Daily PM10 measurements
  - Max 195 ug/m3



Peak Flow and PM_{10}

Pope & Dockery, ARRD 1992

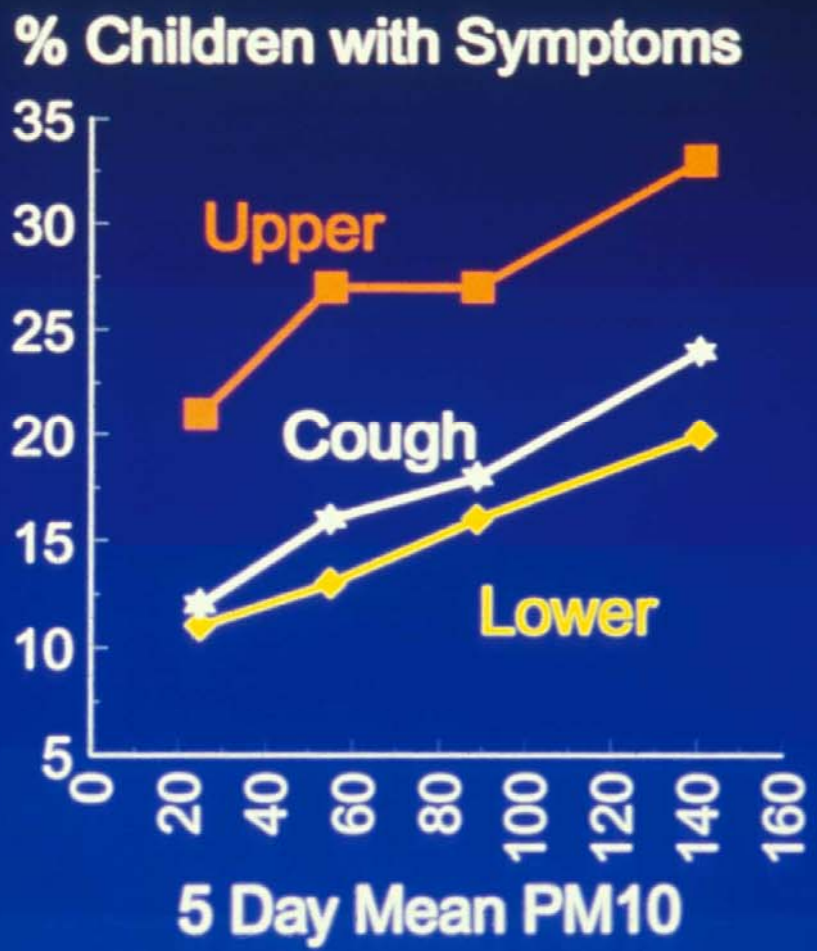
- Panel study
  - 32 Symptomatic Children
  - 33 Asymptomatic Childrn
- Daily Peak Flow Measures (Evening)
  - Deviations from subject's mean
- Daily PM_{10} measurements
  - Max 251 ug/m3

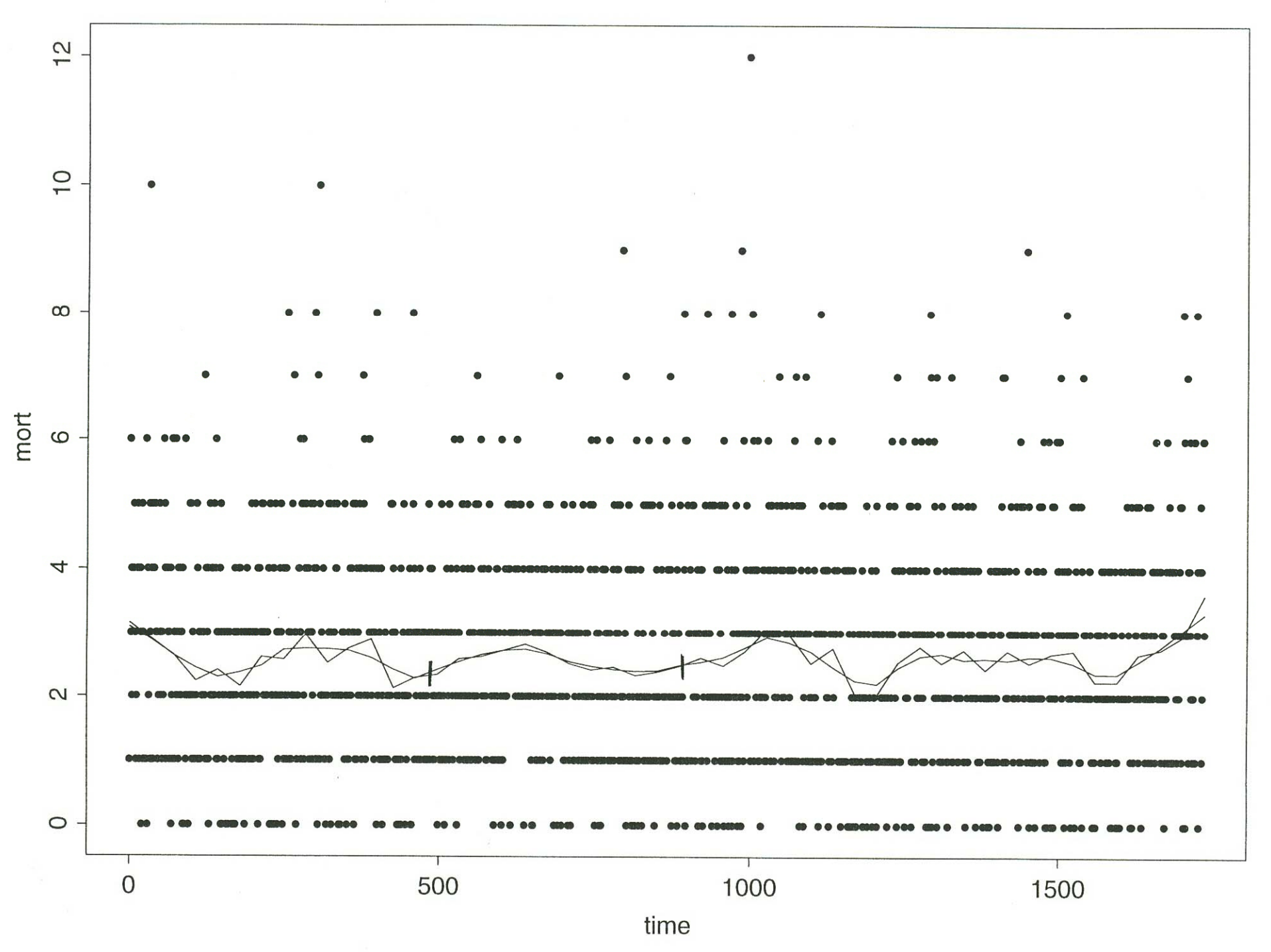


Respiratory Symptoms and PM_{10}

Pope & Dockery, ARRD 1992

- Panel study
  - 32 Symptomatic Children
- Daily Records of Respiratory Symptoms
  - Upper Respiratory
  - Lower Respiratory
  - Cough
- Daily PM_{10} measurements
  - Max 251 ug/m3

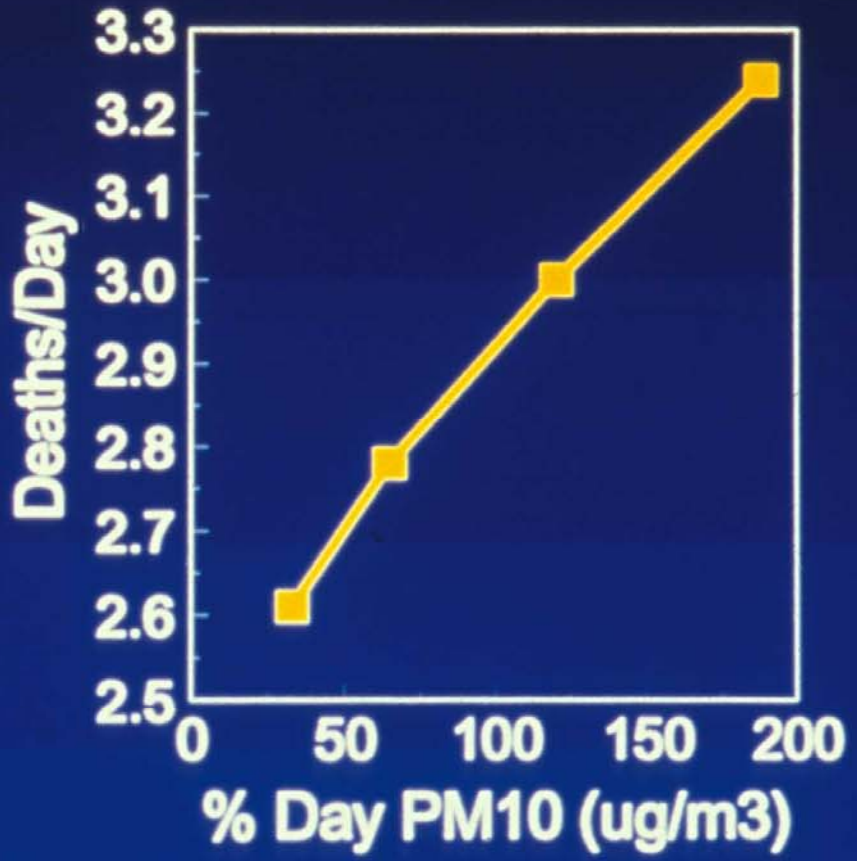



mort
0
2
4
6
8
10
12
0
500
1000
1500
time

Utah Valley Mortality

Pope et al, Arch Env Hlth, 1992

- Daily deaths 1985-90 for Utah Valley
  - Mean 2.7 per day
- Daily PM10 measures
  - Mean 47 ug/m3
  - Max 365 ug/m3
  - Lo SO2, O3, NO2
- Poisson Regression
  - 1.5% per 10ug/m3



Summary of early Utah Valley epidemiological studies

Health effects

- **Increased hospital admissions**
- **Increased respiratory symptoms**
- **Reduced lung function**
- **Increased school absences**
- **Increased respiratory and cardiovascular deaths**

Study References

Pope (1989) Am. J. Public Health
Pope (1991) Arch. Environ. Health

Pope, Dockery, Spengler, Raizenne (1991) Am. Rev. Resp. Dis.

Pope, Dockery (1992) Am. Rev. Resp. Dis.

Pope, Kanner (1993) Am. Rev. Resp. Dis.

Ransom, Pope (1992) Environ. Res

Pope, Schwartz, Ransom (1992) Arch. Environ. Health

Pope, Kalkstein (1996) Environ. Health Perspect.

Pope, Hill, Villegas (1999) Environ. Health Perspect.

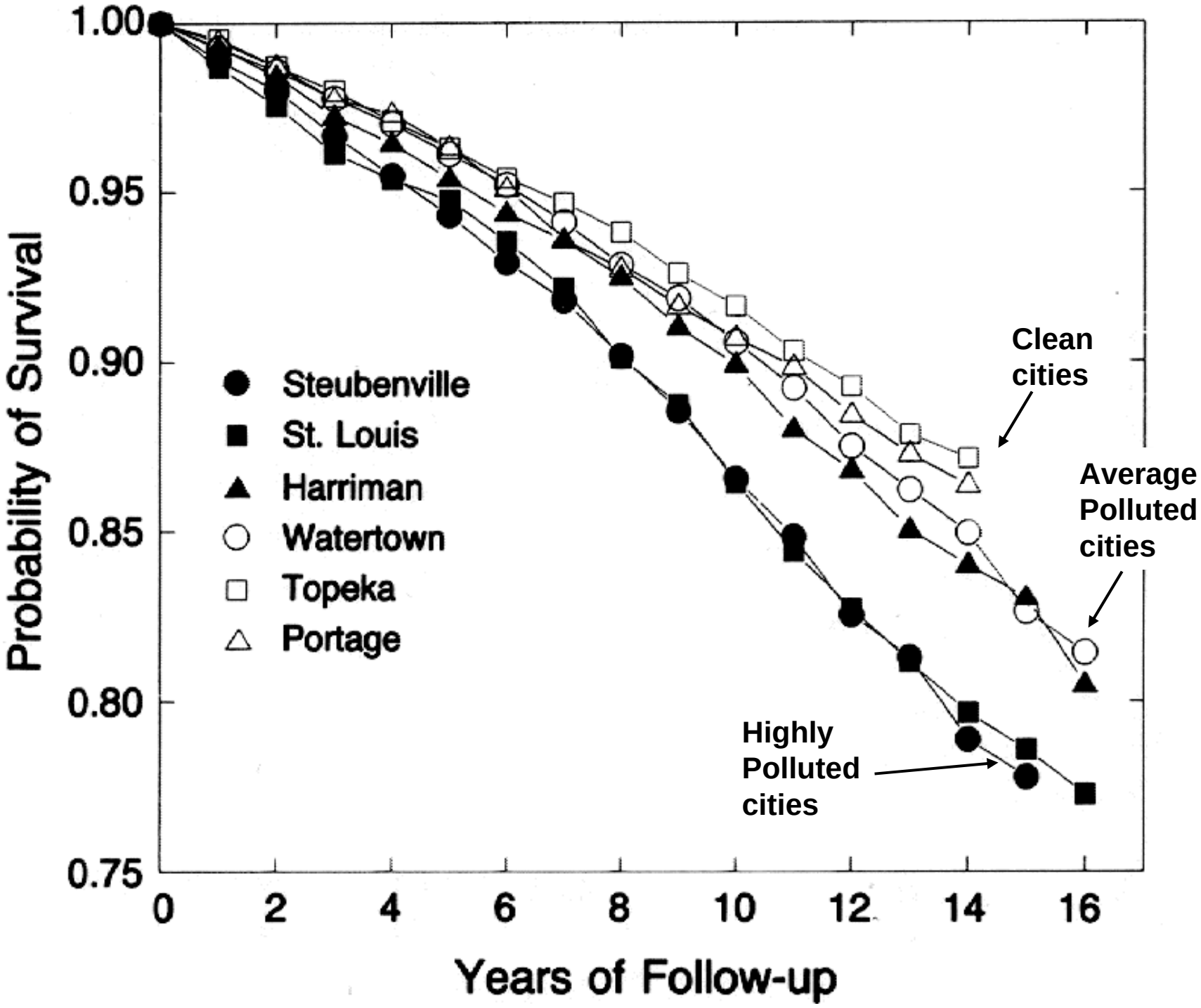
An Association Between Air Pollution and Mortality in Six U.S. Cities

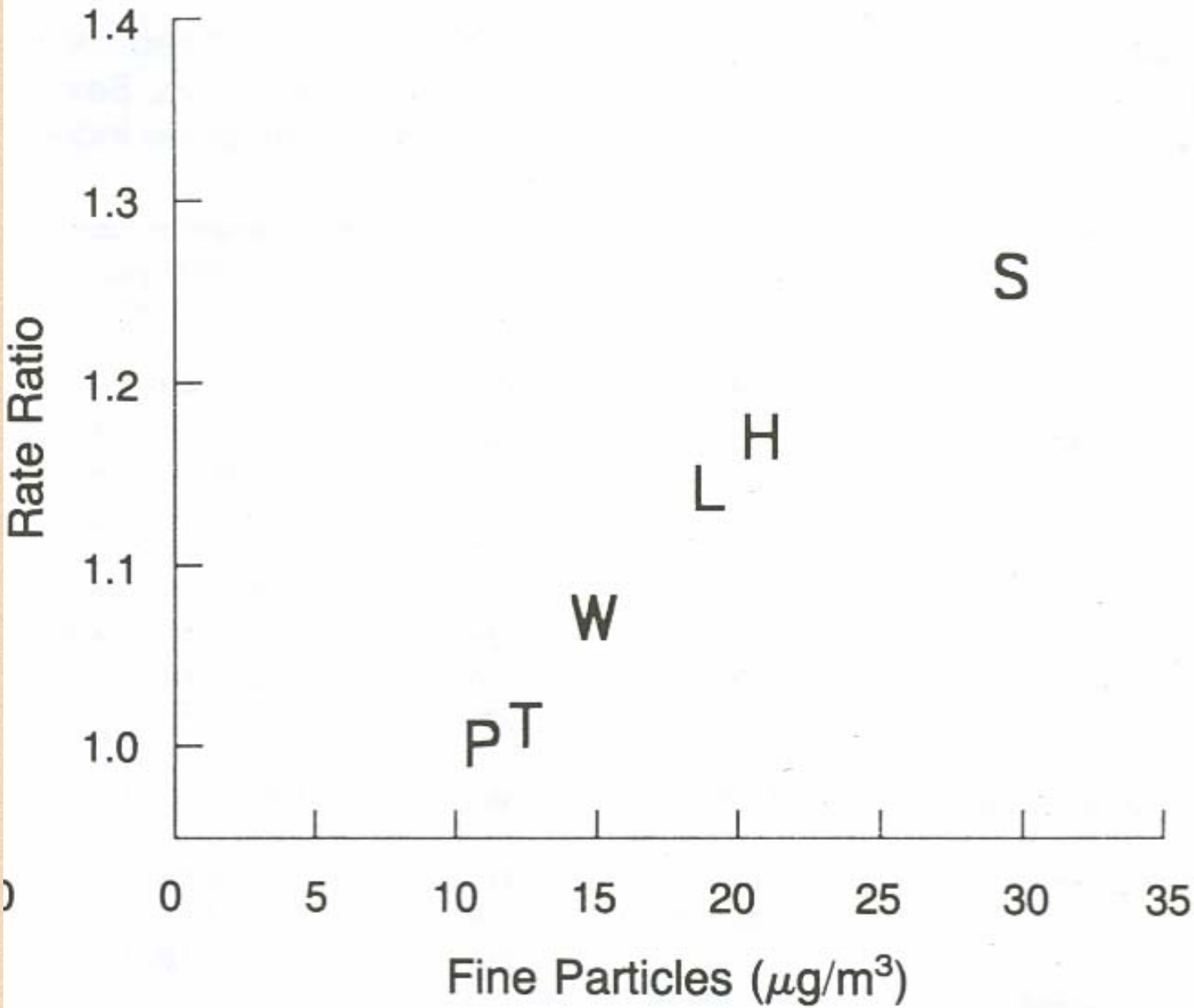
Dockery DW, Pope CA III, Xu X, Spengler JD, Ware JH, Fay ME, Ferris BG Jr, Speizer FE.

***New England Journal of Medicine* 1993**

Methods:

- 14-16 yr prospective follow-up of 8,111 adults living in six U.S. cities.
- Monitoring of TSP PM_{10}, $PM_{2.5}$, SO_4, H^+, SO_2, NO_2, O_3 .
- Data analyzed using survival analysis, including Cox Proportional Hazards Models.
- Controlled for individual differences in: age, sex, smoking, BMI, education, occupational exposure.


1.00
0.95
0.90
0.85
0.80
0.75
Probability of Survival
0
2
4
6
8
10
12
14
16
Years of Follow-up
Steubenville
St. Louis
Harriman
Watertown
Topeka
Portage
Clean cities
Average Polluted cities
Highly Polluted cities


1.4
1.3
1.2
1.1
1.0
Rate Ratio
S
H
L
W
T
P
0
5
10
15
20
25
30
35
Fine Particles (μg/m3)

Adjusted risk ratios (and 95% CIs) for cigarette smoking and $PM_{2.5}$

Cause of Death	Current Smoker, 25 Pack years	Most vs. Least Polluted City
All	2.00 (1.51-2.65)	1.26 (1.08-1.47)
Lung Cancer	8.00 (2.97-21.6)	1.37 (0.81-2.31)
Cardio-pulmonary	2.30 (1.56-3.41)	1.37 (1.11-1.68)
All other	1.46 (0.89-2.39)	1.01 (0.79-1.30)

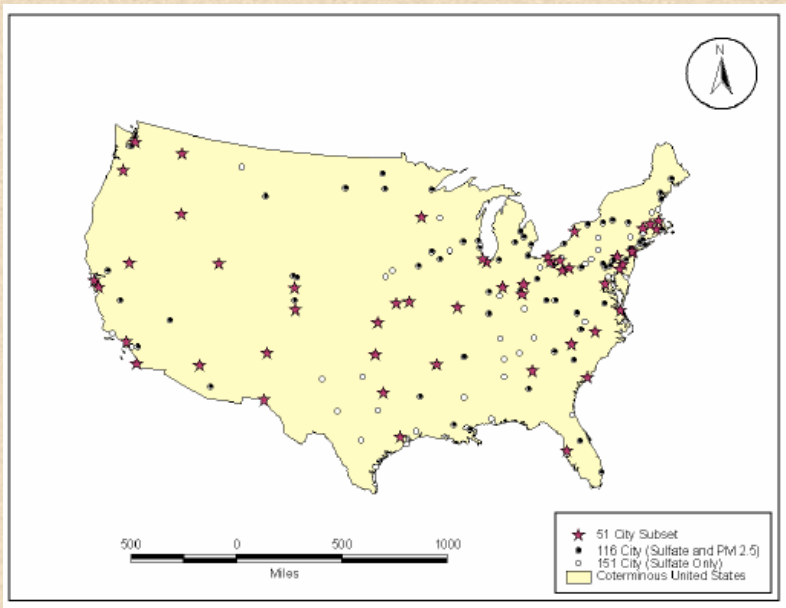
Particulate Air Pollution as a Predictor of Mortality in a Prospective Study of U.S. Adults

Pope CA III, Thun MJ, Namboodiri MM,
Dockery DW, Evans JS, Speizer FE, Heath CW Jr.

Am J Respir Crit Care Med 1995


Clark Heath

Methods: Linked and analyzed ambient air pollution data from 51-151 U.S. metro areas with risk factor data for over 500,000 adults enrolled in the ACS-CPSII cohort.



Adjusted mortality risk ratios (and 95% CIs) for cigarette smoking the range of sulfates and fine particles

Cause of Death	Current Smoker	Sulfates	Fine Particles
All	2.07 (1.75-2.43)	1.15 (1.09-1.22)	1.17 (1.09-1.26)
Lung Cancer	9.73 (5.96-15.9)	1.36 (1.11-1.66)	1.03 (0.80-1.33)
Cardio-Pulmonary	2.28 (1.79-2.91)	1.26 (1.16-1.37)	1.31 (1.17-1.46)
All other	1.54 (1.19-1.99)	1.01 (0.92-1.11)	1.07 (0.92-1.24)

Science
25 July 1997 AAAS

Showdown Over Clean Air Science

Jocelyn Kaiser

Industry and environmental researchers are squaring off over studies linking air pollution and illness in what some are calling the biggest environmental fight of the decade

SPECIAL REPORT

HEALTH EFFECTS INSTITUTE

July 2000

Reanalysis of the Harvard Six Cities Study and the American Cancer Society Study of Particulate Air Pollution and Mortality

A Special Report of the Institute's Particle Epidemiology Reanalysis Project

SUPREME COURT OF THE UNITED STATES

WHITMAN, ADMINISTRATOR OF ENVIRONMENTAL PROTECTION AGENCY, ET AL. *v.* AMERICAN TRUCKING ASSOCIATIONS, INC., ET AL.

No. 99–1257. Argued November 7, 2000—Decided February 27, 2001*

Legal uncertainty largely resolved with 2001 unanimous ruling by the U.S. Supreme Court.

Lung Cancer, Cardiopulmonary Mortality, and Long-term Exposure to Fine Particulate Air Pollution

JAMA, March 6, 2002—Vol 287, No. 9

C. Arden Pope III, PhD
Richard T. Burnett, PhD
Michael J. Thun, MD
Eugenia E. Calle, PhD
Daniel Krewski, PhD
Kazuhiko Ito, PhD
George D. Thurston, ScD

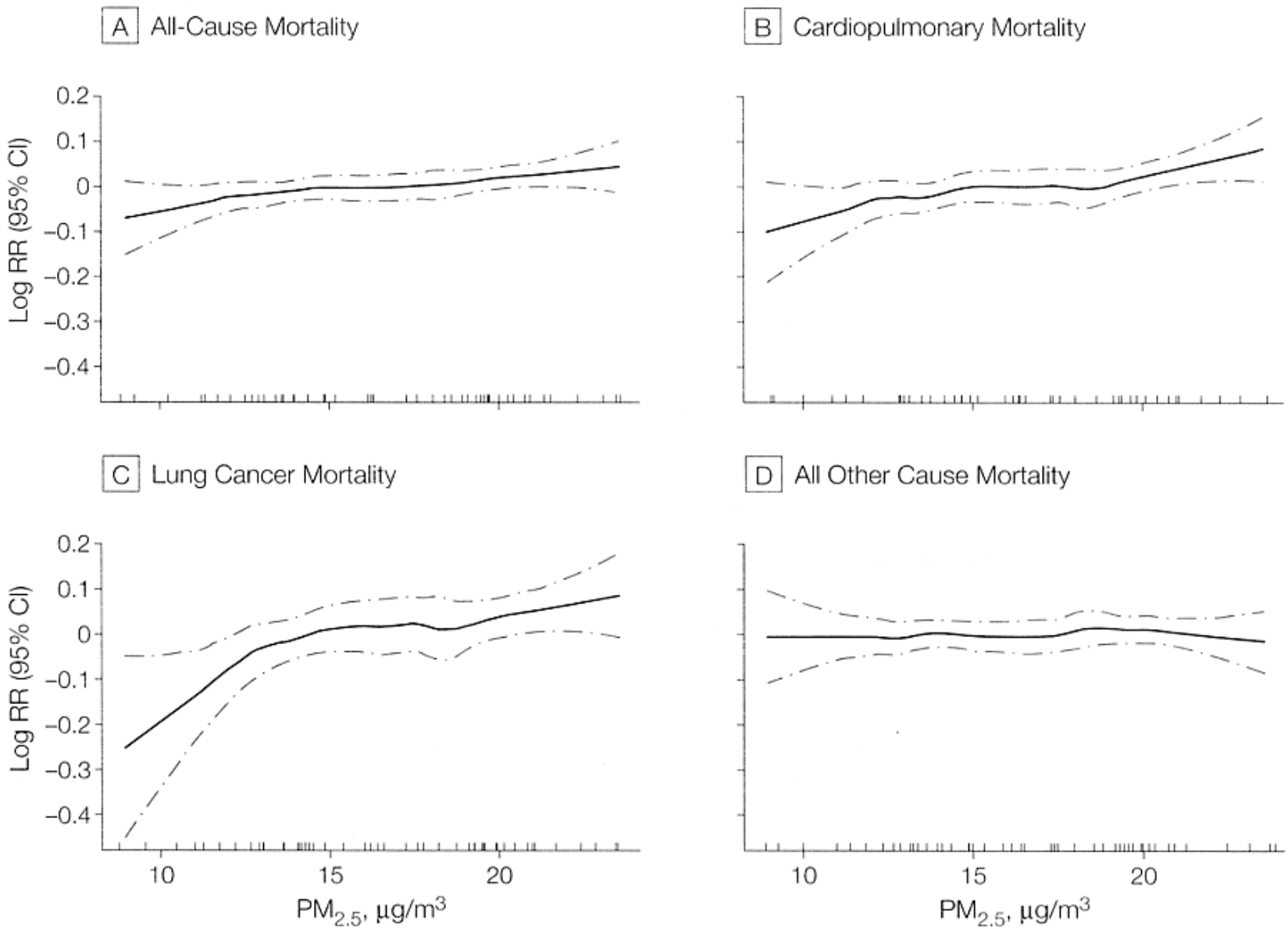
Context Associations have been found between day-to-day particulate ai and increased risk of various adverse health outcomes, including cardiopulmc tality. However, studies of health effects of long-term particulate air pollu been less conclusive.

Objective To assess the relationship between long-term exposure to fir late air pollution and all-cause, lung cancer, and cardiopulmonary mortalit

Design, Setting, and Participants Vital status and cause of death data lected by the American Cancer Society as part of the Cancer Prevention II stu going prospective mortality study, which enrolled approximately 1.2 million adu




Figure 2. Nonparametric Smoothed Exposure Response Relationship



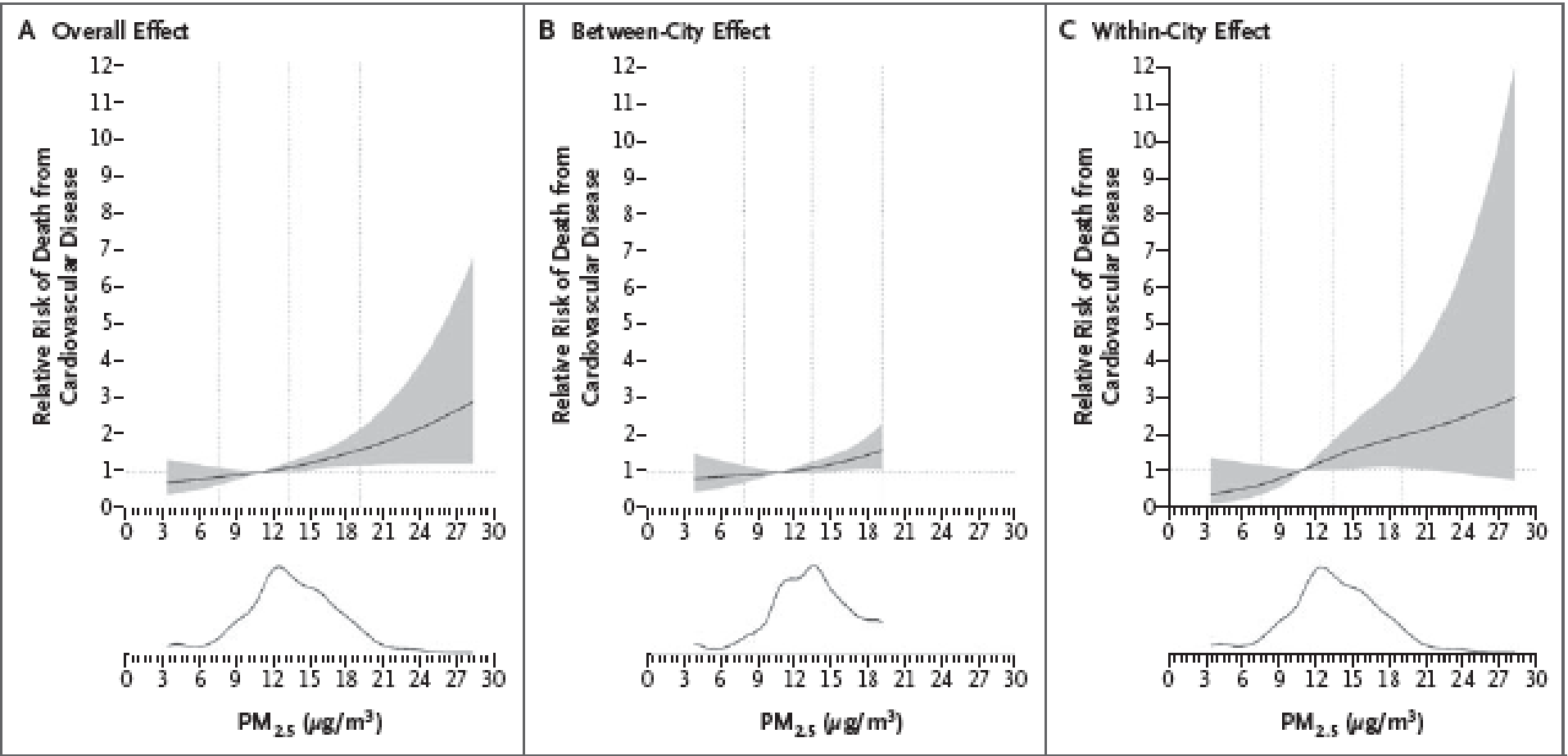


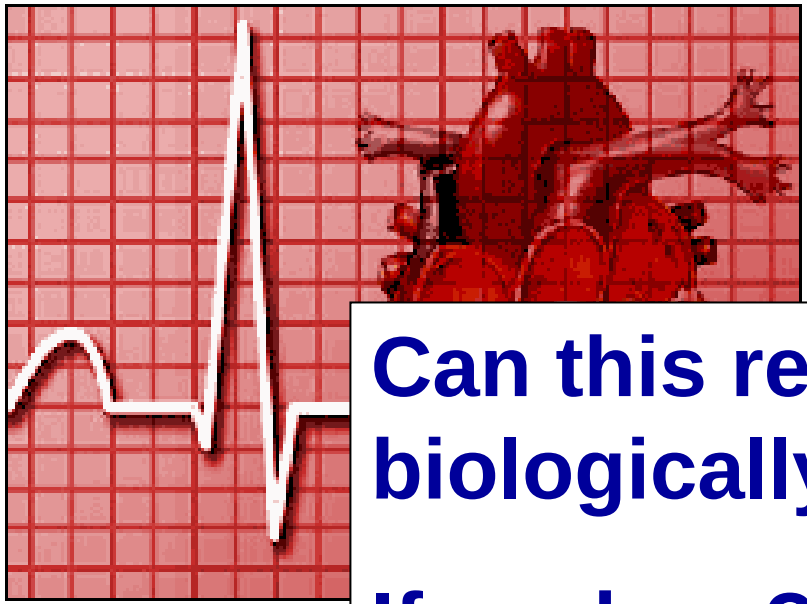
Figure 1. Level of Exposure to Fine Particulate Matter and the Risk of Death from Cardiovascular Causes in Women.

The graphs demonstrate the observed relationship between the risk of death from cardiovascular disease and the level of particulate matter of less than 2.5 μm in aerodynamic diameter ($PM_{2.5}$), including both definite and possible deaths from coronary heart disease or cerebrovascular disease. Panel A shows the overall relationship between the $PM_{2.5}$ level and death, Panel B the effects between metropolitan areas, and Panel C the effects within metropolitan areas, with an indicator variable used to adjust for each city. These results suggest a generally linear relationship between exposu
extremes of exposure. Risk is depicted in comparison wi
trates the density of exposure distribution for air pollut
household income, smoking status, systolic blood pres
tension, or hypercholesterolemia.

Miller et al. Long-Term exposure to Air Pollution and Incidence of Cardiovascular Events in Women. NEJM 2007

Air Pollution: Bad For Your Heart

DALLAS, Dec. 16, 2003



(AP / CBS)

(AP) Air pollution in U.S. cities causes twice as many deaths from heart disease as it does from lung cancer and other respiratory ailments, a surprising new study suggests.

QUOTE

"It certainly did su
observed these r
anticipated that b
your lungs would
direct impact on y
C. Arden Pope III, B'

Can this really be true?—is it biologically plausible?

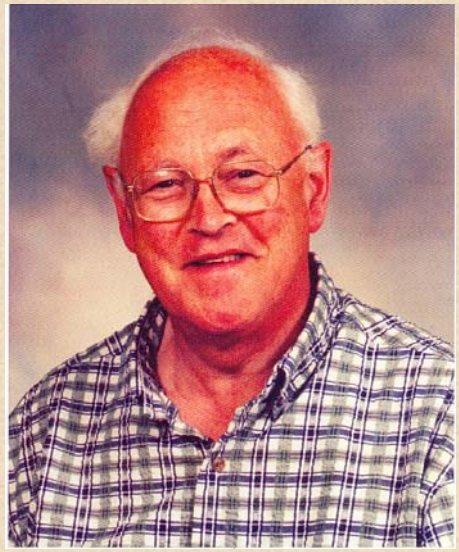
If so, how?—what are the pathopysiological pathways that link breathing air pollution and cardiovascular deaths?

Effects of fine PM on the → Lungs

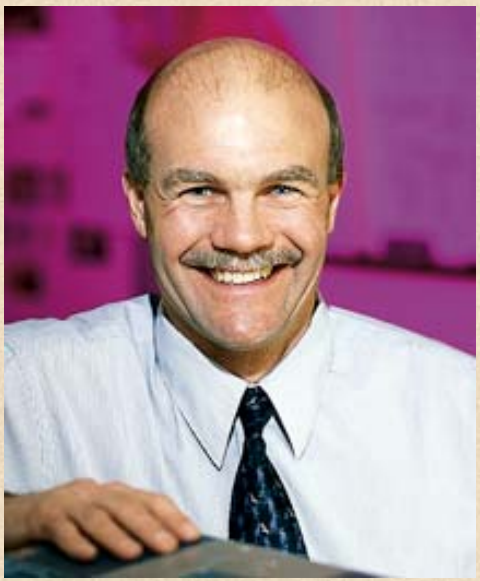
- Pulmonary Inflammation
- Reduced lung function
- Increased respiratory symptoms
- Accelerated progression and exacerbation of COPD

Southern California Children's Health Study

Effects of air pollution on children's health, especially lung function growth.

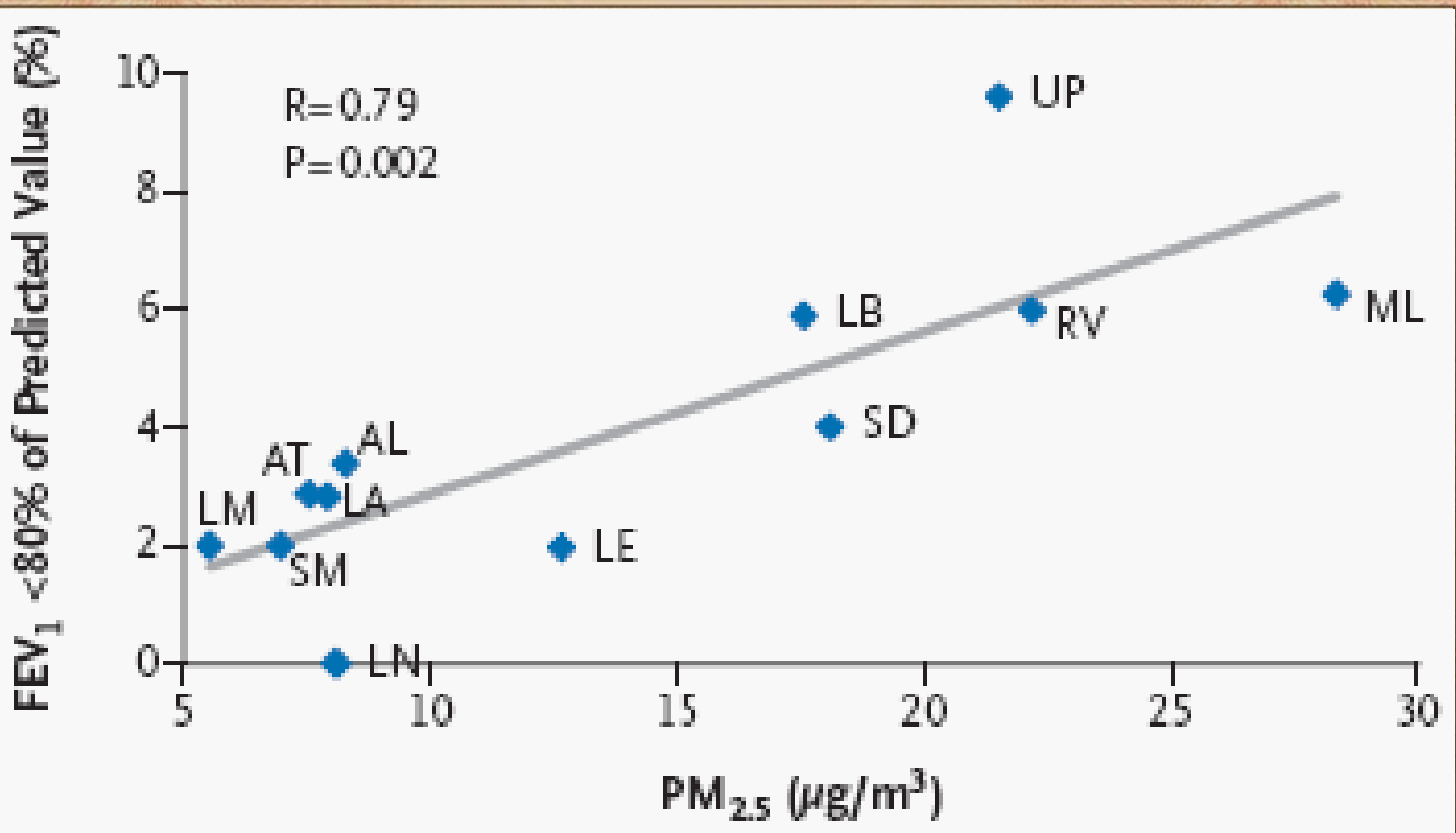


David Bates, Advisor



W. James Gauderman

John Peters



Gauderman et al. The effect of air pollution on lung development from 10 to 18 years of age. *New England Journal of Medicine* 2004

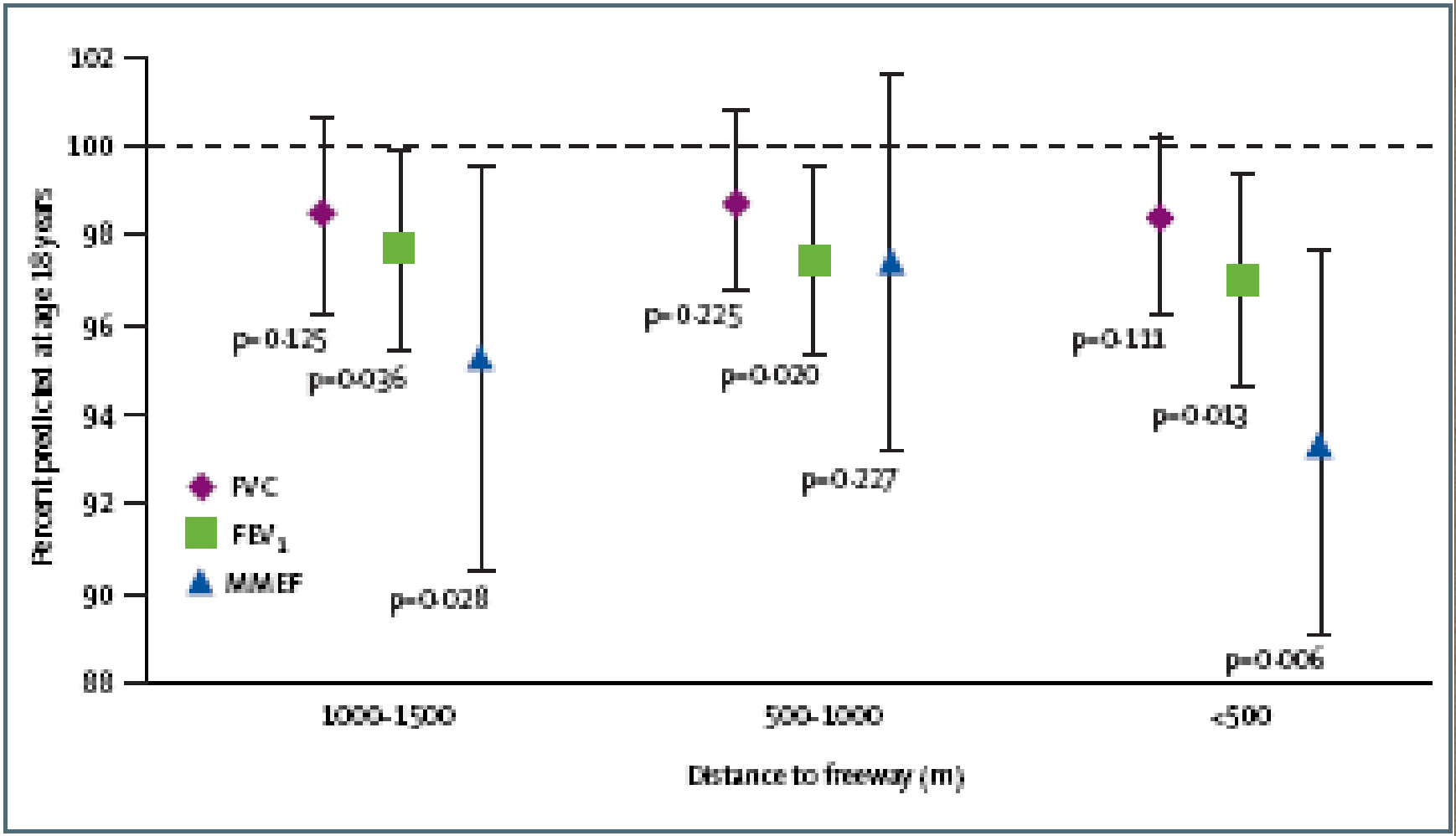


Figure: Percent-predicted lung function at age 18 years versus residential distance from a freeway
The horizontal line at 100% corresponds to the referent group, children living >1500 m from a freeway.

Gauderman et al. Effect of exposure to traffic on lung development from 10 to 18 years of age: a cohort study. *Lancet* 2007

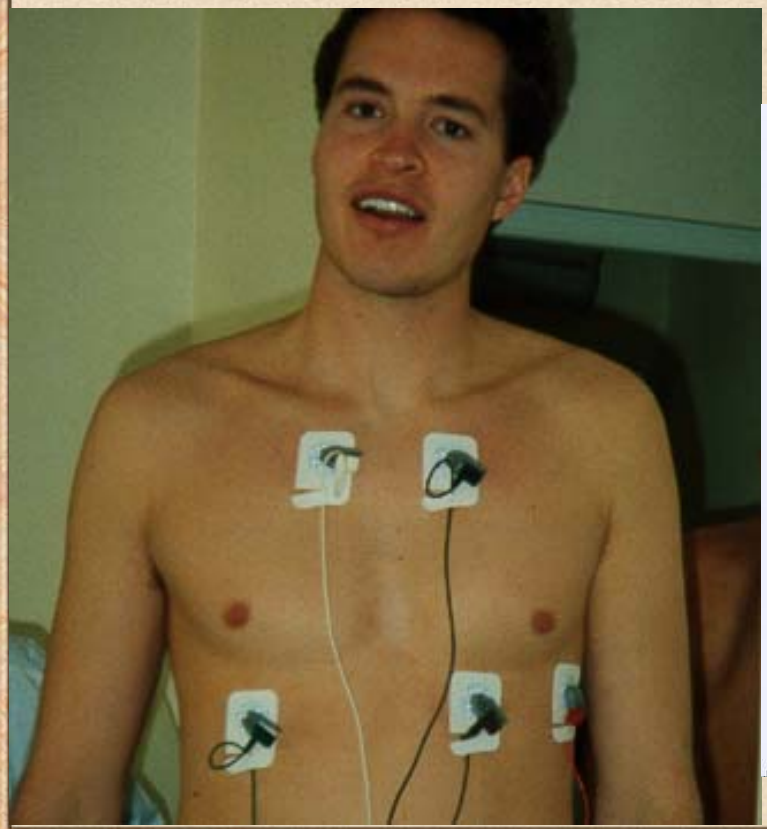
Effects of fine PM on

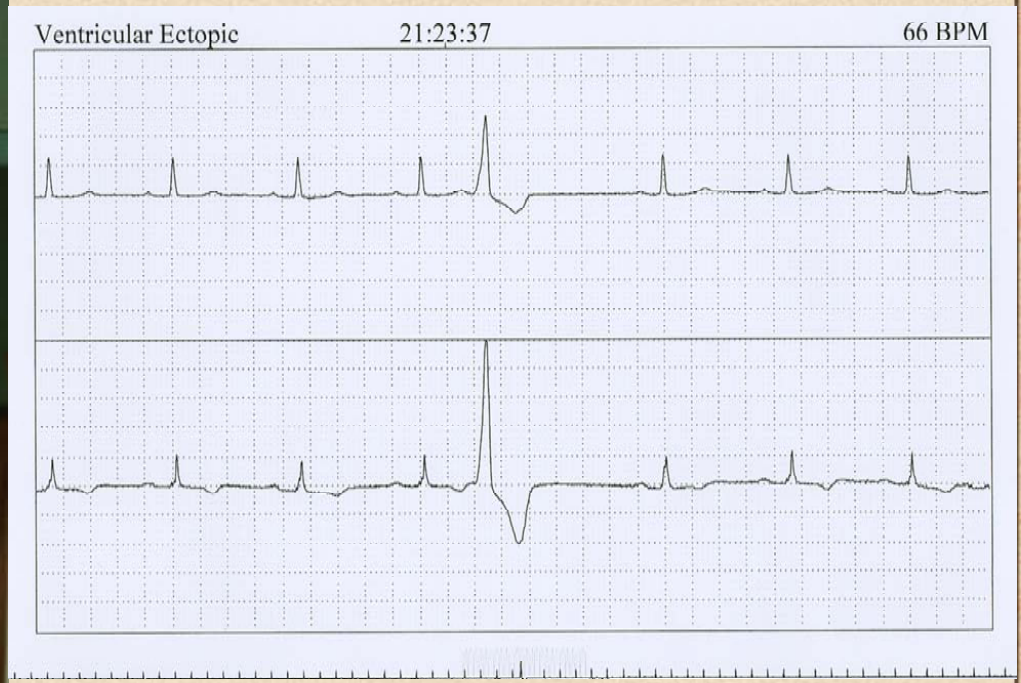
Blood Markers of Systemic Inflammation and Oxidative Stress

- **Increased CRP**
- **Proinflammatory mediators**
- **Leukocyte & platelet activation**
- **Increased blood coagulability**

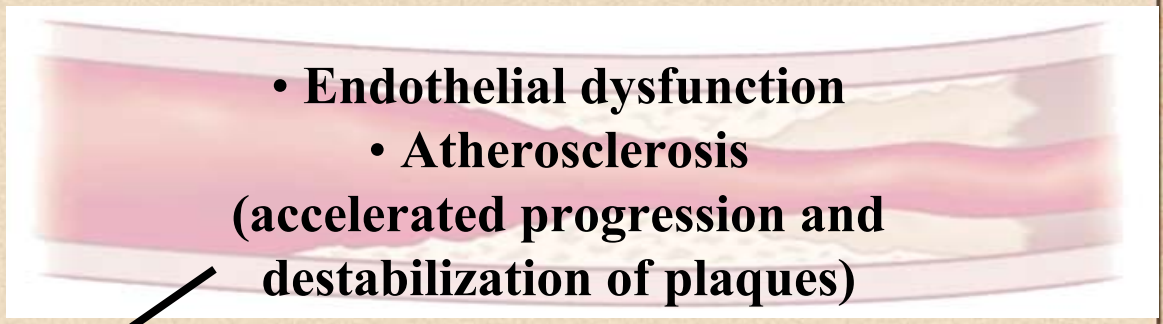
Effects of fine PM on

Cardiac Autonomic function and Cardiac Arrythmia



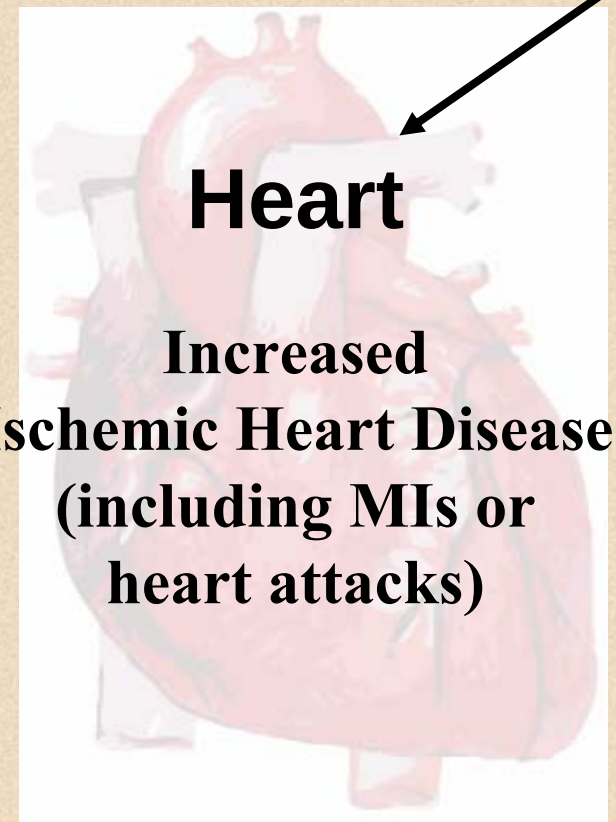


Effects of fine PM on → **Blood Vessels (vasculature)**



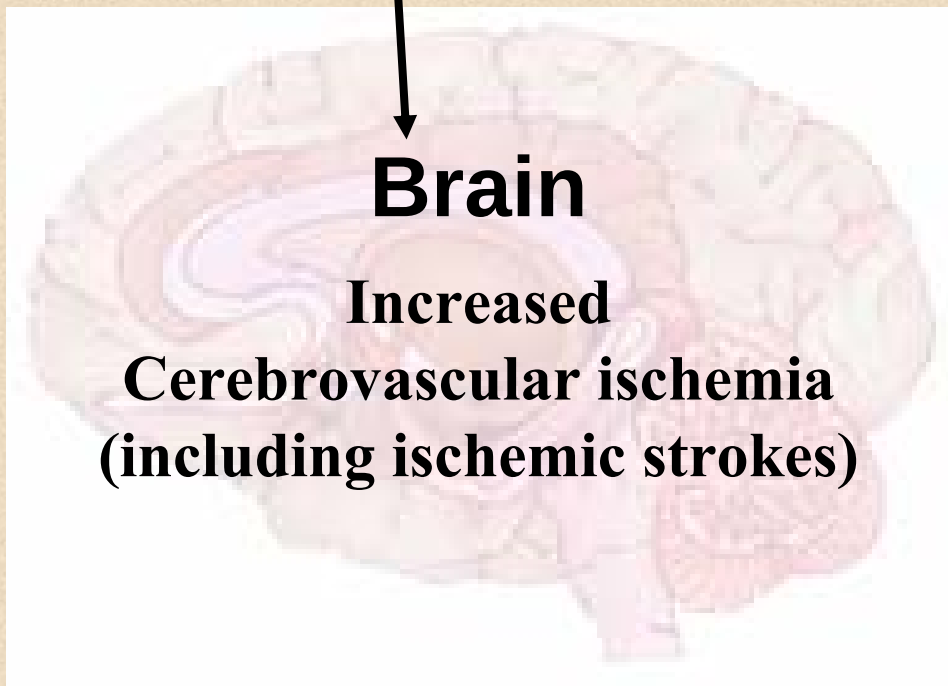
- Endothelial dysfunction
- Atherosclerosis

(accelerated progression and destabilization of plaques)



Heart

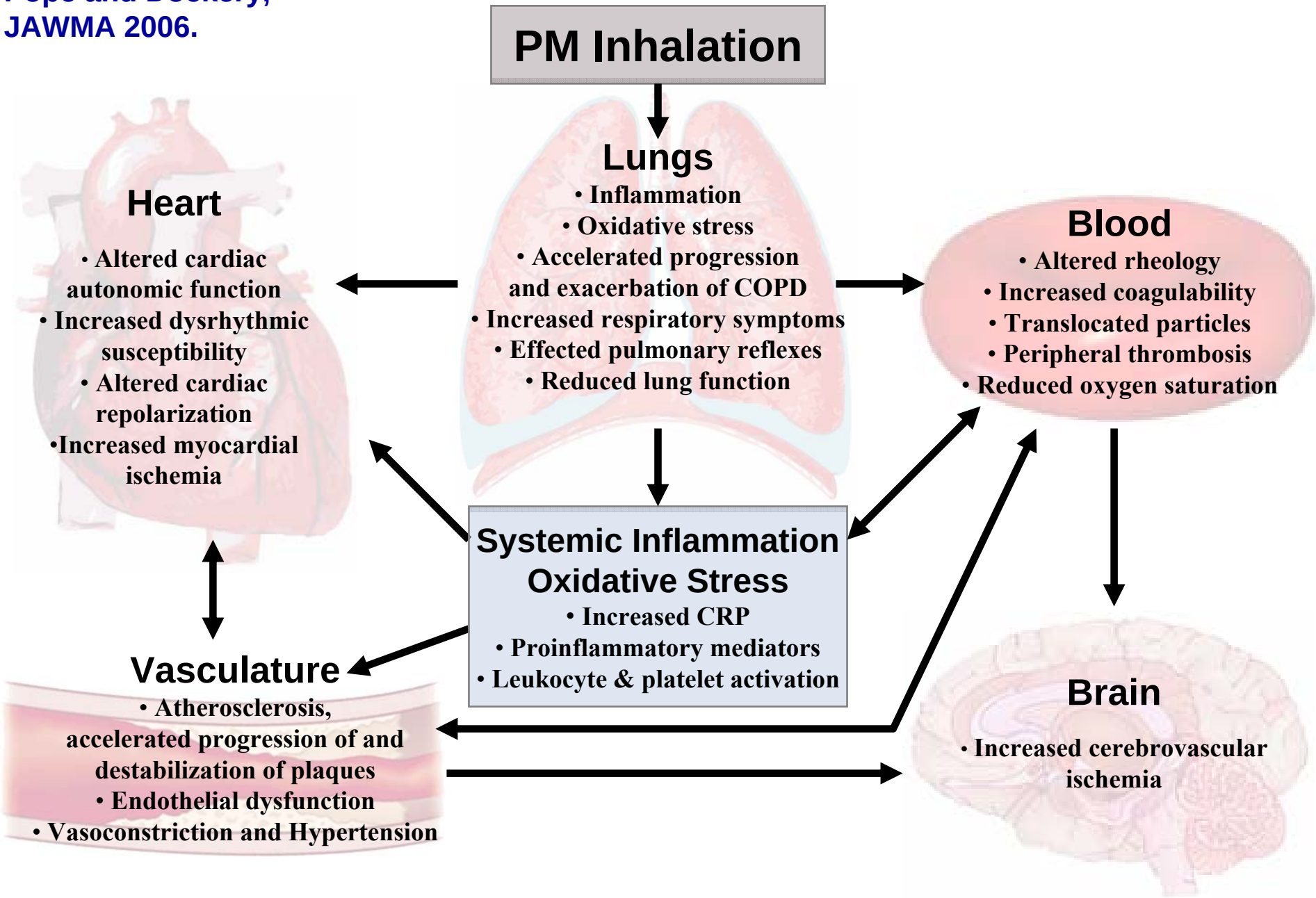
Increased Ischemic Heart Disease (including MIs or heart attacks)

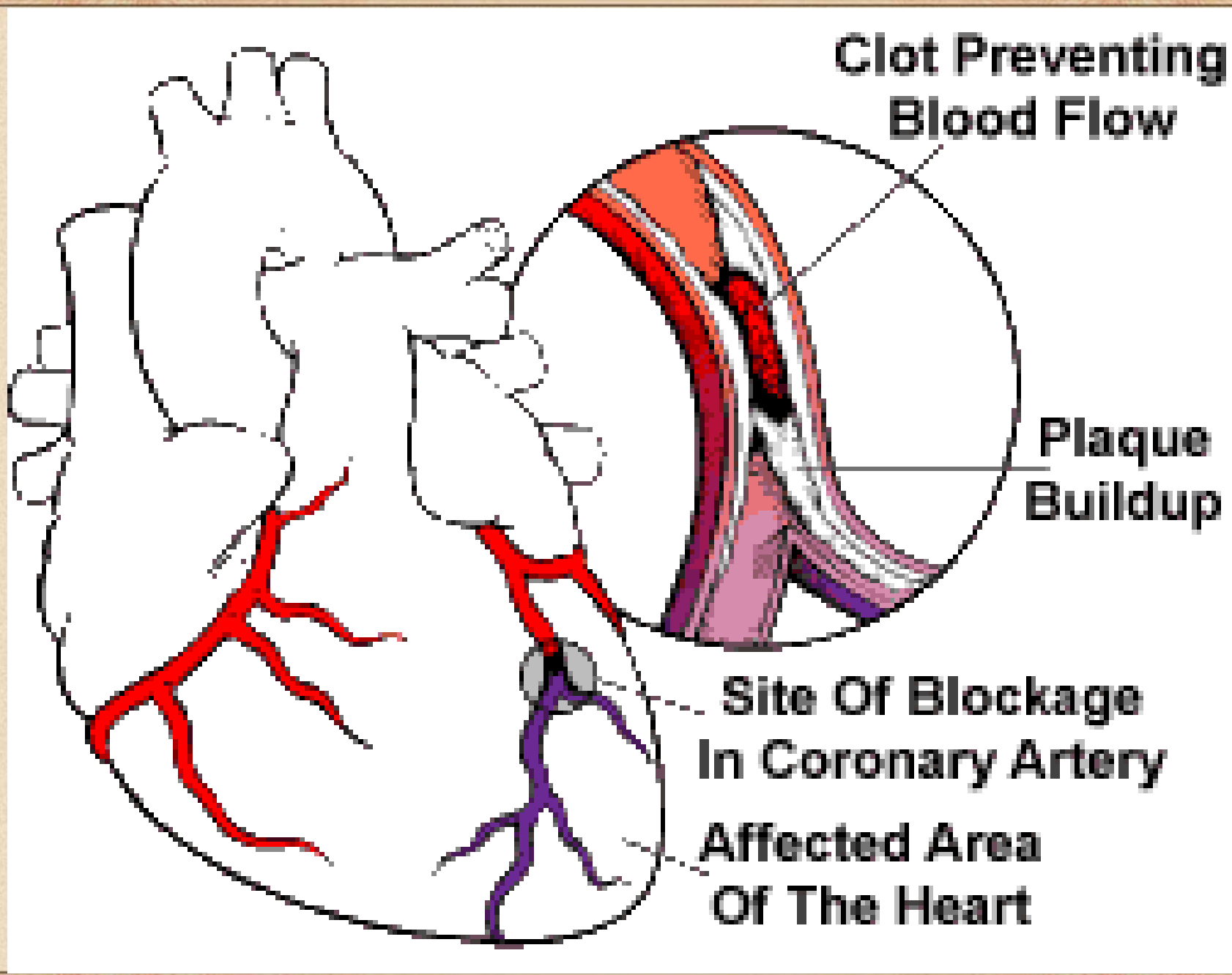


Brain

Increased Cerebrovascular ischemia (including ischemic strokes)

Pope and Dockery, JAWMA 2006.




Clot Preventing
Blood Flow
Plaque
Buildup
Site Of Blockage
In Coronary Artery
Affected Area
Of The Heart

So what does this have to do with air pollution?

Fine Particulate exposure

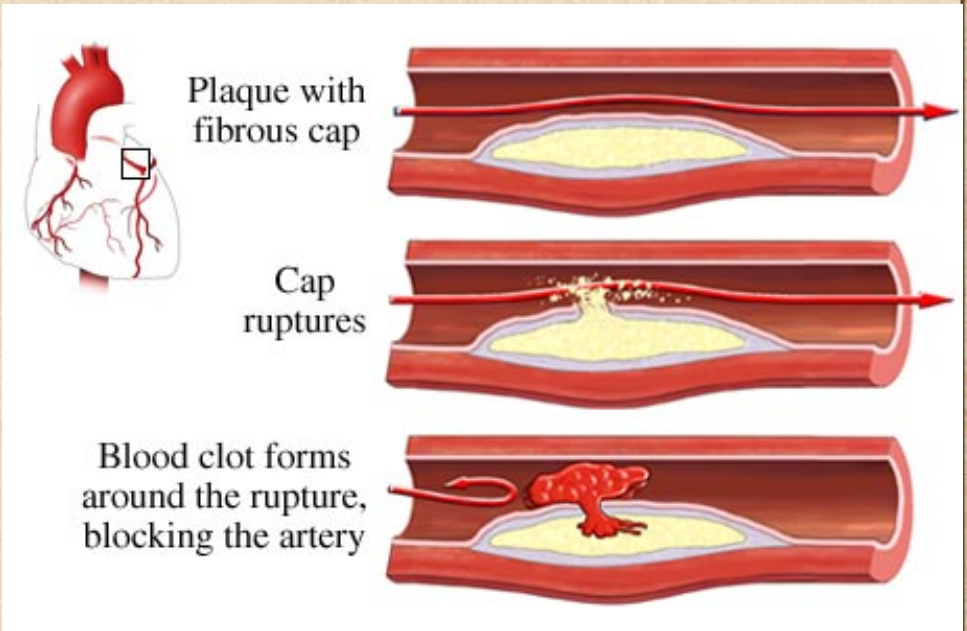
↓

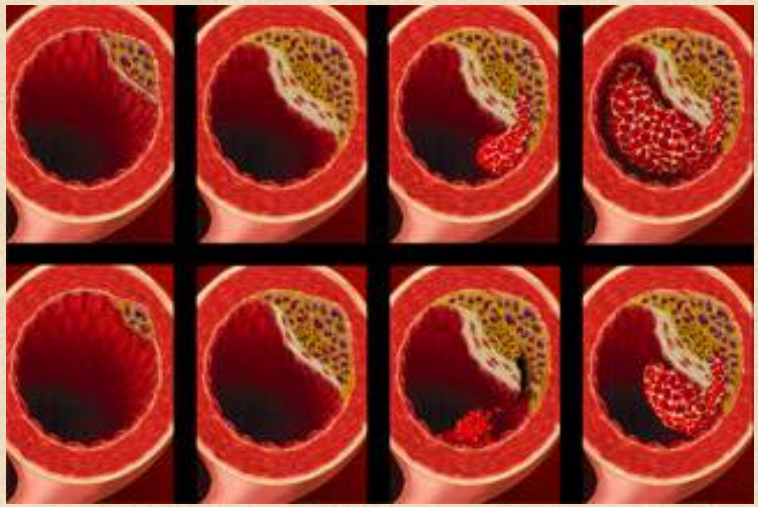
Pulmonary and systemic inflammation and oxidative stress

(along with blood lipids)

↓

Progression and destabilization of atherosclerotic plaques





A series of studies (1997-2002) by Stephan van Eeden, James Hogg, and others found that in rabbits naturally prone to develop atherosclerosis,

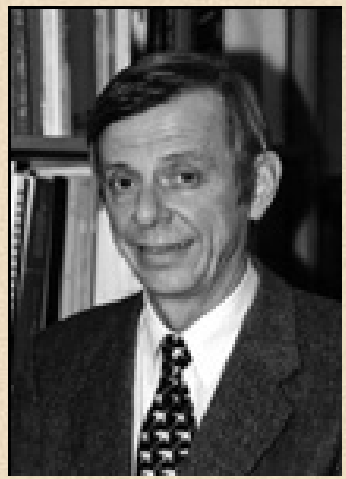
Fine particulate exposure

↓↓

Accelerated progression of atherosclerotic plaques

with greater vulnerability to plaque rupture

Stephan van Eeden



James Hogg

Sun et al. (*JAMA* 2005)

Representative Photomicrographs of Aortic Arch Sections

Normal Chow

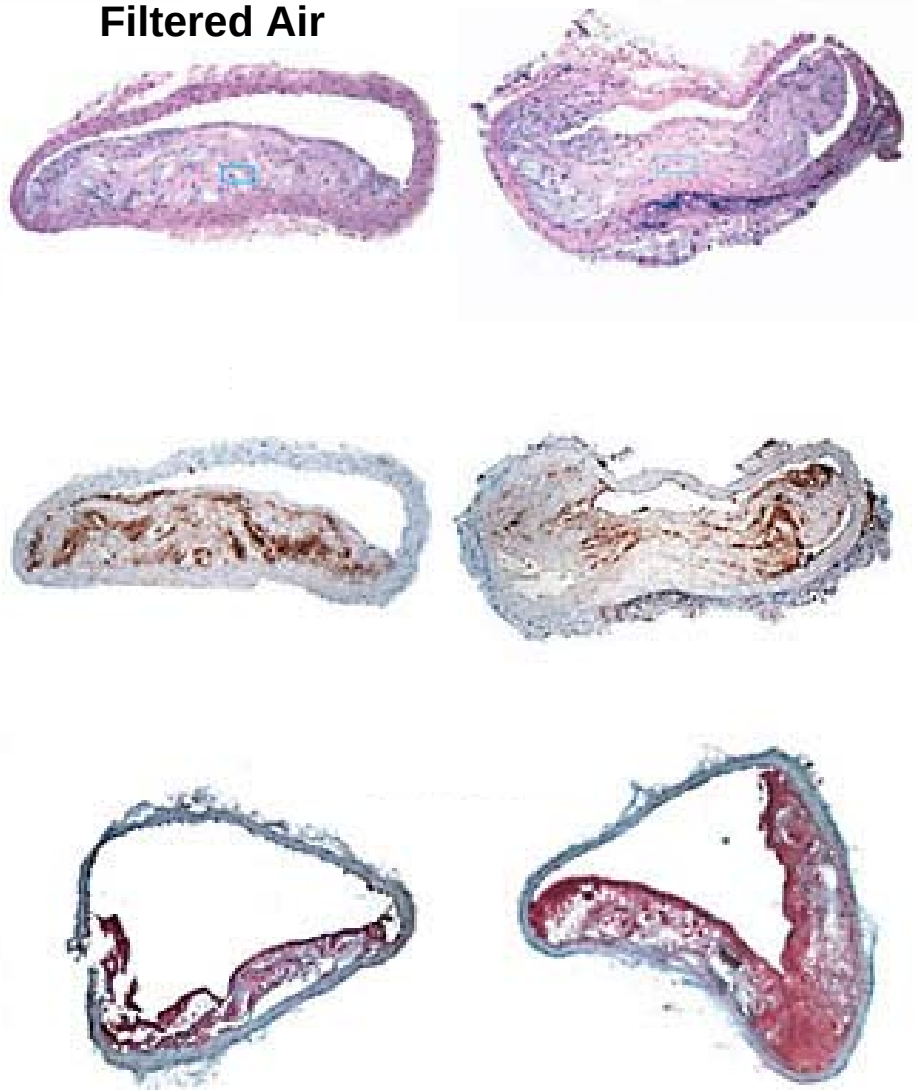
Clean Filtered Air

PM Polluted Air

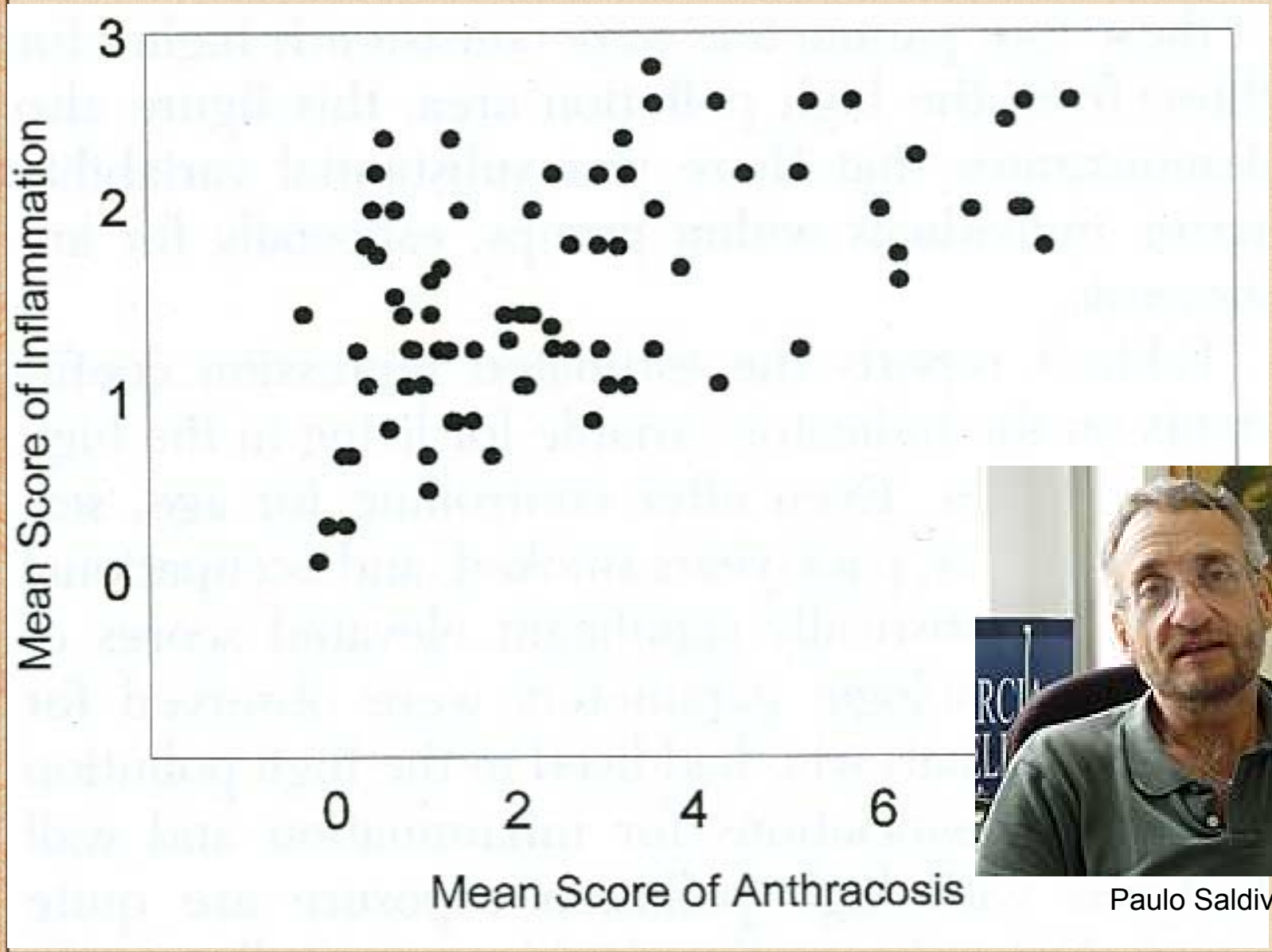
High-Fat Chow

Clean Filtered Air

PM Polluted Air



Example 1. Souza, Saldiva, Pope, Luiza. *Chest* 1998



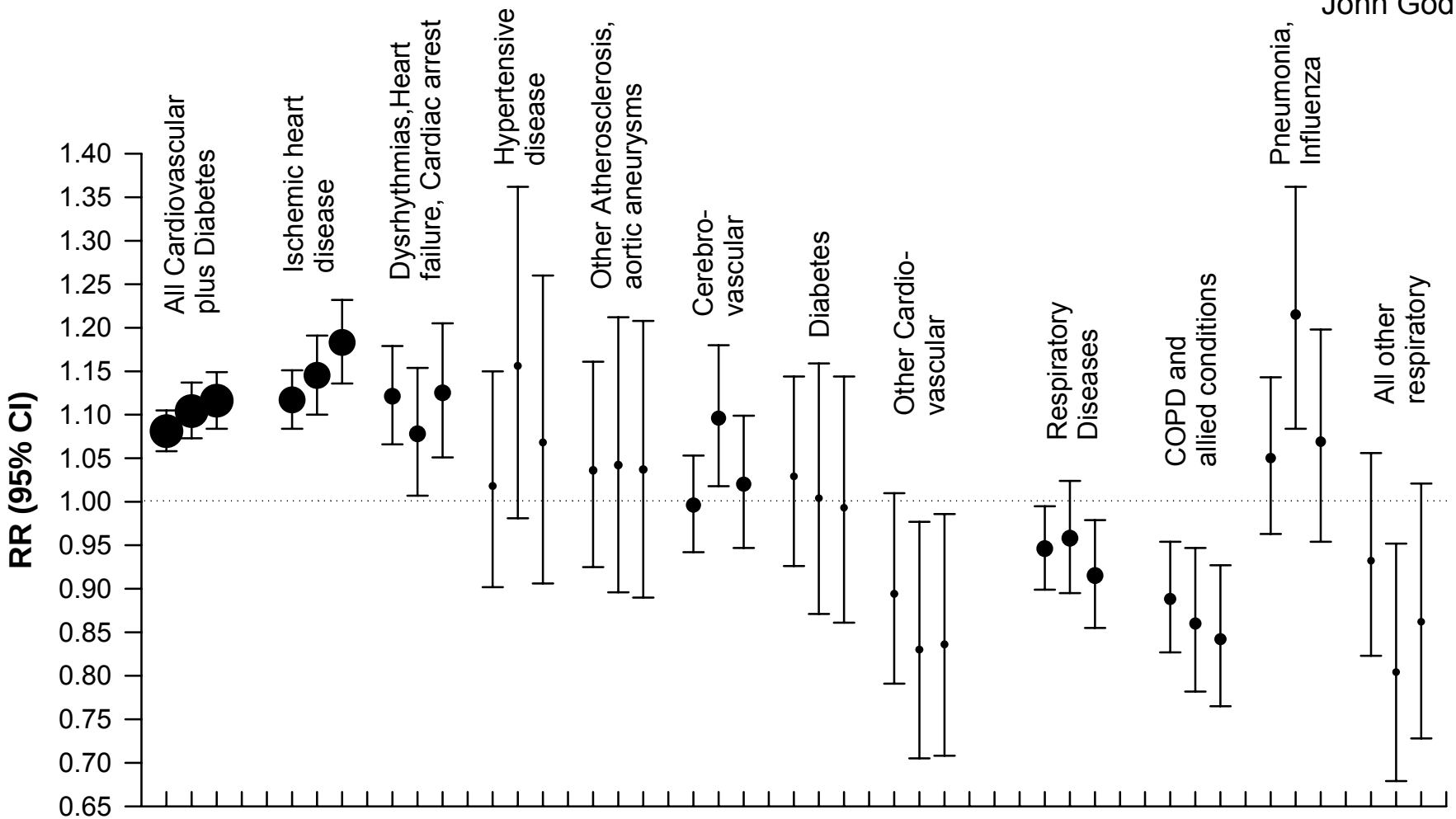
Paulo Saldiva

Example 2. Pope, et al. ***Circulation*** 2004

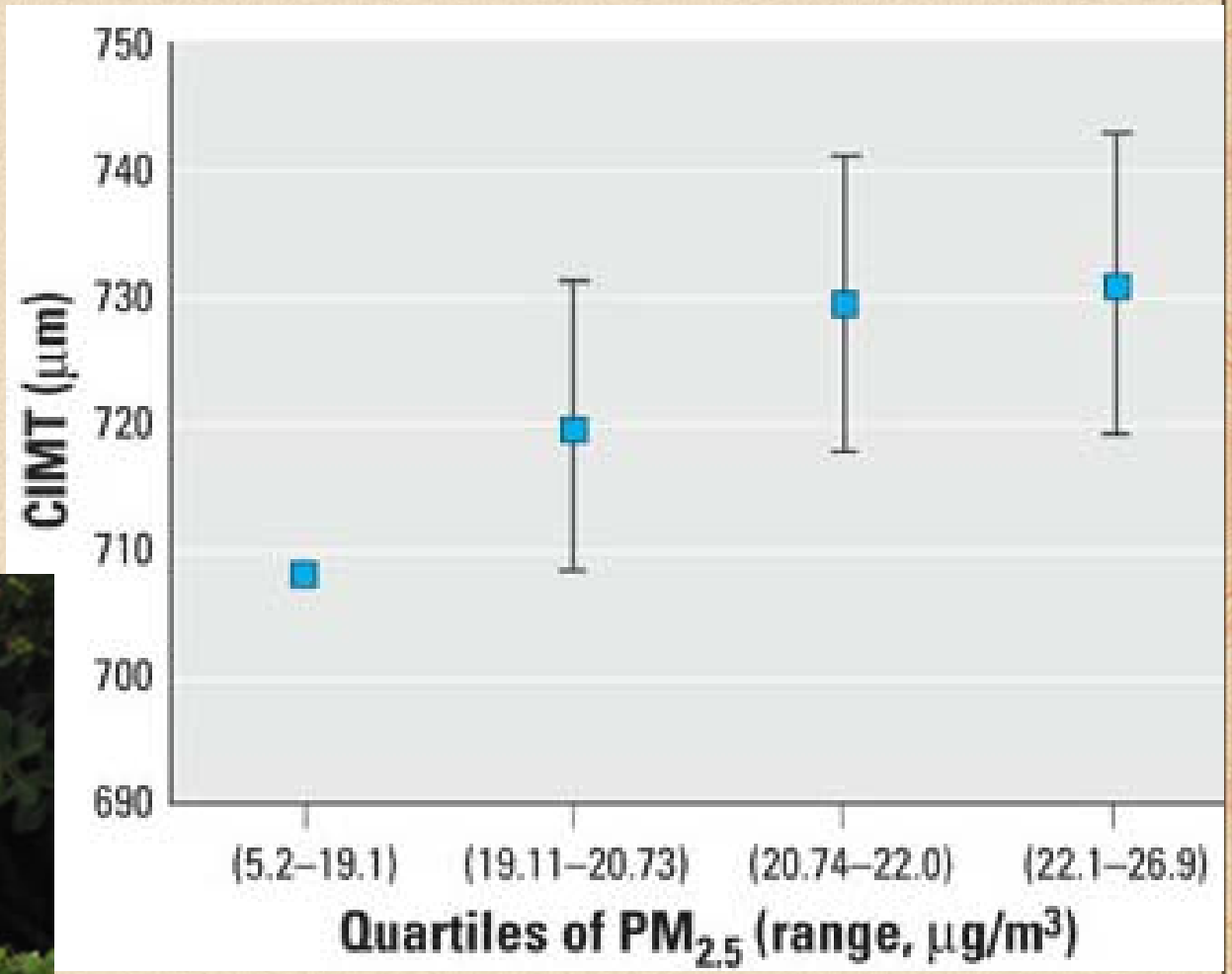
John Godleski

Cardiovascular Mortality and Long-Term Exposure to Particulate Air Pollution

Epidemiological Evidence of General Pathophysiological Pathways of Disease



Example 3: Kunzli et al. *EHP* 2005



Ursula Ackermann-Liebrich and Nino Kunzli

Example 4.

Ischemic Heart Disease Events Triggered by Short-Term Exposure to Fine Particulate Air Pollution

C. Arden Pope III, PhD; Joseph B. Muhlestein, MD; Heidi T. May, MSPH; Dale G. Renlund, MD; Jeffrey L. Anderson, MD; Benjamin D. Horne, PhD, MPH

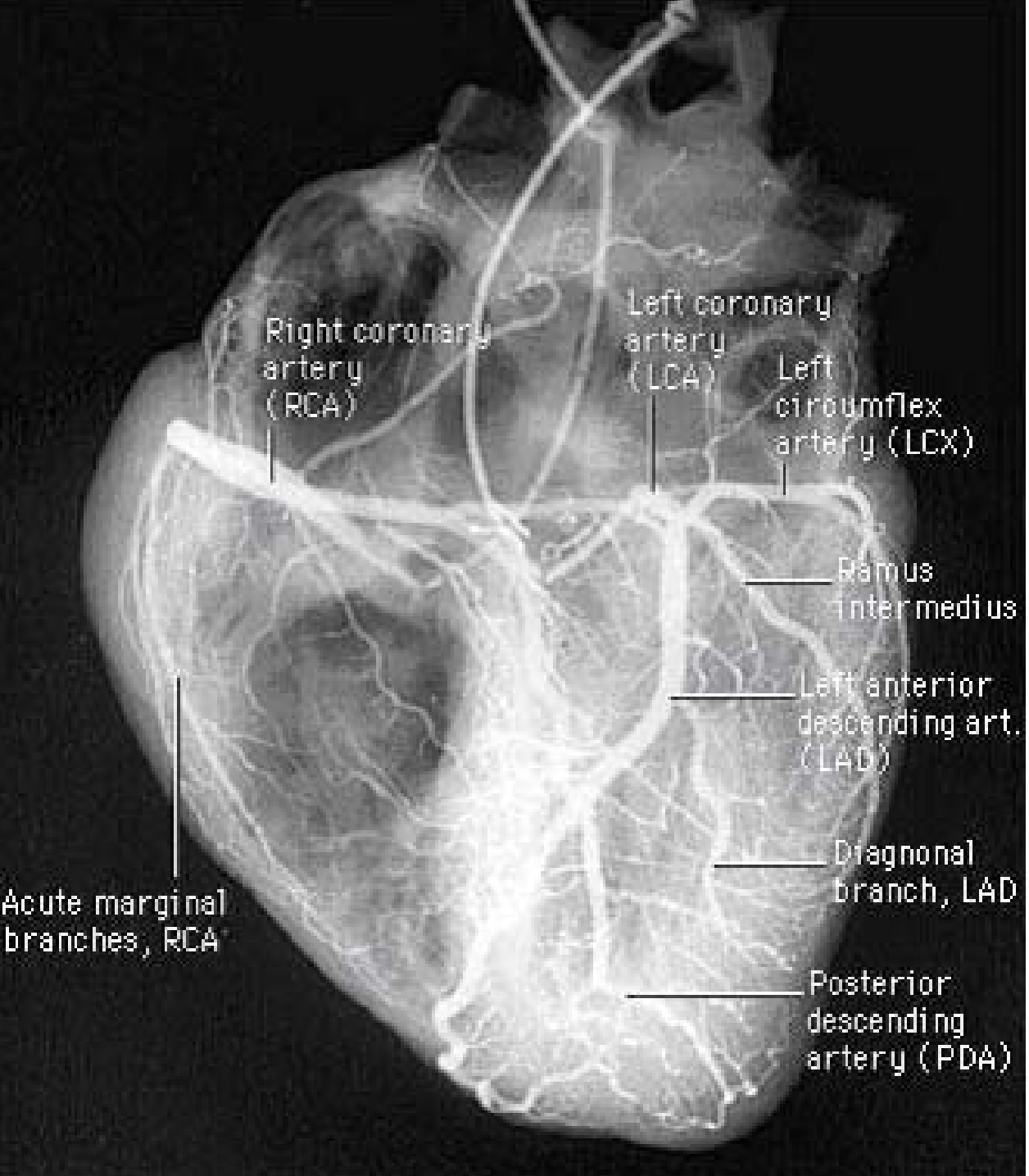
Circulation. 2006;114-2443-2448.

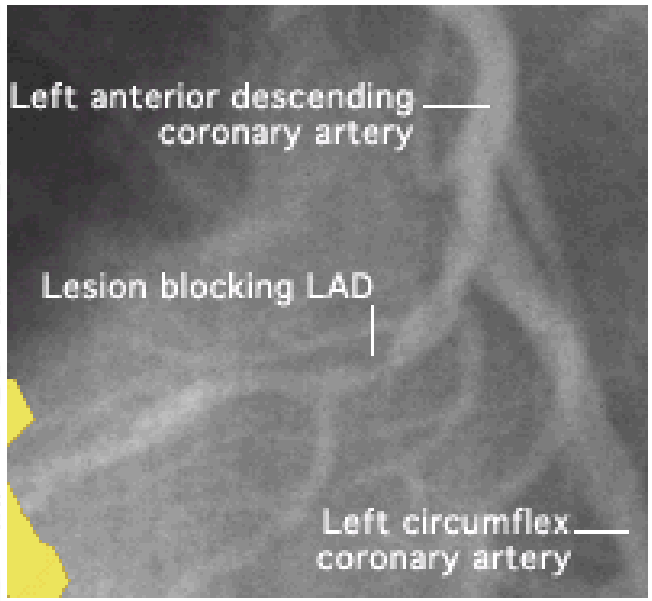
Methods:

Case-crossover study of acute ischemic coronary events (heart attacks and unstable angina) in 12,865 well-defined and followed up cardiac patients who lived on Utah's Wasatch Front.

Jeffrey Anderson

Using cardiac angiography, cardiologists can obtain images of the arteries of the heart.





The NEW ENGLAND JOURNAL of MEDICINE

Air Pollution and Health — Good News and Bad

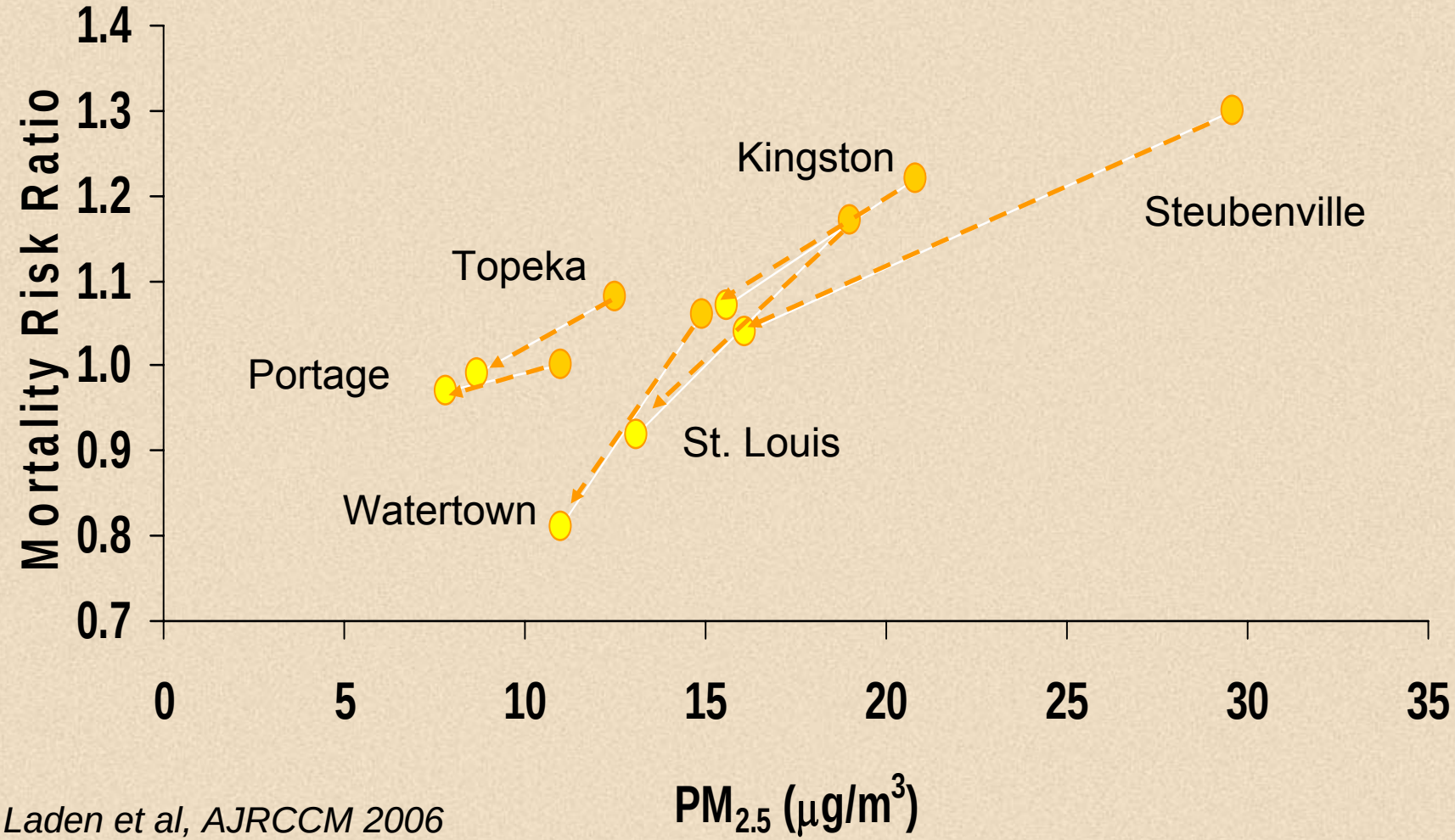
C. Arden Pope III, Ph.D.

NEJM 2004

From at least one perspective, these results are good news—

Air pollution is just one of many risk factors for cardiopulmonary disease, but it is a risk factor that can be modified and controlled.

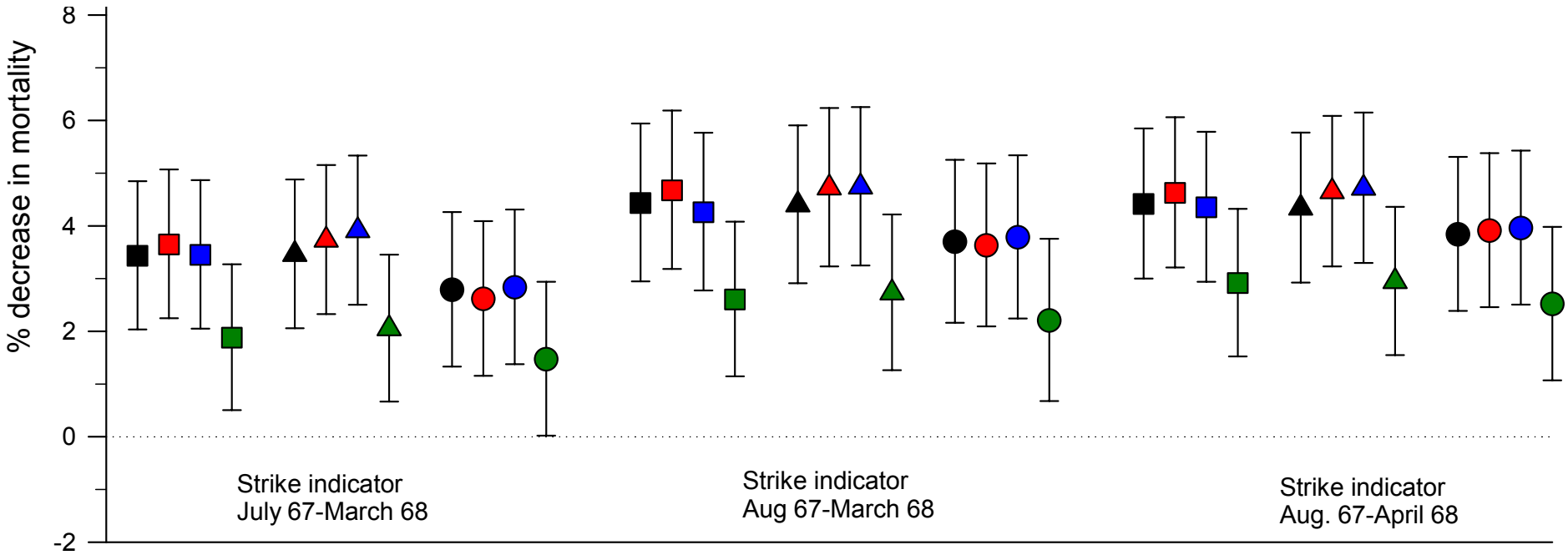
Six Cities Cohort Follow-up



Laden et al, AJRCCM 2006

Mortality Effects of a Copper Smelter Strike and Reduced Ambient Sulfate Particulate Matter Air Pollution

Pope et al. EHP 2007



Beijing commuters, Dec. 14, 2004. (Reuters/ReinhardKrause files, Science News, Jan. 25,2007)