Air Pollution and Children's Health

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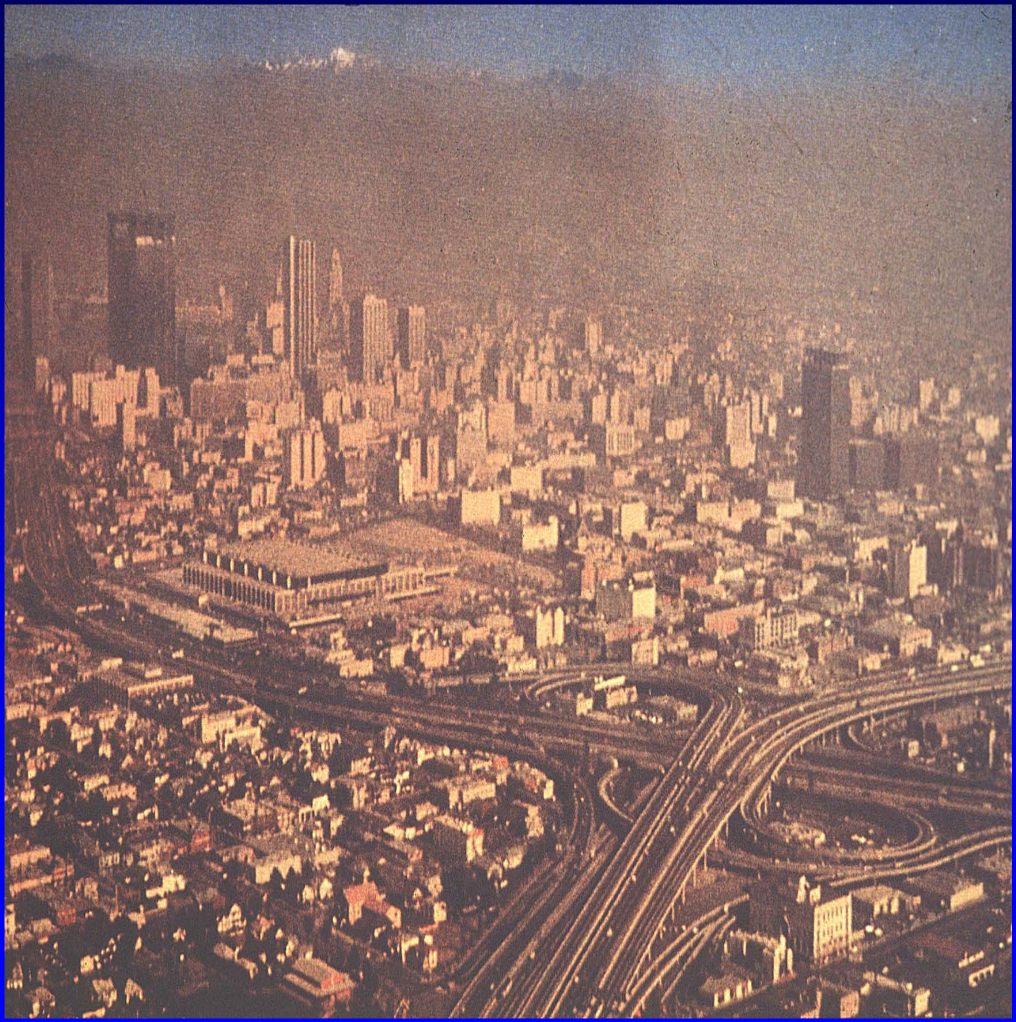
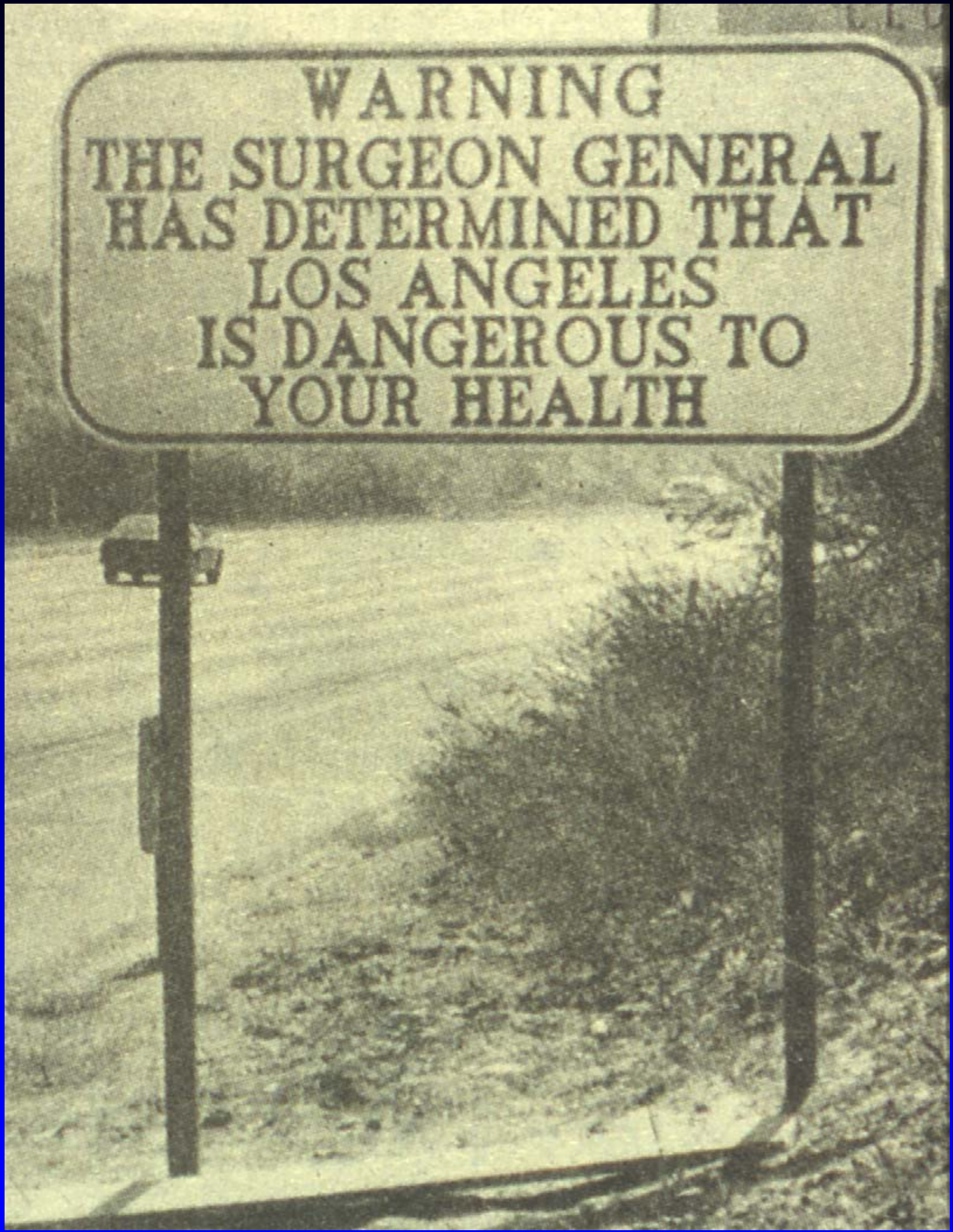
Does breathing air pollution cause health effects in children?

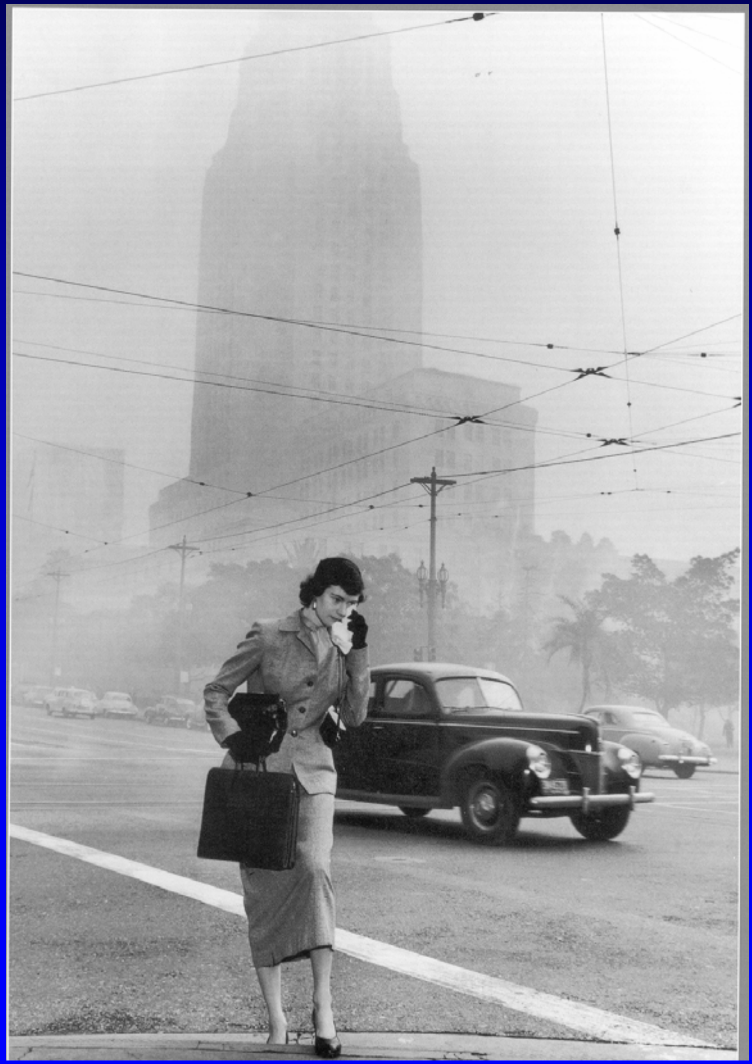


Don’t we already know air pollution is bad for us?



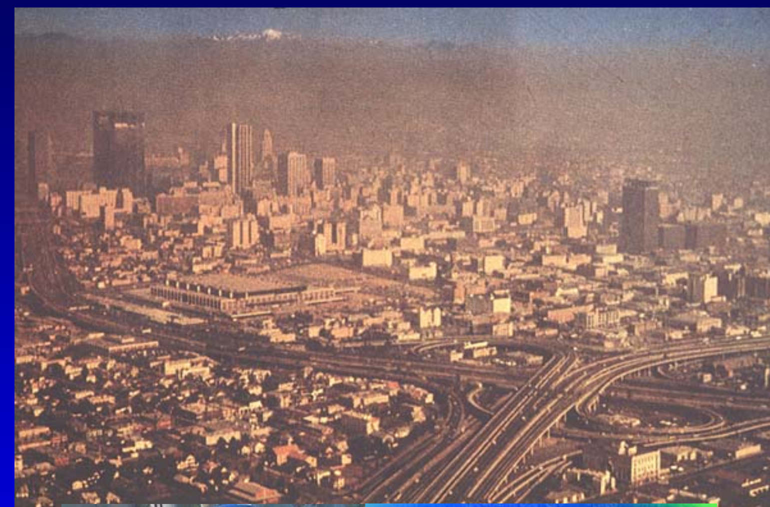
Well Established

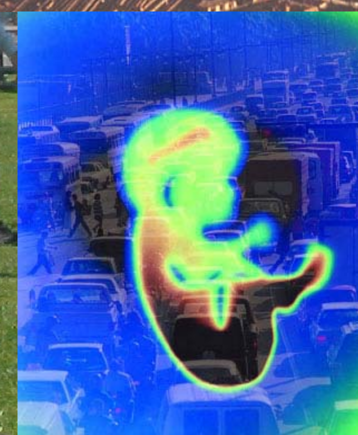
- Air pollution causes acute (short-term) effects, e.g.
  - Physician visits
  - Lung function changes
  - Acute symptoms in asthmatics and other susceptible subgroups



Less-Well Understood

- Are <u>chronic</u> health effects caused by exposure to outdoor air pollution?
  - Reduced Lung Development?
  - Onset of Asthma?
  - Pre-natal effects?





Why Study Children?

- **Exposure**
  - **They spend more time outdoors**
  - **They are more active**

- **Physiology**
  - **They have higher ventilation rates**
  - **They are still growing**

- **Logistics**
  - **Easier to find…kids go to school**

The USC Children's Health Study

Principal Investigator:

John Peters

Co-investigators:

Ed Avol
Kiros Berhane
Jim Gauderman
Frank Gilliland
Mike Jerrett
Fred Lurmann
Nino Kuenzli
Rob McConnell
Duncan Thomas

The USC Children's Health Study

Funding:

California Air Resources Board

NIEHS

U.S. EPA

NHLBI

The Hastings Foundation

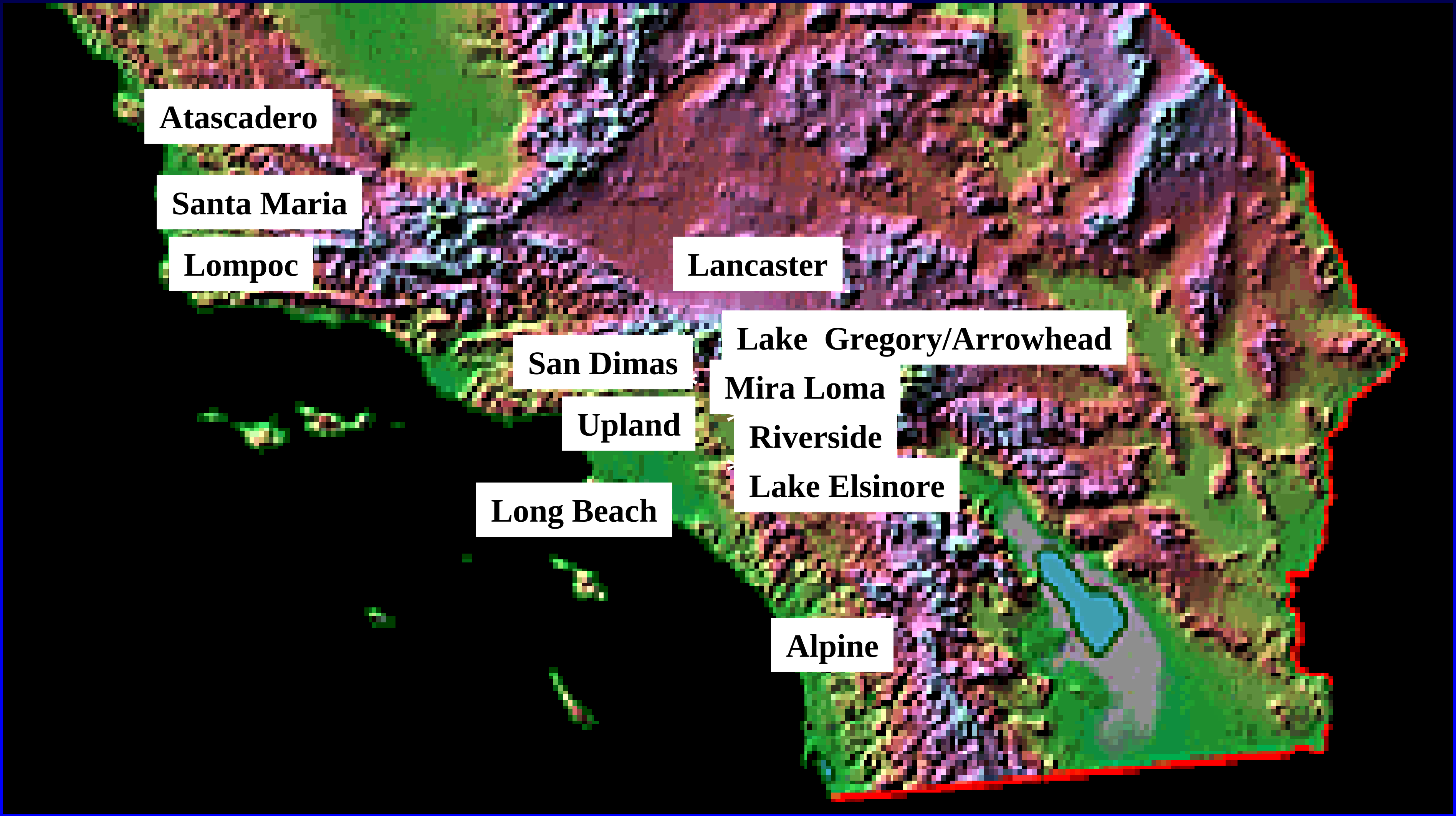
CHS Goals

- Is childhood exposure to ambient pollutants associated with:
  - Lung function development?
  - Chronic respiratory symptoms?
  - School absence?
  - Onset of asthma?

Child groups studied and their ages each year

Grade	(#)	1993	1994	1995	1996	1997	1998	1999	2000	2001
4th	(1,800)	10	11	12	13	14	15	16	17	18
7th	(900)	13	14	15	16	17	18			
10th	(900)	16	17	18						
4th	(2,000)				10	11	12	13	14	15

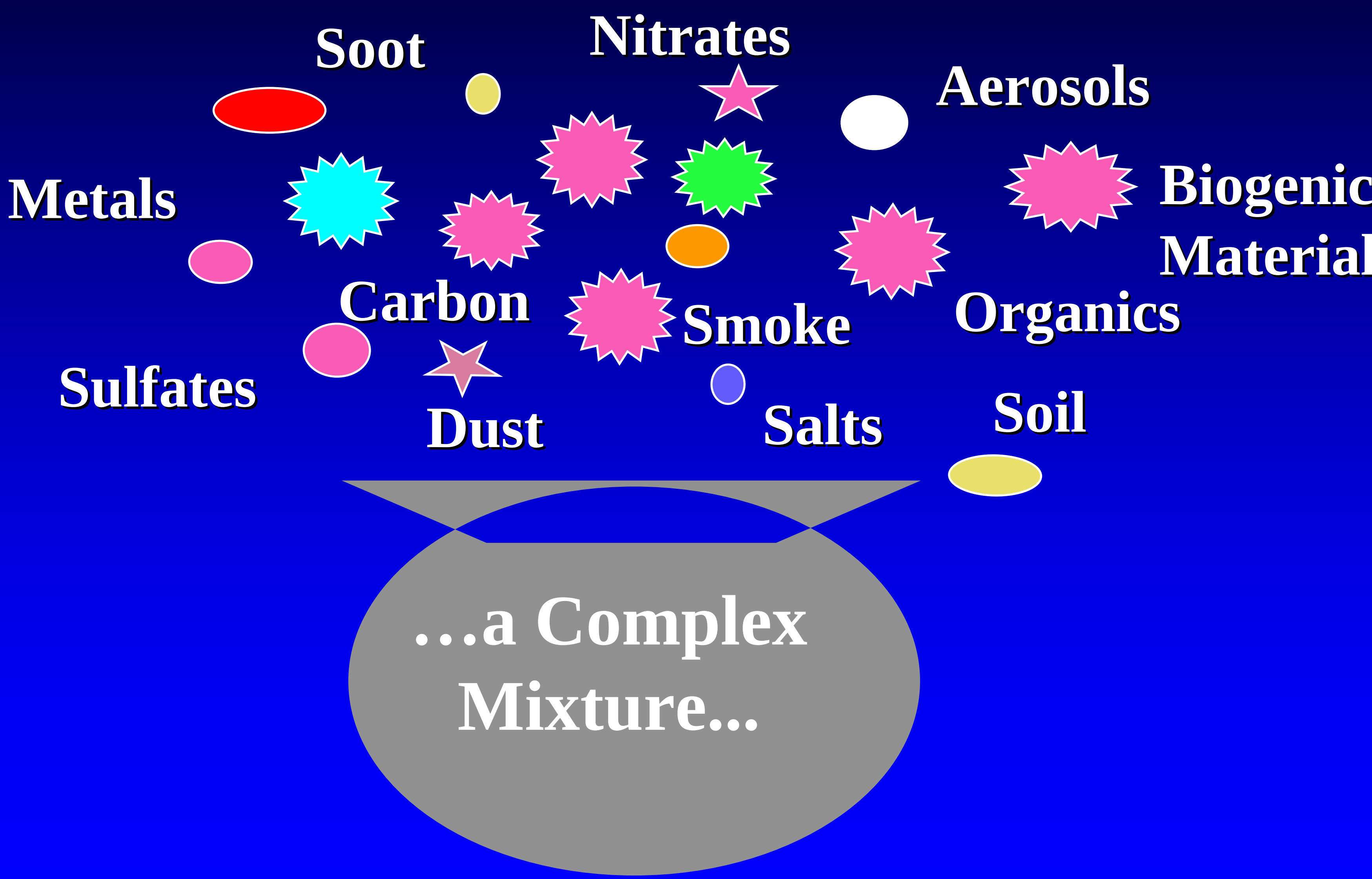
12 CHS Study Communities



Summary of Pollutants

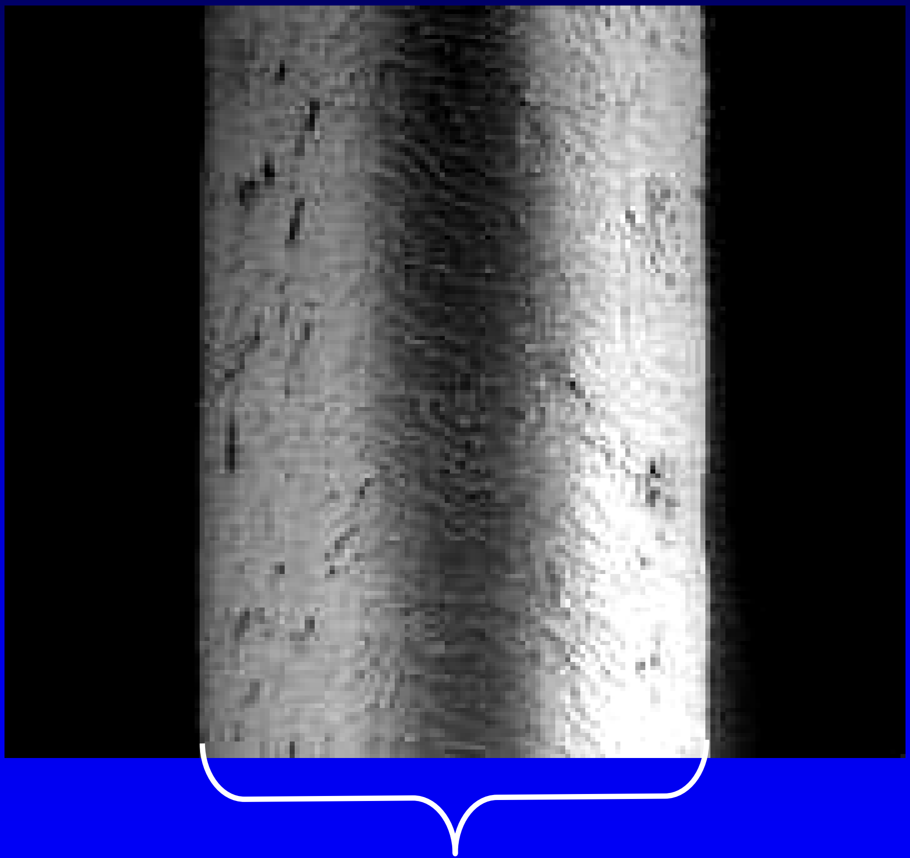
- Continuous monitoring at a central site in each study community since 1994
  - Particulate Matter: PM_{10}, $PM_{2.5}$, EC, OC
  - Nitrogen Dioxide (NO_2)
  - Acid vapor: Primarily nitric acid
  - Ozone (O_3)

What is PM?

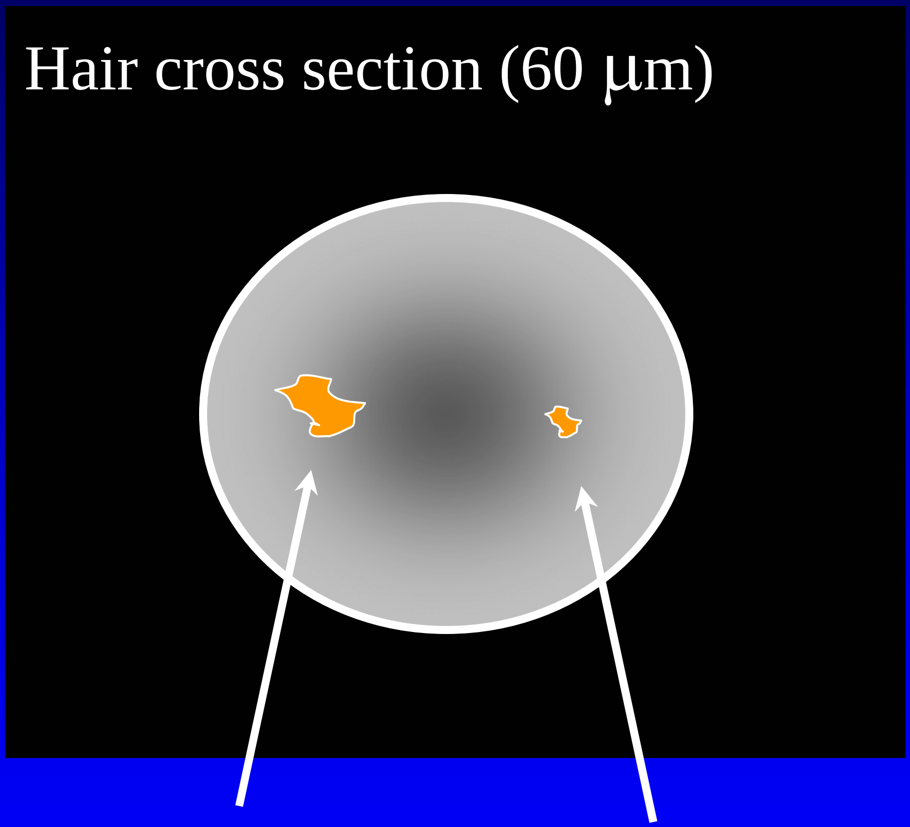


Soot
Nitrates
Aerosols
Metals
Biogenic
Material
Carbon
Smoke
Organics
Sulfates
Dust
Salts
Soil
…a Complex
Mixture...

How Small is Particulate Matter?



Human Hair
(60 μm diameter)

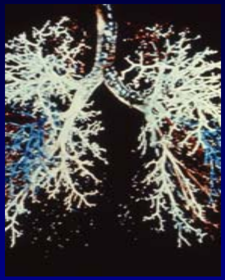


PM10
(10 μm)

PM2.5
(2.5 μm)

The Effect of Air Pollution on Lung Development from 10 to 18 Years of Age

(Gauderman et al., New Eng J Med, 351:1057-67, 2004)



Grade	(#)	1993	1994	1995	1996	1997	1998	1999	2000	2001
4th	1,759	10	11	12	13	14	15	16	17	18
7th	(900)	13	14	15	16	17	18			
10th	(900)	16	17	18						
4th	(2,000)				10	11	12	13	14	15

Annual Spirometry

Lung function measures:

- Forced expiratory volume in 1 second (FEV_1)
- Forced vital capacity (FVC)
- Maximal mid-expiratory flow (MMEF)

Additional Data...

Active smoking?

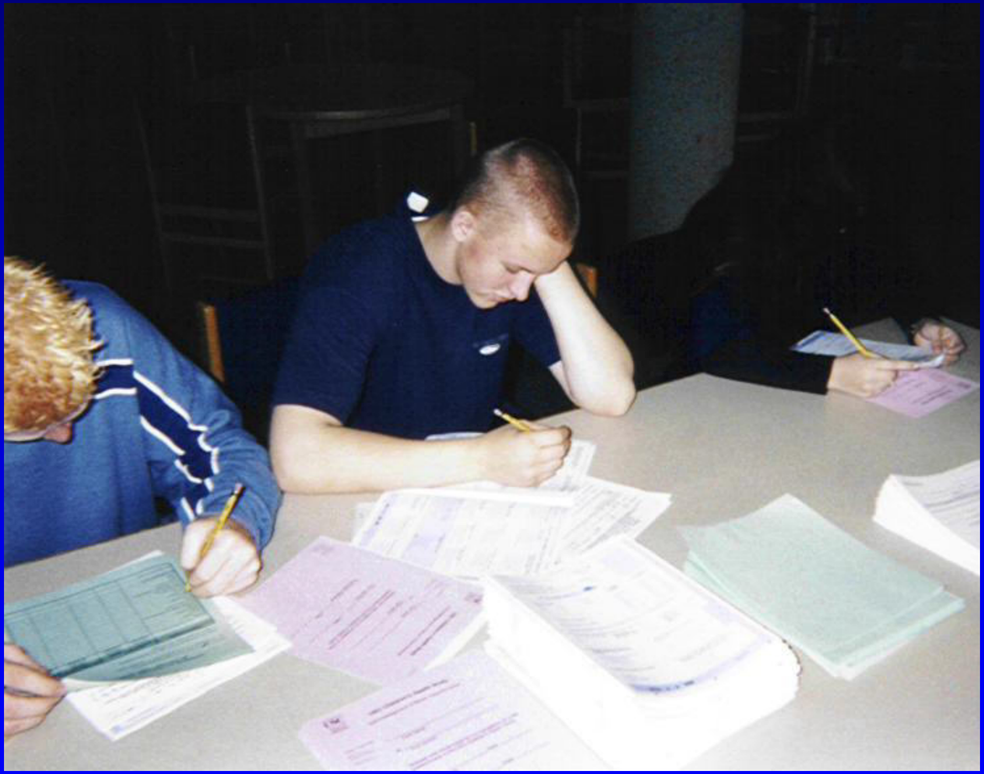
Height?

Asthma?

Gas stove?

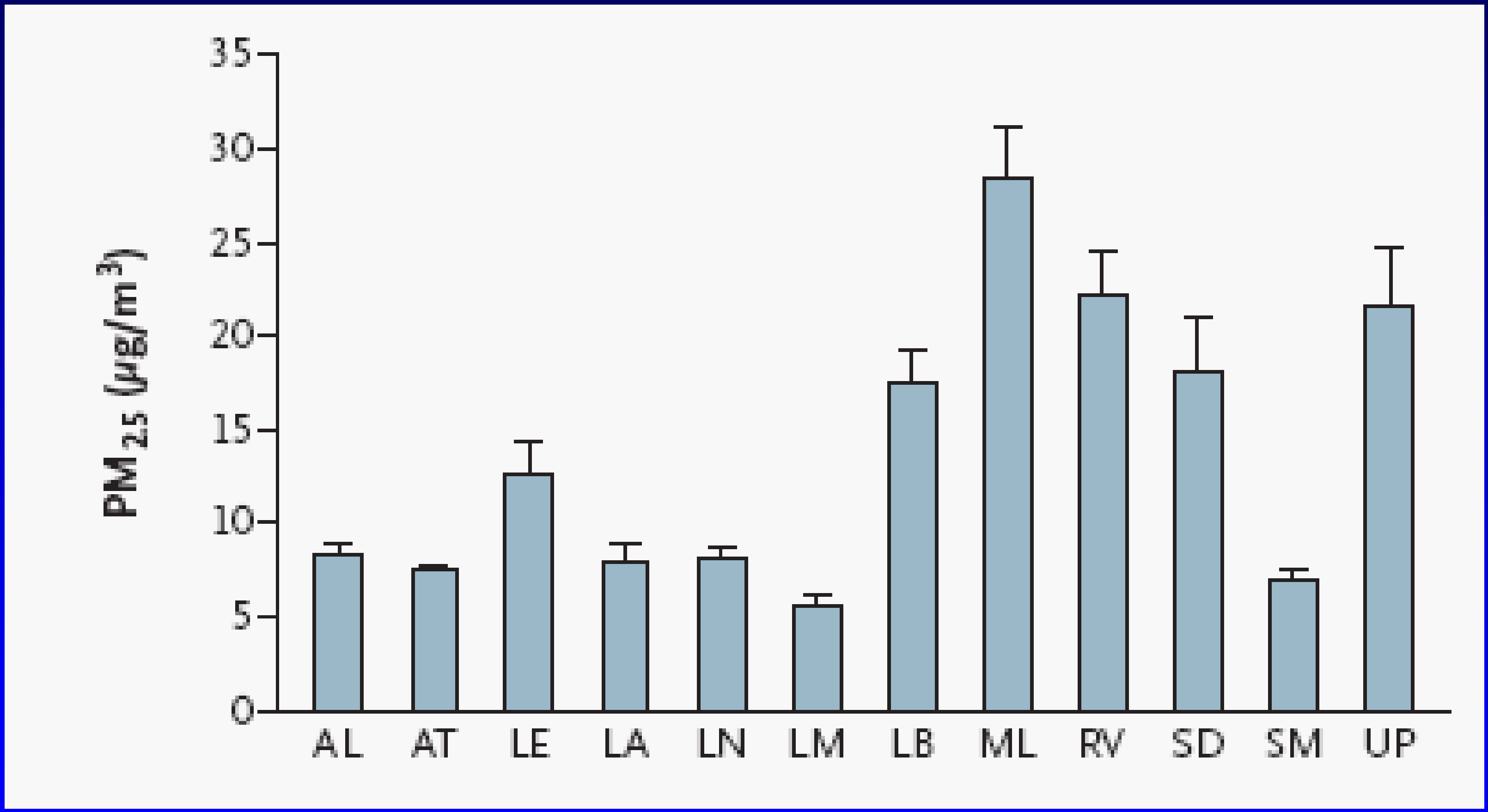
Respiratory illness?

Passive Smoking?

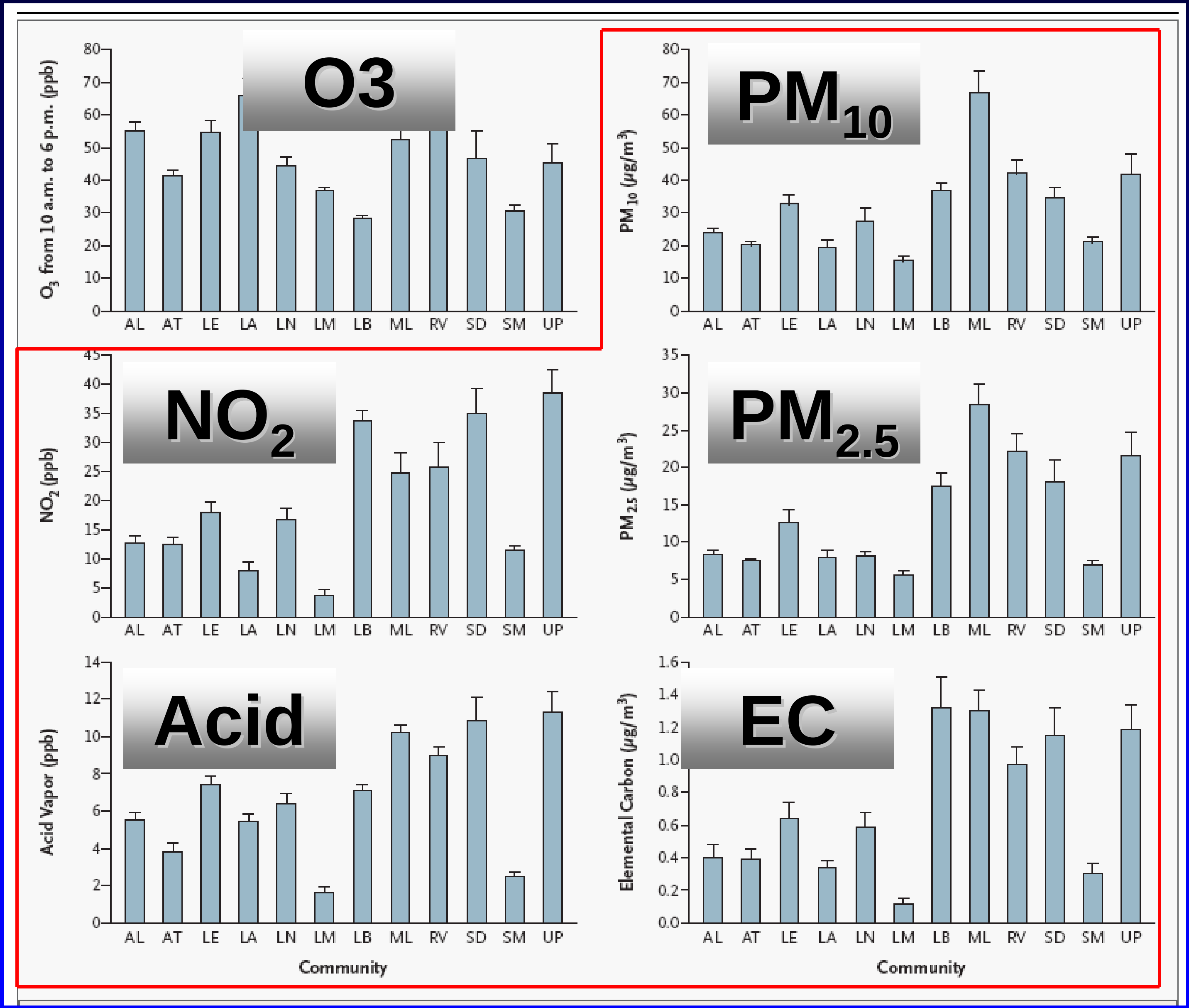


Results

Mean $PM_{2.5}$ levels, 1994-2000



Mean pollutant levels, 1994-2000



The L.A. Basin has elevated levels of all of these pollutants

Pollutant Correlations (R) Across Communities

Table 1. Correlation of Mean Air-Pollution Levels from 1994 through 2000 across the 12 Study Communities.*

Pollutant	O_3 (10 a.m.–6 p.m.)	NO_2	Acid Vapor†	PM_{10}	$PM_{2.5}$	Elemental Carbon	Organic Carbon
				R value			
O_3							
1-Hour maximal level	0.98	0.10	0.53	0.31	0.33	0.17	0.25
10 a.m.–6 p.m.		−0.11	0.35	0.18	0.18	−0.03	0.13
NO_2			0.87	0.67	0.79	0.94	0.64
Acid vapor†				0.79	0.87	0.88	0.76
PM_{10}					0.95	0.85	0.97
$PM_{2.5}$						0.91	0.91
Elemental carbon							0.82

R ≈ 0.0, little or no correlation
R > 0.0, positive correlation (max is 1.0)
R < 0.0, negative correlation (min is -1.0)

Characteristics of the Study Subjects

Community		No of Subjects[a]	Mean No PFT's	Female Sex (%)	Asthma[b] (%)	Any Smoking[c] (%)
Alpine	(AL)	145	6.1	50	13	27
Atascadero	(AT)	128	7.0	54	24	32
Lake Elsinore	(LE)	144	6.0	44	13	31
Lake Arrowhead	(LA)	166	6.3	54	13	30
Lancaster	(LN)	137	5.5	51	12	30
Lompoc	(LM)	115	6.1	43	8	34
Long Beach	(LB)	160	6.0	49	13	24
Mira Loma	(ML)	163	5.9	50	10	25
Riverside	(RV)	179	5.8	49	17	15
San Dimas	(SD)	138	6.0	51	11	28
Santa Maria	(SM)	147	5.9	48	15	27
Upland	(UP)	137	7.1	53	15	34
All		1,759	6.1	50%	14%	28%

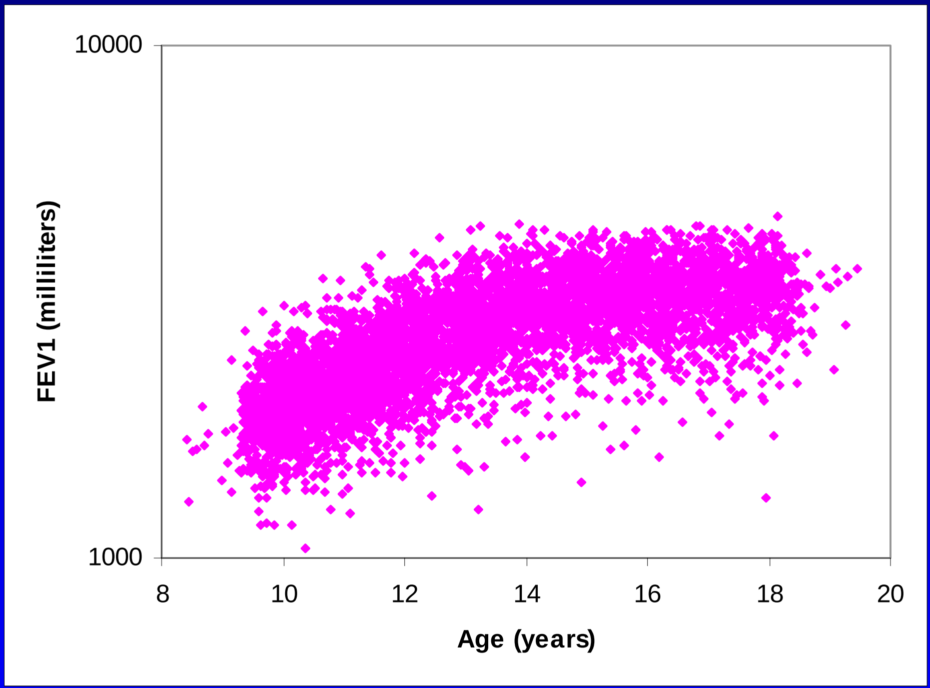
Sample Sizes Over Time

- **1993: 1,759 (4th grade)**
- **1995: 1,414**
- **1997: 1,252**
- **1999: 1,031**
- **2001: 747 (12th grade)**

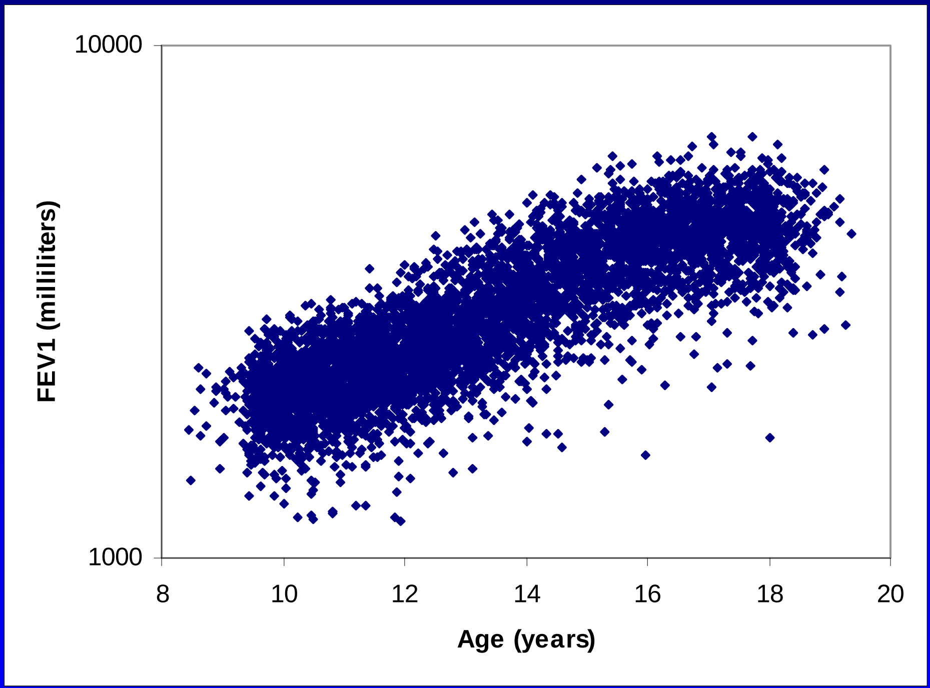
Approximately 10% loss per year

FEV$_1$ Growth Over 8 Years

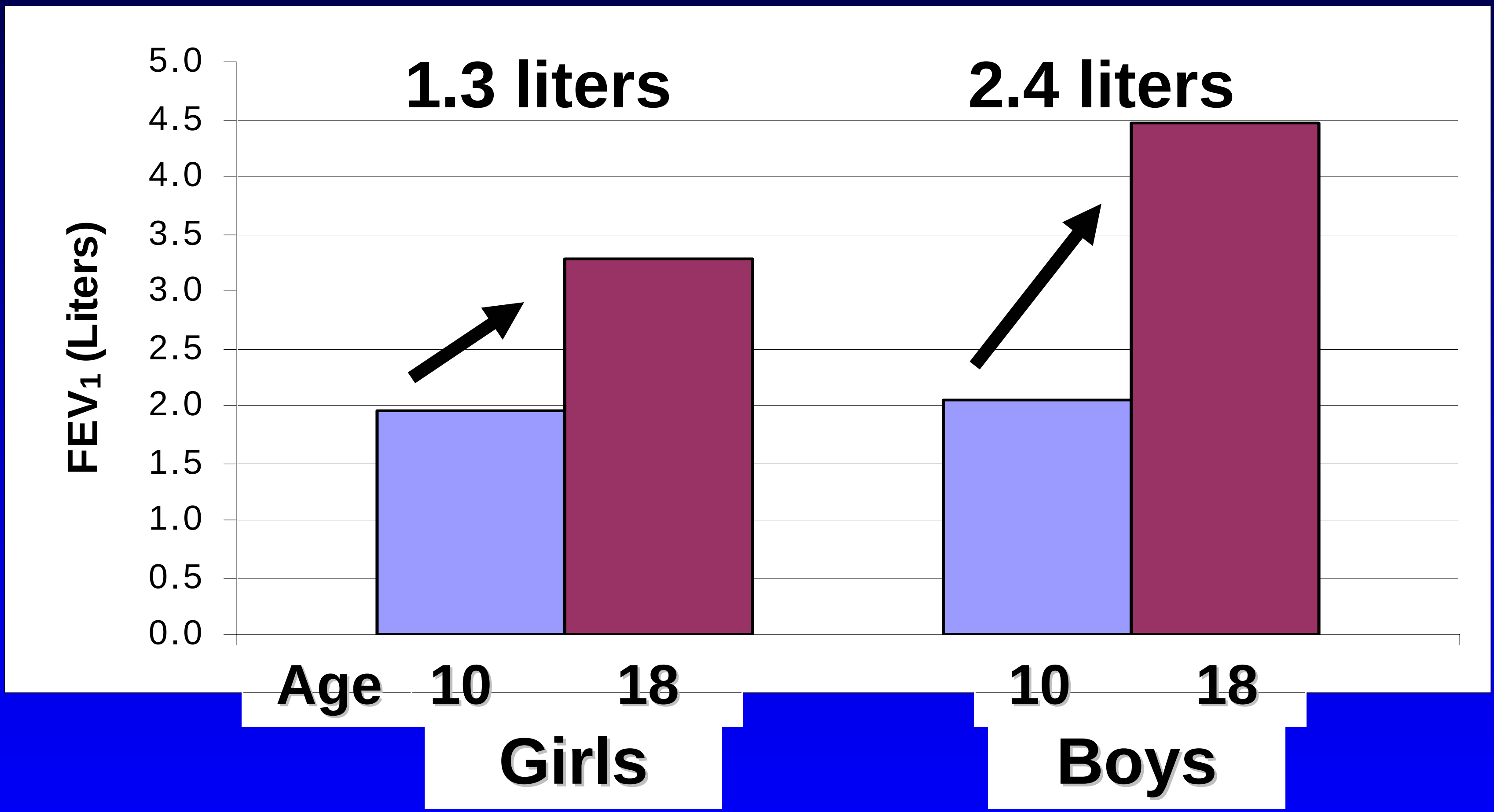
Girls



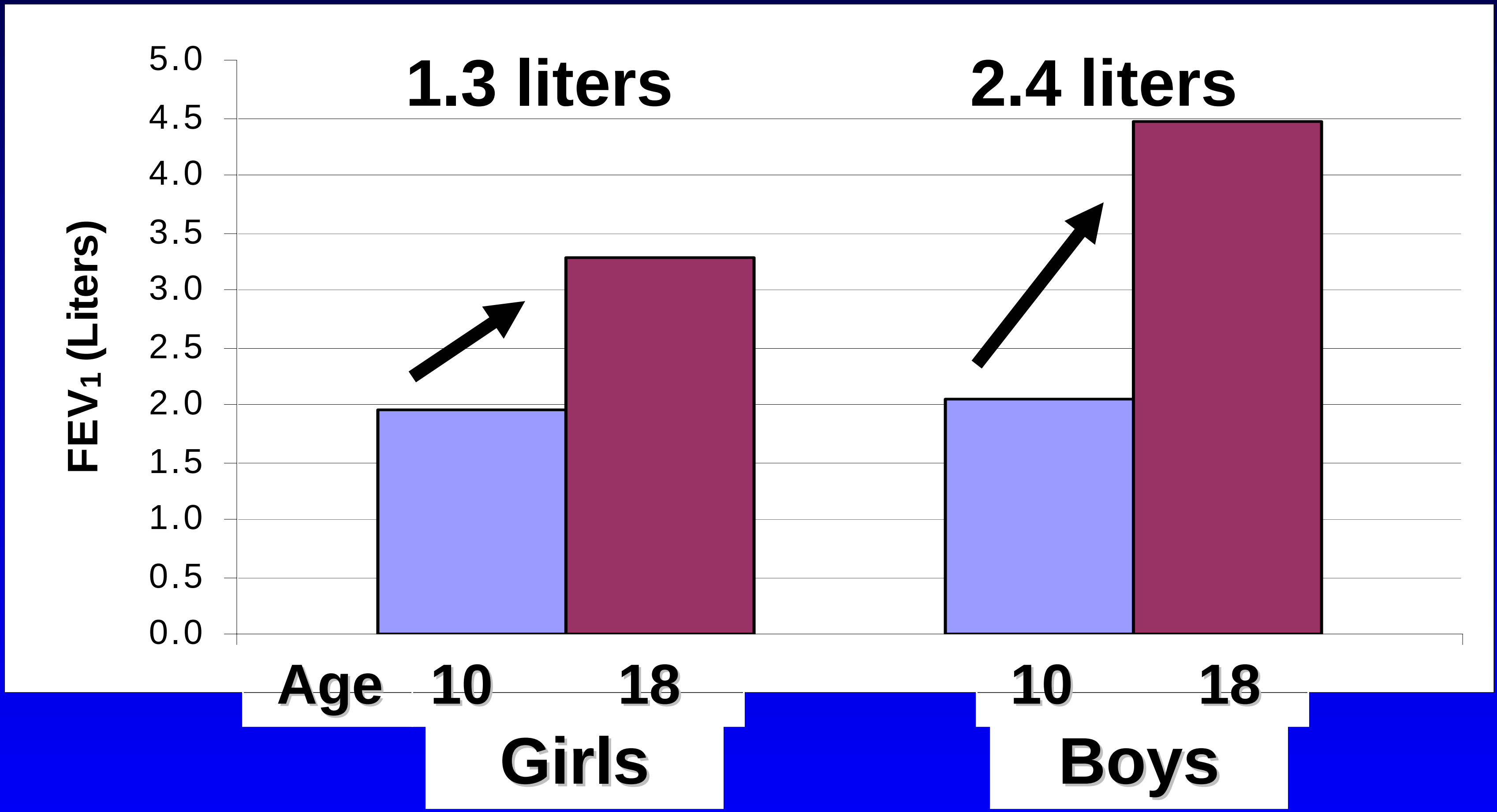
Boys



Average FEV_1 in Girls and Boys

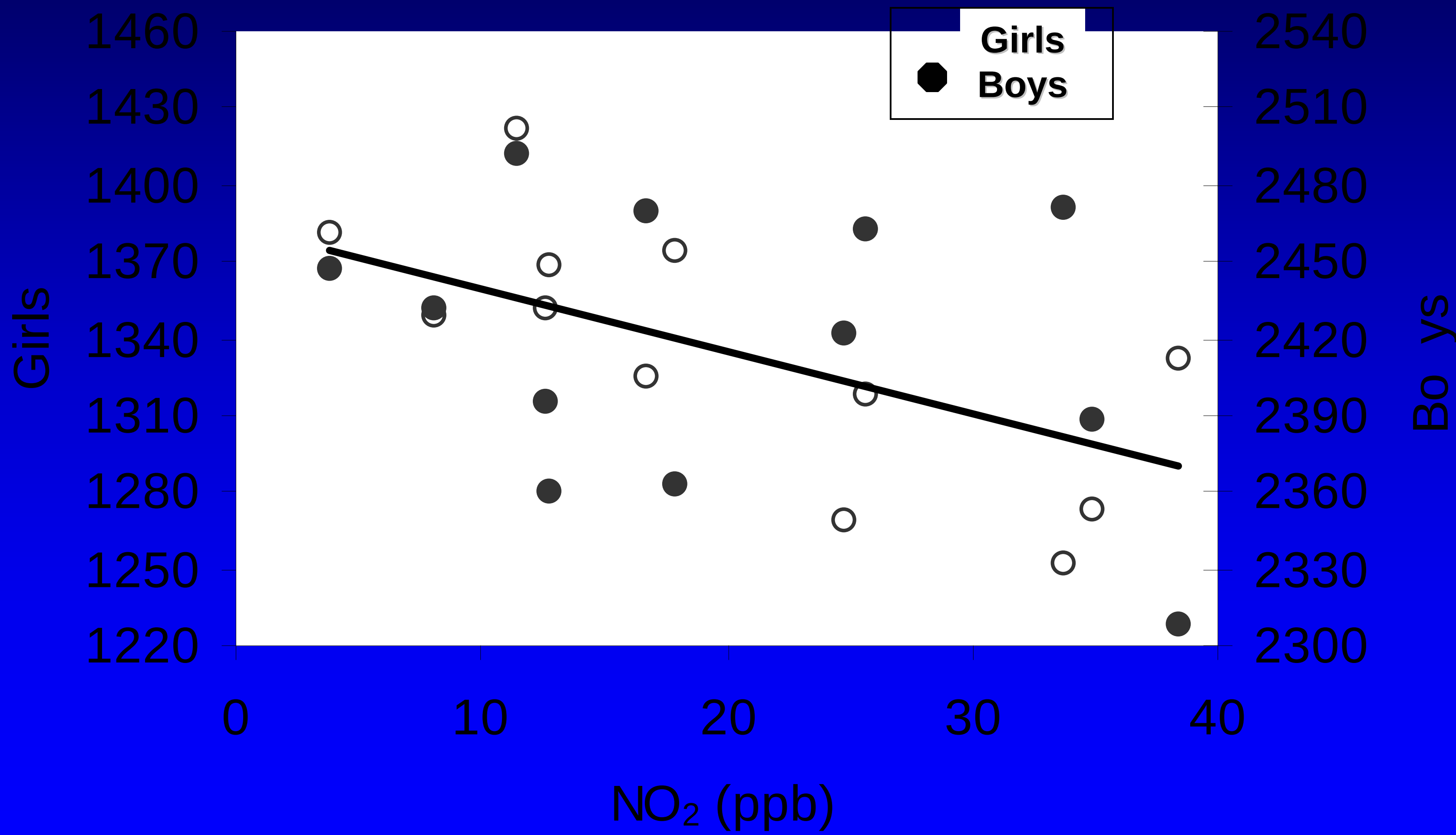


Average FEV_1 in Girls and Boys

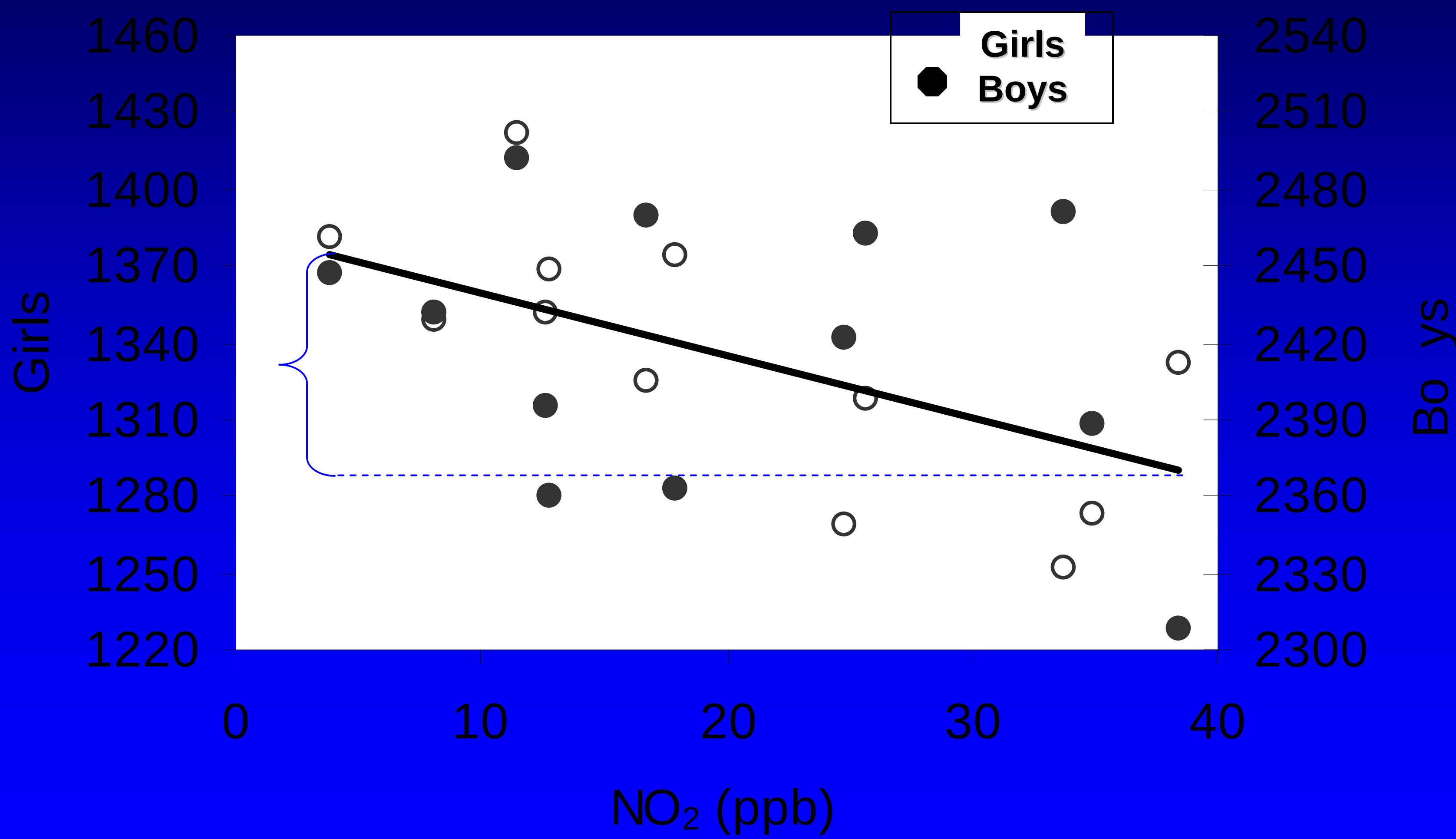


Key Question: Does 8-year growth vary across communities with respect to pollution?

8-yr FEV_1 Growth in Girls and Boys vs. 7-year average NO_2 levels



8-yr FEV_1 Growth in Girls and Boys vs. 7-year average NO_2 levels



Pollution Effects on 8-yr Growth

- 8-year lung growth deficits associated with:
  - NO_2, Acid vapor, PM mass, Elemental Carbon
- Robust to adjustment for:
  - Indoor pollutants (gas stove, parental smoking, pets)
  - Parental education
- Associations in all types of kids:
  - Boys and girls
  - Non-asthmatics
  - Non-smokers
- No associations with ozone

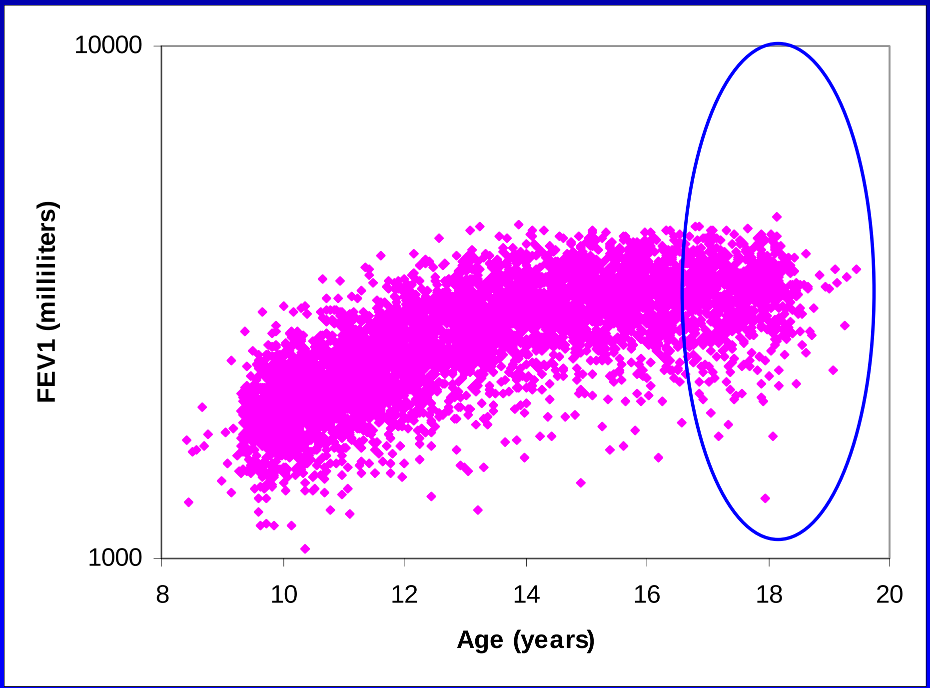
8-year growth deficits

- What is the net effect?
- Are the results clinically meaningful?

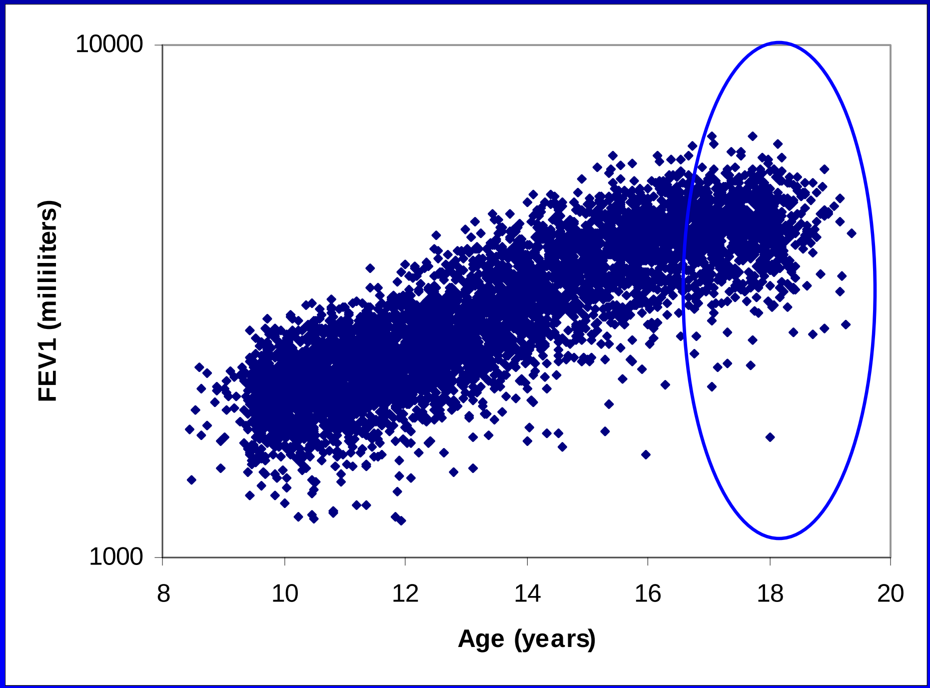
Cumulative Pollutant Effects

- **Does 8-years of exposure to air pollution cause clinically significant deficits in lung function at age 18?**

Girls



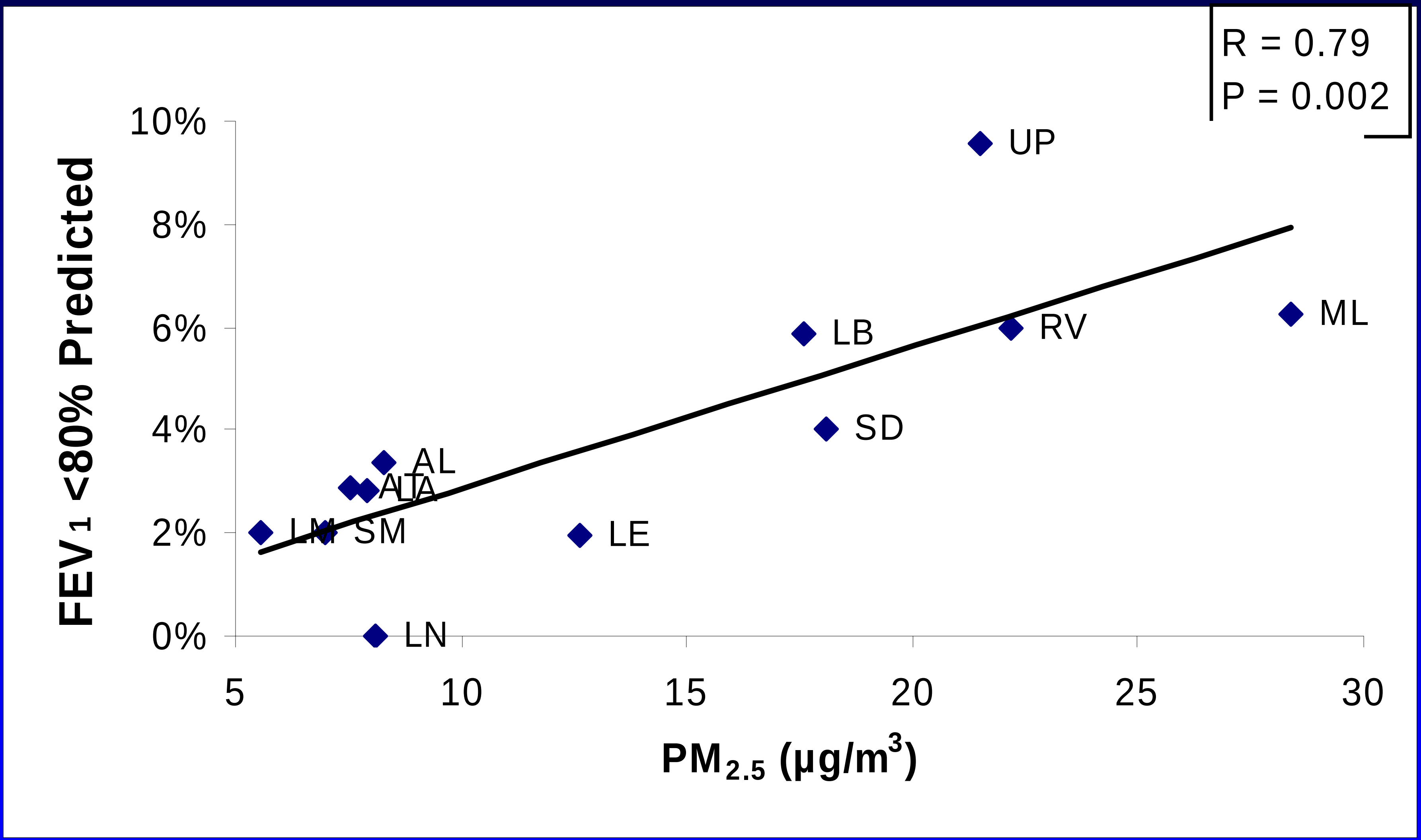
Boys



Attained Lung Function

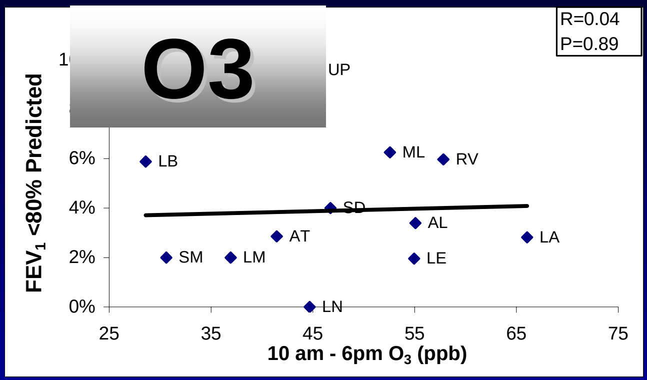
- What should lung function be at age 18?
  - Computed EXPECTED FEV_1 at age 18 based on sex, race/ethnicity, height, BMI, and asthma
- How does actual lung function compare to expected?
  - Computed OBSERVED/EXPECTED for each child
  - 'Low FEV_1' = OBSERVED/EXPECTED < 80%
- Is 8 years of breathing polluted air related to a greater chance of having clinically Low FEV_1?

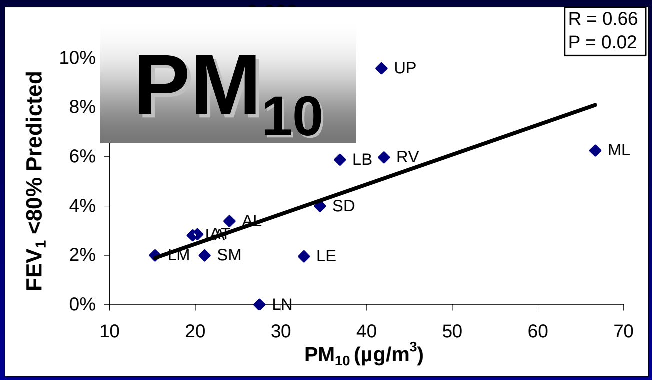
Low FEV_1 at Age 18 vs. Pollution

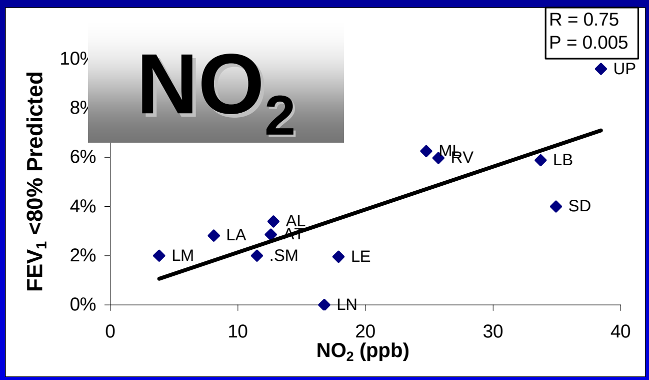


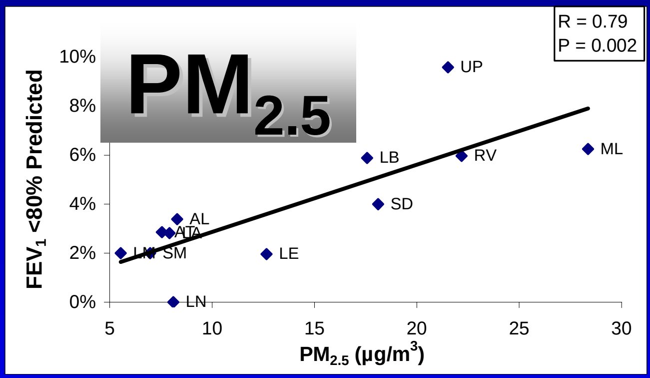
(Gauderman et al., 2004)

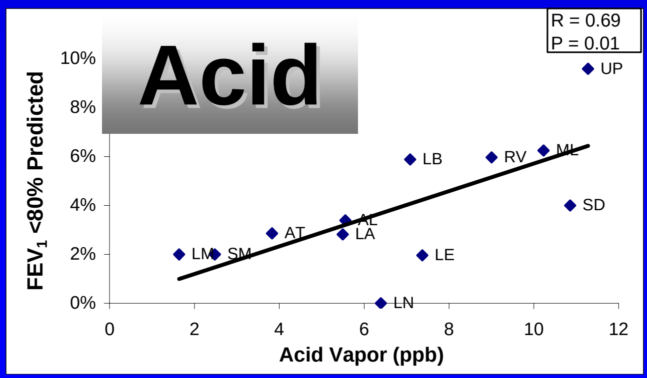
Low FEV_1 at Age 18 vs. Pollution

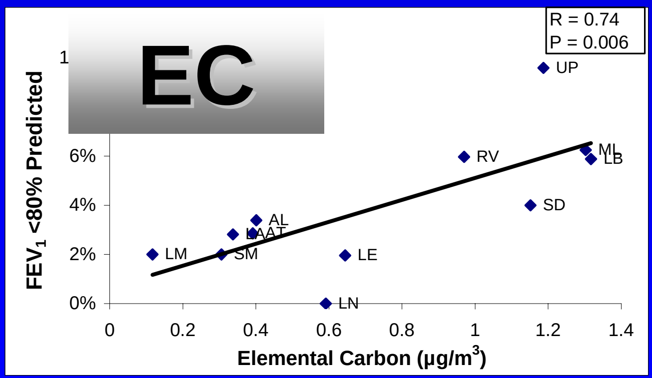




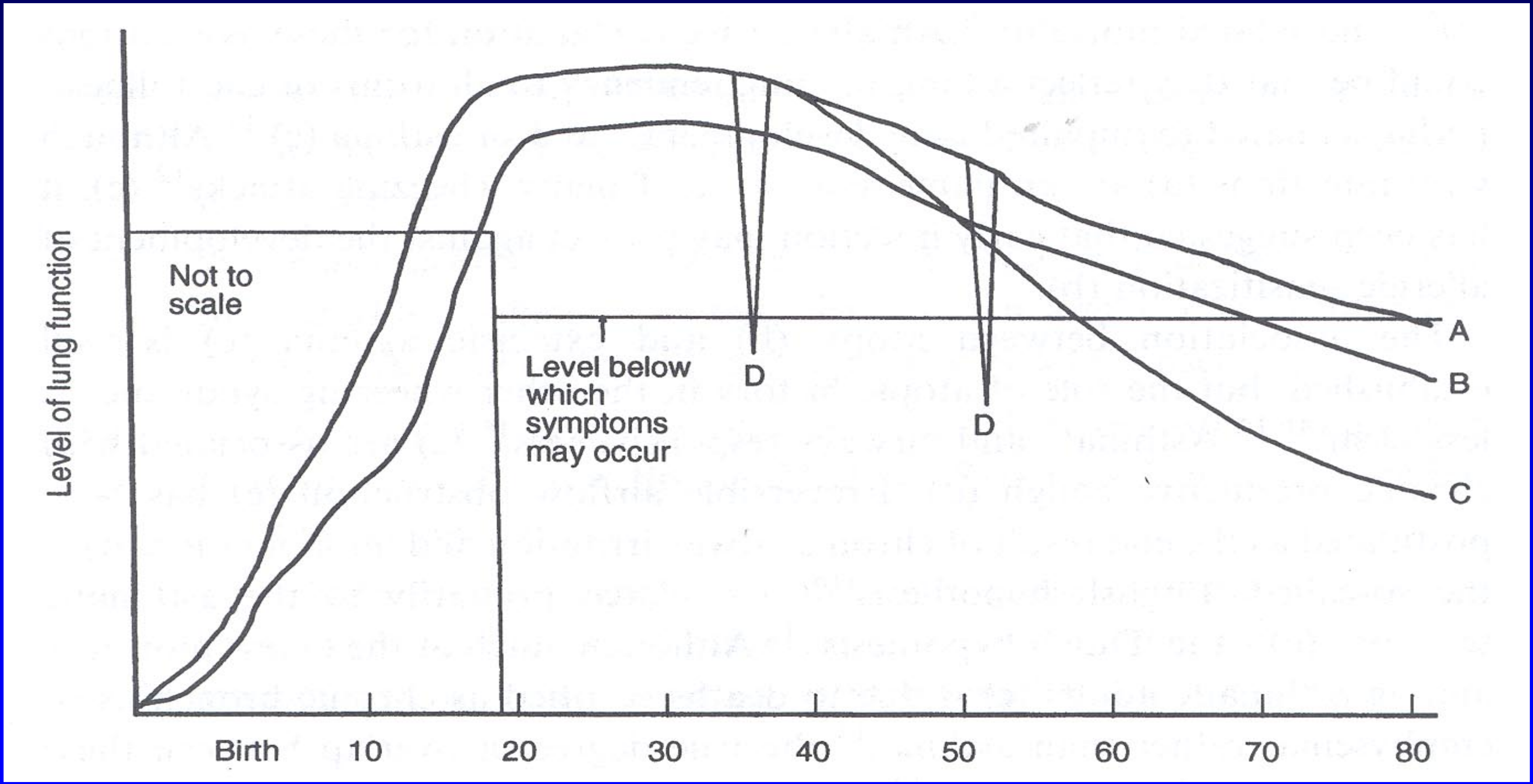








Why we care about annual lung growth rates...



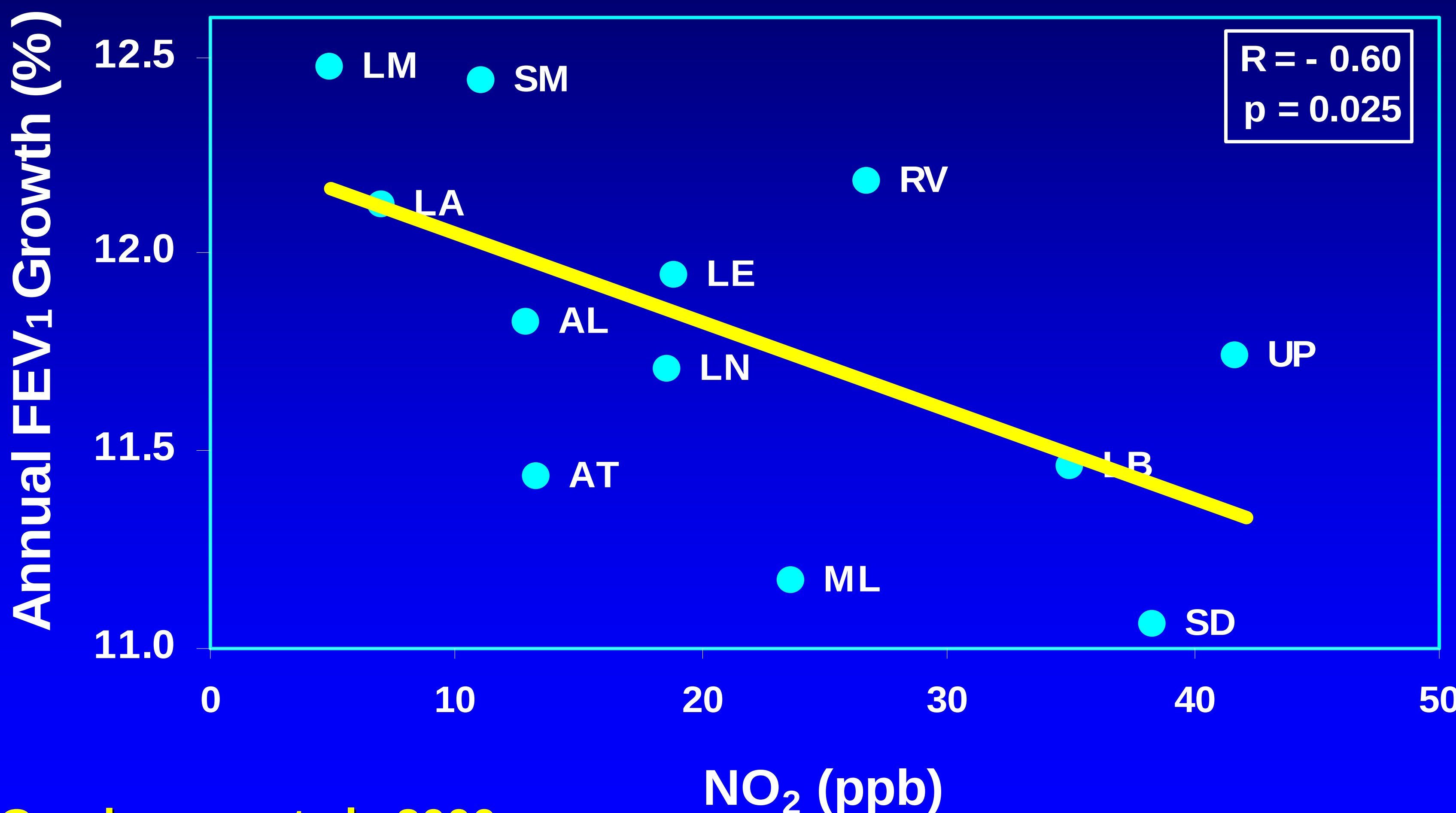
- (Adapted from Strachan et al 1997)

Additional Results

4-year Lung Function Development

Grade	1993	1994	1995	1996	1997	1998	1999	2000	2001
4th	10	11	12	13	14	15	16	17	18
7th	13	14	15	16	17	18			
10th	16	17	18						
4th				10	11	12	13	14	15

Lung function growth vs. NO_2
Cohort I: 1993-1997

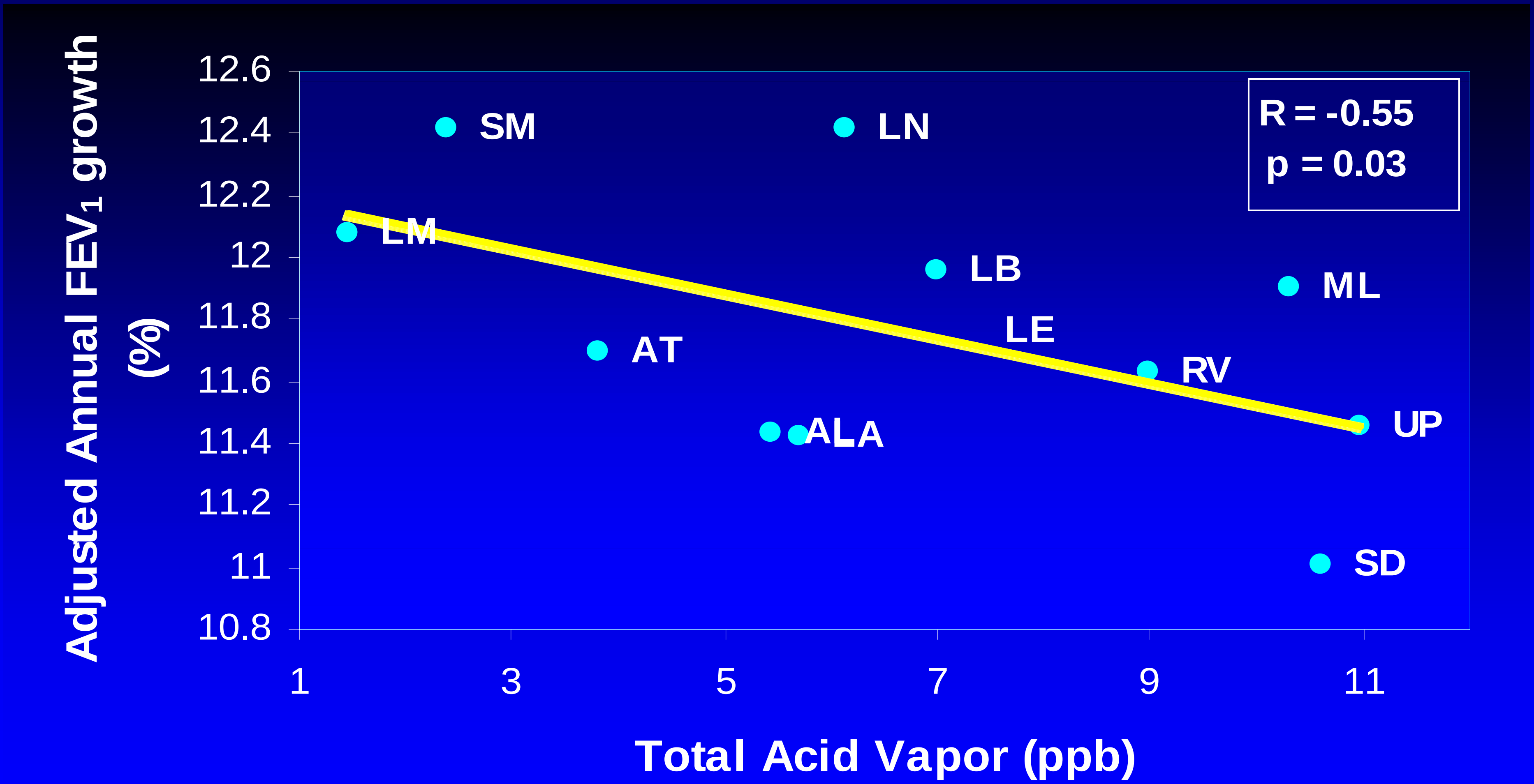


Gauderman at al., 2000

4-year Lung Function Development: Replication Study

Grade	1993	1994	1995	1996	1997	1998	1999	2000	2001
4th	10	11	12	13	14	15	16	17	18
7th	13	14	15	16	17	18			
10th	16	17	18						
4th				10	11	12	13	14	15

Lung function growth vs. Acid
Cohort 2: 1996-2000



Gauderman at al., 2002

Other studies of lung function and pollution

- Longitudinal studies (growth)
  - Young children in Poland (Jedrowski et al., 1999)
  - Young children in Austria (Horak et al., 2002)

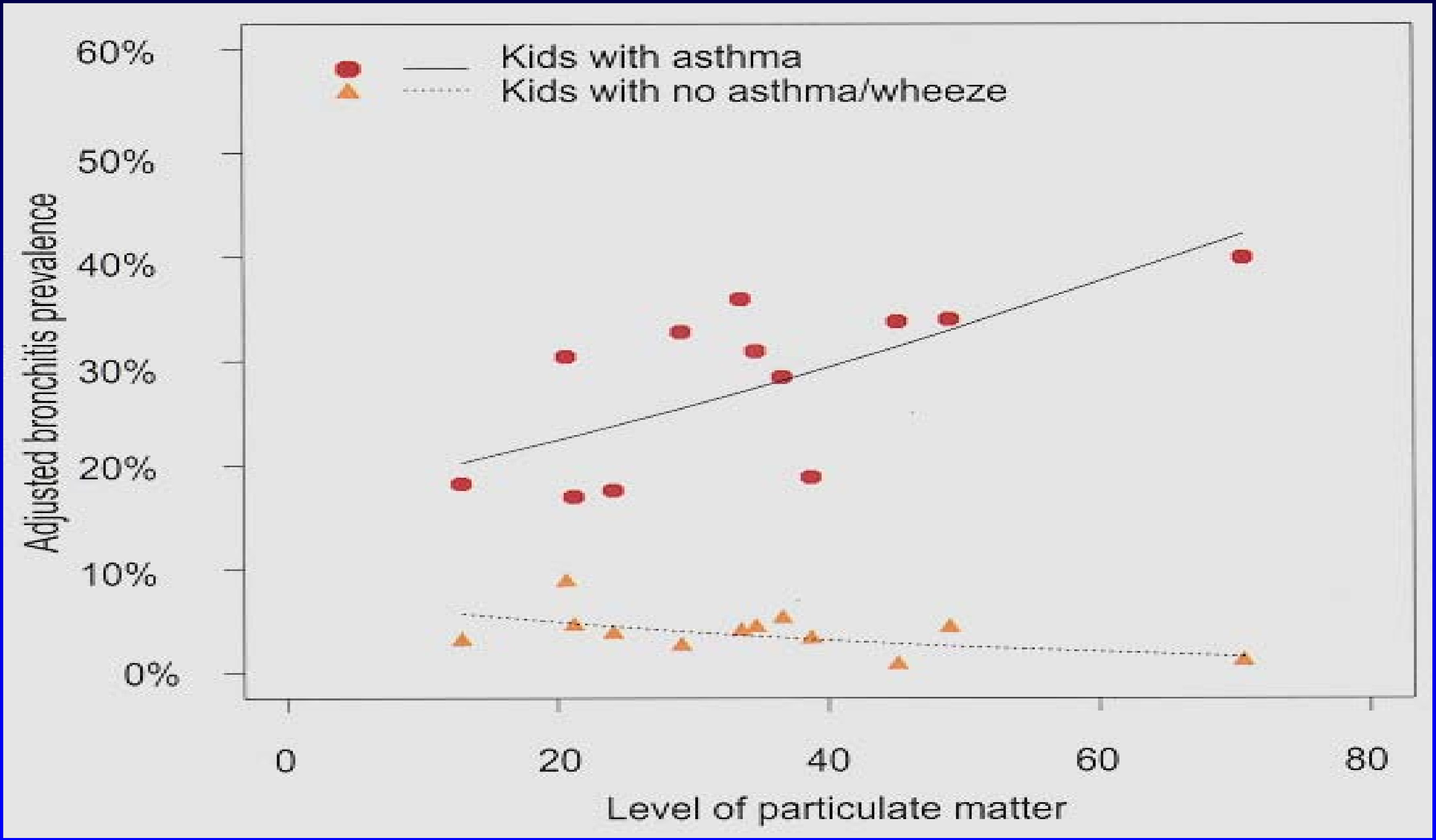
- Cross-sectional studies
  - 6-cities study (Dockery et al., 1989)
  - 24-cities study (Raizenne et al., 1996)
  - NHANES II (Schwartz, 1989)

CHS: School Absence

- 20 ppb increase in O_3 was associated with an 83% increase in school absence due to acute respiratory disease (Gilliland et al., 2001)

- Large economic impact of pollution-related absences (Hall and Lurmann, 2003)

CHS: PM_{10} and Bronchitis in Asthmatics



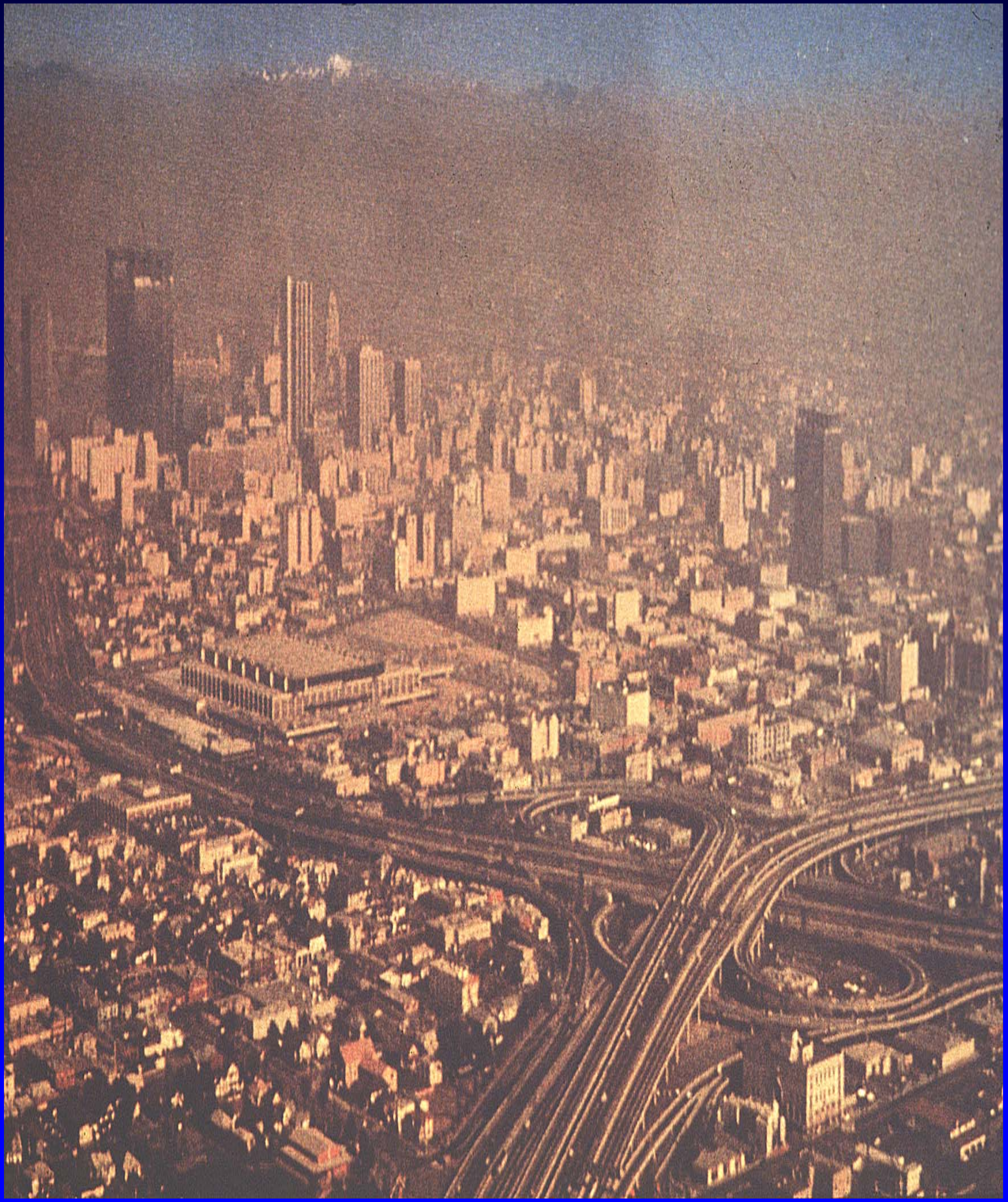
(McConnell, et al., 1999; see also McConnell et al., 2003)

CHS: Ozone and New-onset Asthma

	Low O_3 Towns		High O_3 Towns	
Sports	# asthma	RR	# asthma	RR
0	58	1.00	46	1.00
1	50	1.28	40	1.28
2	20	0.82	16	1.28
≥3	9	0.79	20	3.31

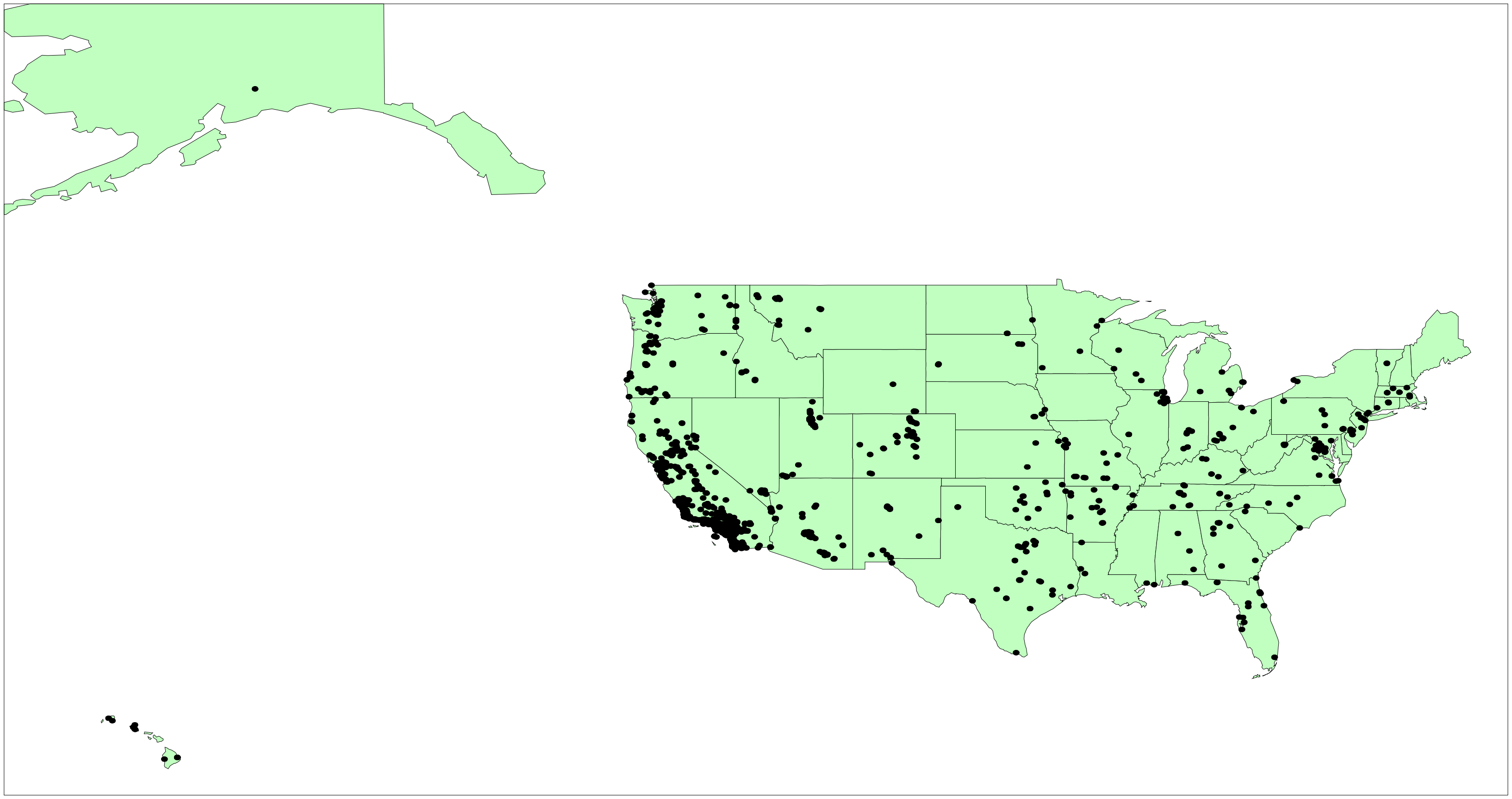
(McConnell et al., 2002)

Will reductions in pollution improve health?



CHS Movers Study

Where have CHS children moved?

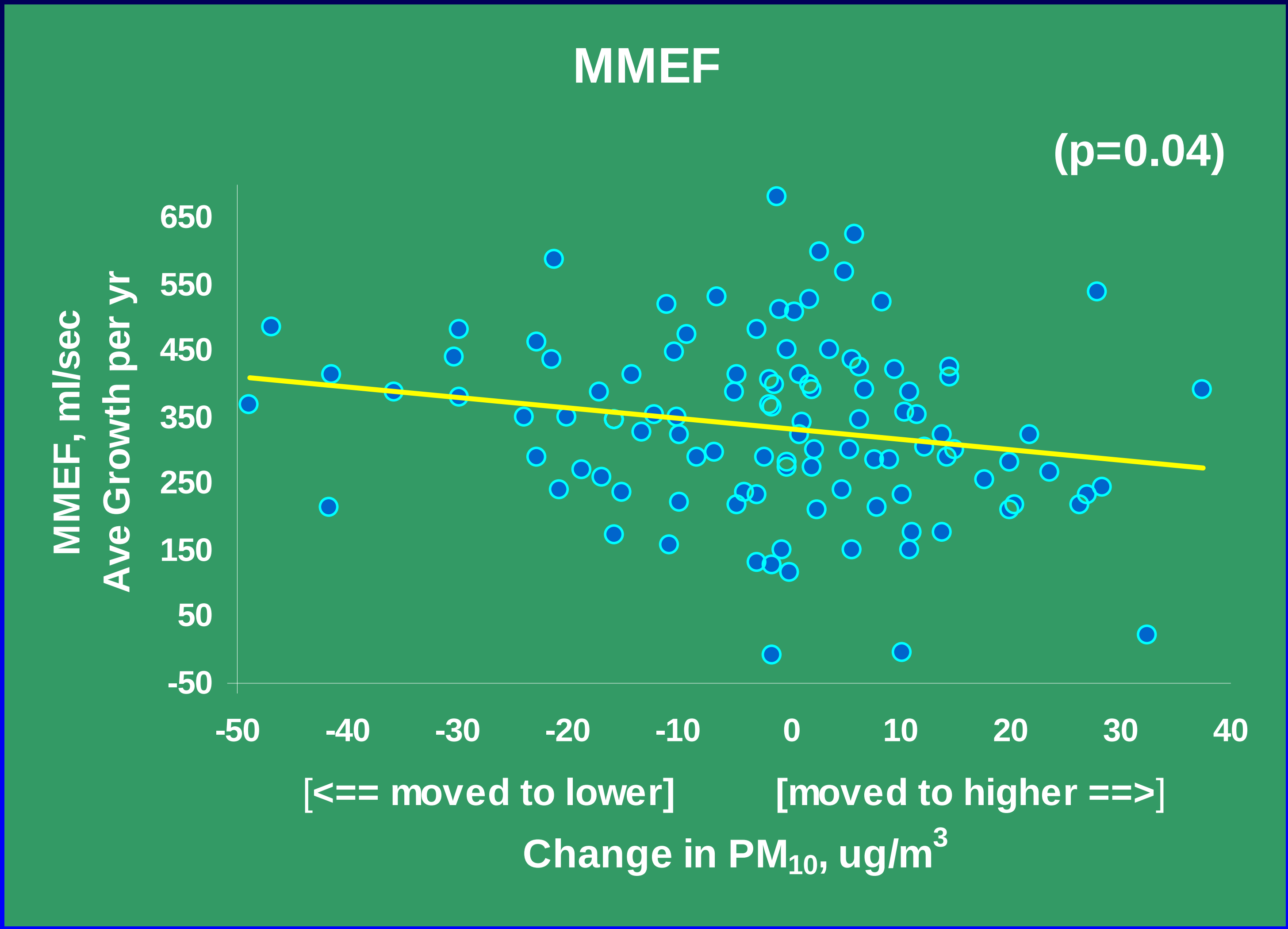


Some to higher pollution, some to lower

CHS Movers Study

We tested lung function of 110 movers in the western U.S.

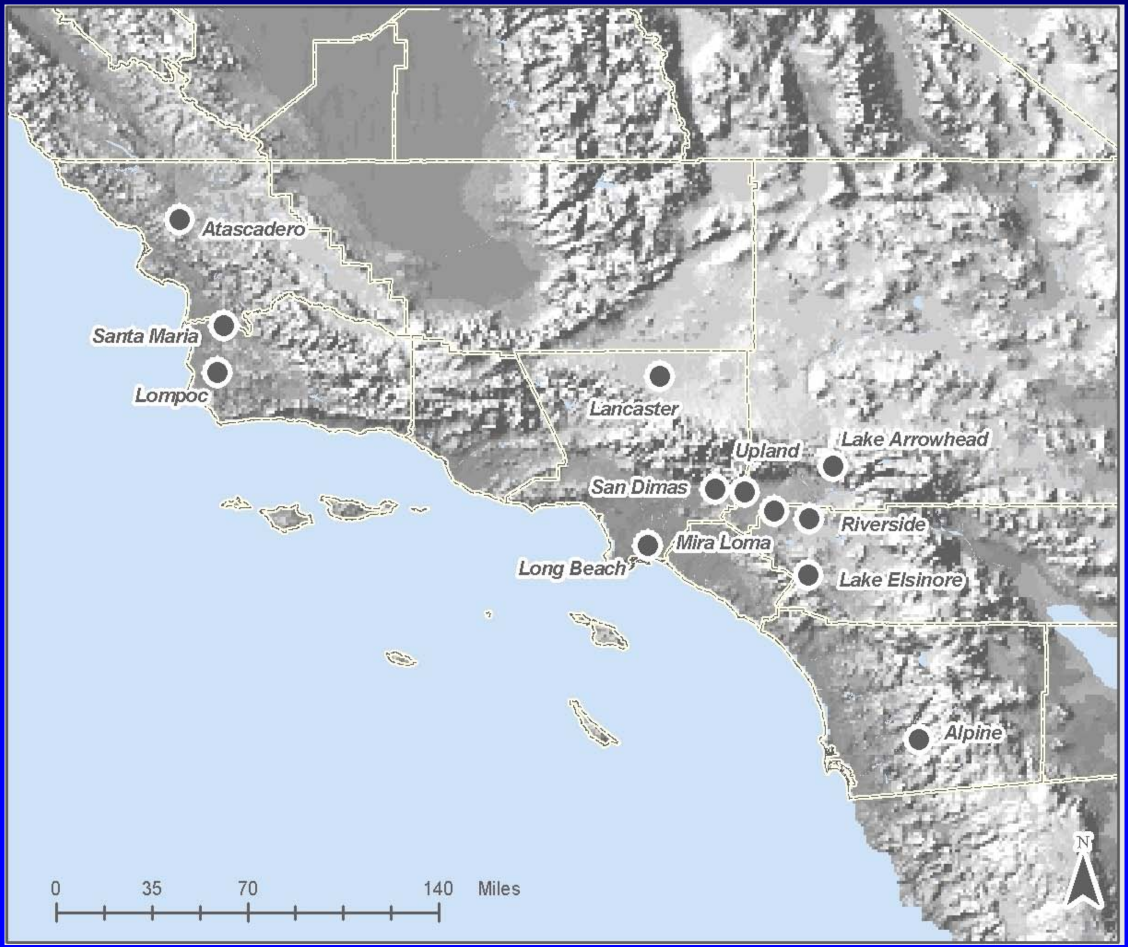
Lung Function Growth in Movers



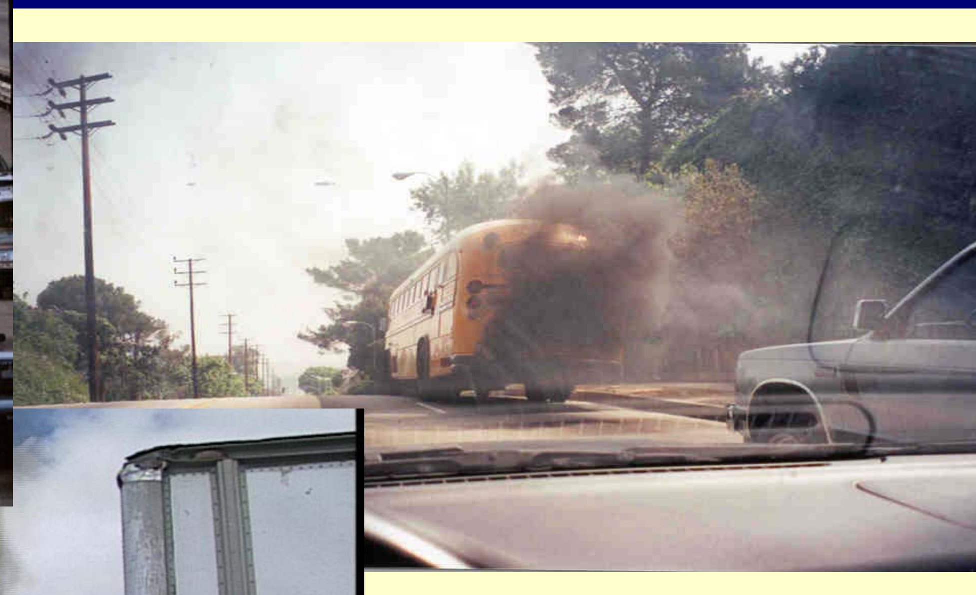
(Avol et al., 2001)

Air Pollution and Health

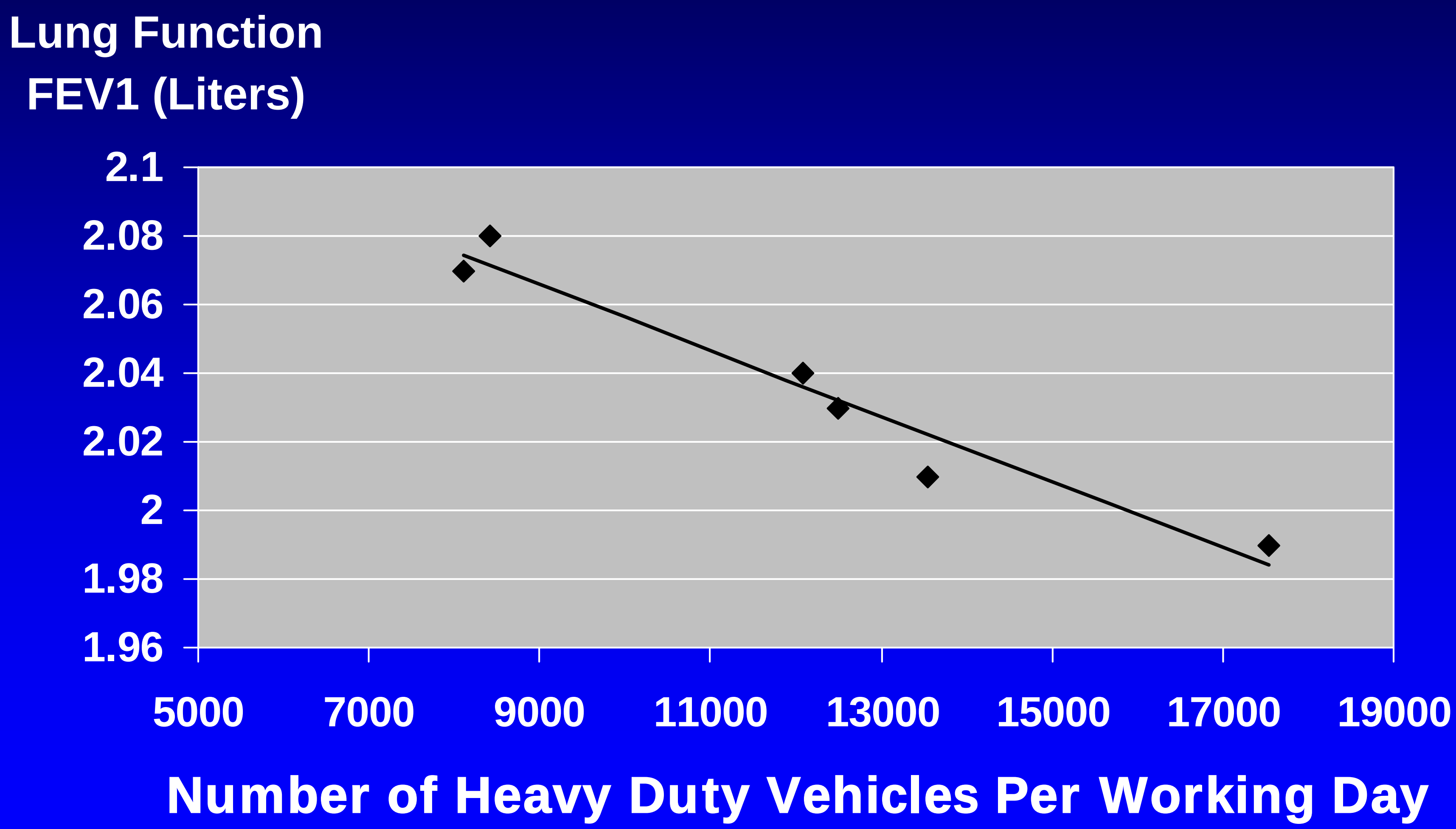
- High pollution communities vs. low pollution
  - Lower lung function
  - Increased symptoms
  - Increased asthma



What About Local Exposures?



Local Exposures: Living within 300m of major roadways affects lung function



(Brunekreef et al 1997, Netherlands)

Local Exposures

- **Several studies in Europe linking traffic exposure to respiratory symptoms**
- **S.F. bay area study relating pollution exposure at schools to symptoms (Kim et al. 2004)**
- **CHS study of residential NO_2, traffic, and asthma (Gauderman et al., *Epidemiology*, in press)**

CHS: Ongoing Studies

- Lung function in young adults
  - Do deficits persist into adulthood?
- Local exposures
  - New cohort of ~6,000 K–1^{st} grade children
  - Monitoring NO, NO_2, O_3 at homes, schools
  - Asthma, Exhaled NO
- Genetics
  - Are some more susceptible to pollutant effects?

Air Pollution and Adverse Birth Outcomes in the South Coast Air Basin, 1989-1993

Beate Ritz, M.D., Ph.D.

Michelle Wilhelm. Ph.D.

UCLA, Dept. of Epidemiology

& Environmental Health Sciences

Why Study Air Pollution and Pregnancy?

- Developing organism is uniquely sensitive to environmental toxins within a short time window

- Adverse outcomes are common; in US:
  - ~10% are preterm
  - ~ 5% are low weight

South Coast Air Basin

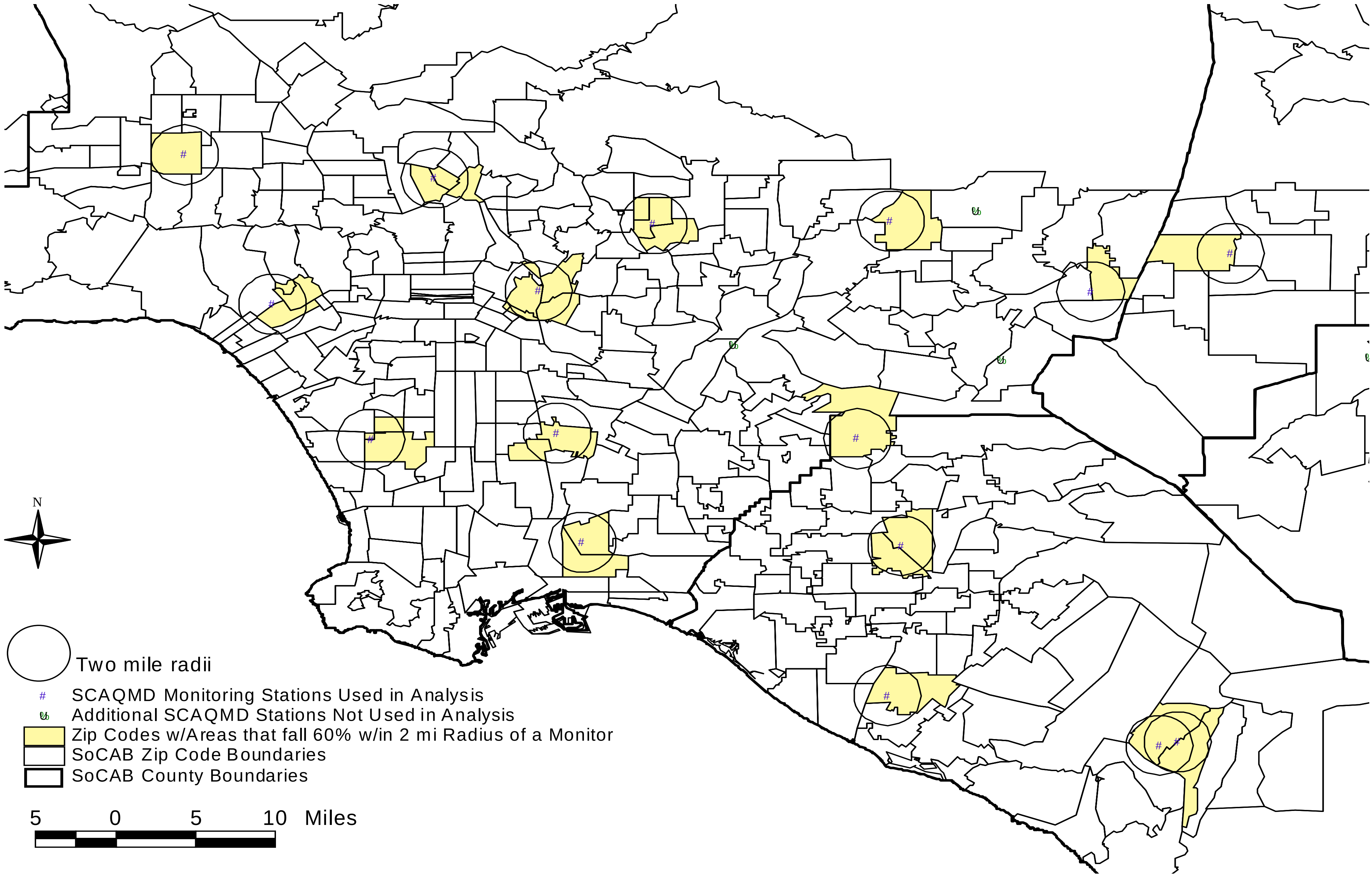
- Large number of births (~ half of all CA births, most in LA county)
- Birth certificates are readily available
- Dense air pollution monitoring network

Exposure assessment 1989-1993 study

- Mothers residing within a 2-mile radius of stationary ambient CO (PM_{10}) monitors at the time of birth
  - (relaxed to 10 miles for birth defects)

- For each child, calculated the last trimester or last 6 week etc average CO (PM_{10}) using the closest monitoring station

Map of SCAQMD Monitoring Stations and Zip Codes Included in Analysis

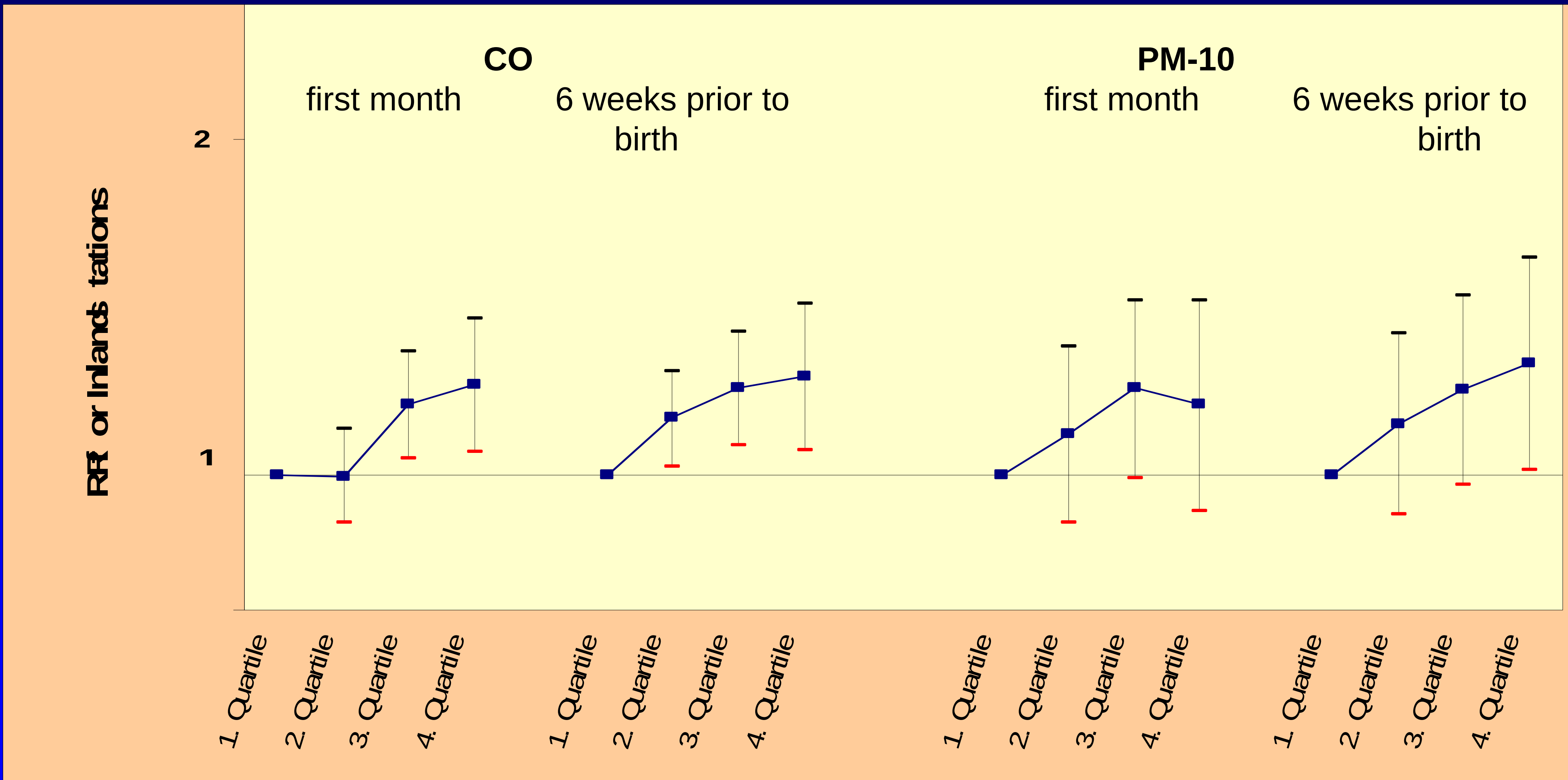


Adjusted Odds Ratios (95%CI) for Term LBW
3rd trimester ambient CO levels

CO-level (ppm):	**All children** *case N=2,809* *non-case N=122,7640*	**Higher parity children** *case N=1,454* *non-case N=73,687*	**Young Women** *case N=420* *non-case N=15,111*
< 2.2	1.0	1.0	1.0
2.2 - <5.5	1.04 (0.96, 1.13)	1.03 (0.92, 1.15)	1.02 (0.83, 1.26)
> 5.5	1.22 (1.03, 1.44)	1.33 (1.07, 1.65)	1.54 (1.07, 2.22)

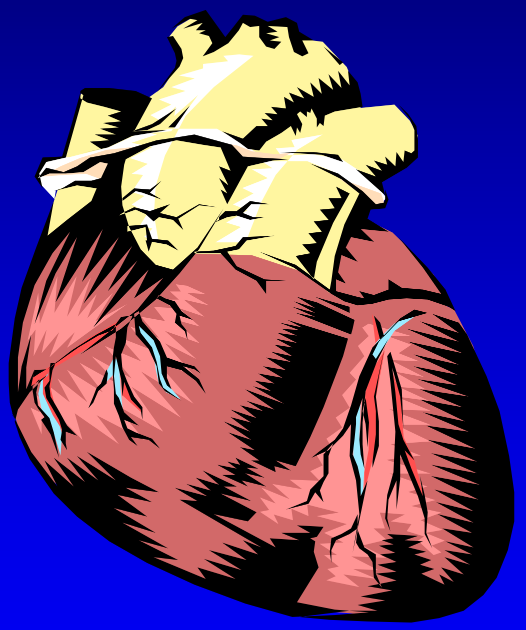
(Ritz et al., 1999)

Adjusted Rate Ratios (95% CI) for Preterm Birth by Quartile of Ambient CO and PM_{10} (9 Inland Stations only) (Ritz et al., 2000)



Birth Defects

- Data from CA Birth Defect Monitoring Program (1989-1993)
- Evaluated 6 different common heart defects
- Exposure during first 3 months of pregnancy for each infant



CO and Ventricle Septum Effects

(Ritz et al., 2001)

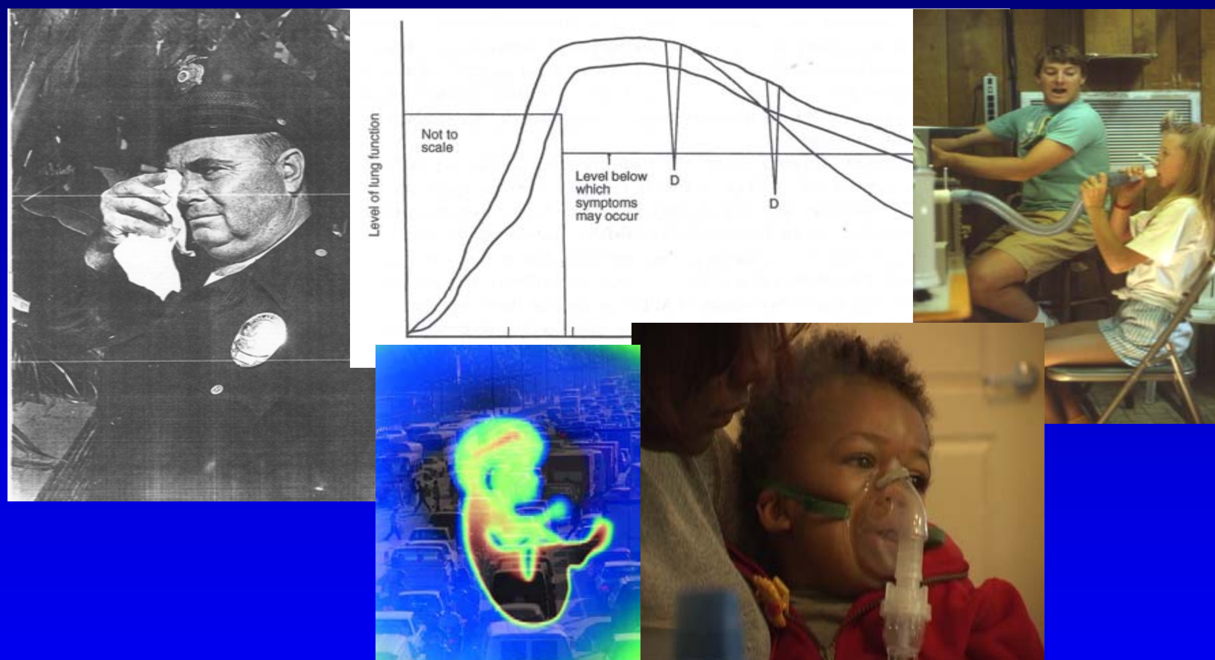
Pregnancy month	CO (ppm)	Odds Ratios (95% CI) *Case N=234 Control N=7944*
1st month		
	<1.14	1
	1.14-<1.60	1.05 (0.66-1.68)
	1.60-<2.47	1.12 (0.59-2.12)
	>=2.47	1.23 (0.53-2.82)
2nd month		
	<1.14	1
	1.14-<1.57	1.63 (1.00-2.66)
	1.57-<2.39	1.97 (1.00-3.91)
	>=2.39	2.84 (1.15-6.99)
3rd month		
	<1.12	1
	1.12-<1.51	0.77 (0.49-1.22)
	1.51-<2.27	0.54 (0.29-1.02)
	>=2.27	0.70 (0.31-1.58)

Pre-Natal Effects Summary
Southern California, 1989-1993

- CO and term low birth weight (third trimester)
  - Most weight gain in fetus during third trimester
- CO/PM_{10} and preterm birth (6 weeks prior to birth)
- Birth defects
  - CO and cardiac ventricular septal birth defects
  - Ozone also linked to birth defects
  - Effects during 2^{nd} month when heart formation occurs

Summary

- **Air pollution associated with acute *and* chronic effects**



- **Health effects observed at pollution levels that meet current US/EPA standards**

Summary

- Children are a susceptible group
  - Rapid growth
  - More exposure than adults

- Regional and local exposures are important

Summary

- **Reductions in air pollution will likely lead to measurable improvements in children's health**