EH522
INDOOR ENVIRONMENTAL QUALITY & HEALTH

Lecture 1

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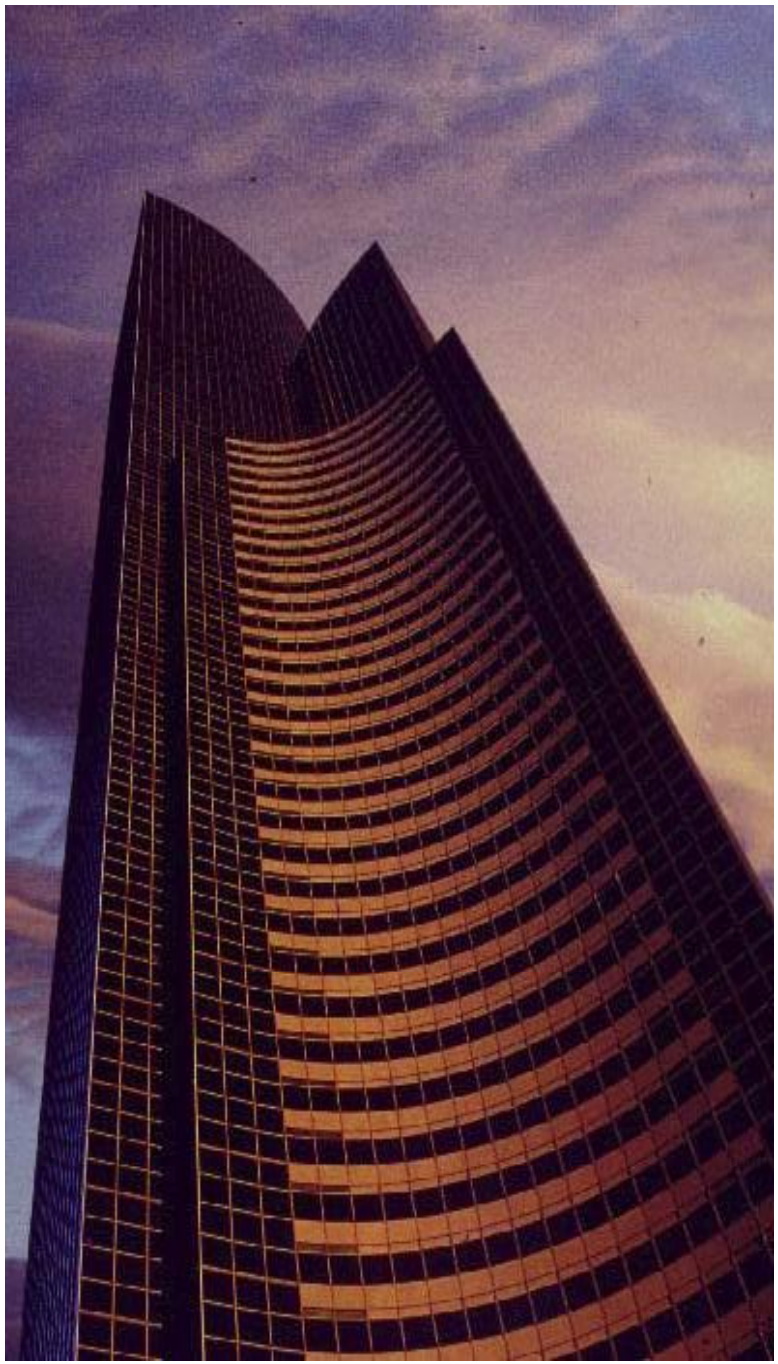
School of Public Health



Textbooks

- ASHRAE: Indoor Air Quality Guide, 2010. Best practices for design, construction and commissioning

- Spengler, J., J. Samet, and J. McCarthy. 2001. Indoor Air Quality Handbook. New York: McGraw-Hill

- Indoor Environmental Quality, Thad Godish, CRC Press, 2000

- Bearg, David. Indoor Air Quality and HVAC systems.

Reading Materials

Journals:

- *Indoor Air*
- *Atmospheric Environment*
- *American Industrial Hygiene Association Journal*
- *Environmental Science & Technology*
- *Environment International*
- *Journal of the Air & Waste Management Association*

Websites

- *WHO, Indoor Air Program (http://www.who.int/indoorair/en)*
- US EPA, Indoor Air Quality program (http://www.epa.gov/iaq/)
- *US Surgeon General (http://www.surgeongeneral.gov/topics/healthyhomes)*
- *American Industrial Hygiene Association (http://www.aiha.org/)*
- *ASHRAE (http://www.ashrae.org/)*

Websites (Cont.)

- *OSHA (http://www.osha.gov)*
- NIOSH (http://www.*cdc.gov/**niosh**)*

Teaching methods

- Combination of lectures, case studies and homework/ mini IEQ projects.
- Active learning through class participation and case based teaching
- Where appropriate, guest speakers may contribute to the course (leading experts and practitioners)
- Class readings will be assigned every week
- Course website for communications and materials

Grading/Performance evaluation

- Homework assignments and mini IEQ project (50%)

- Final examination: (50%)

  (Based on ALL reading materials given in class, homework assignments and lecture material)

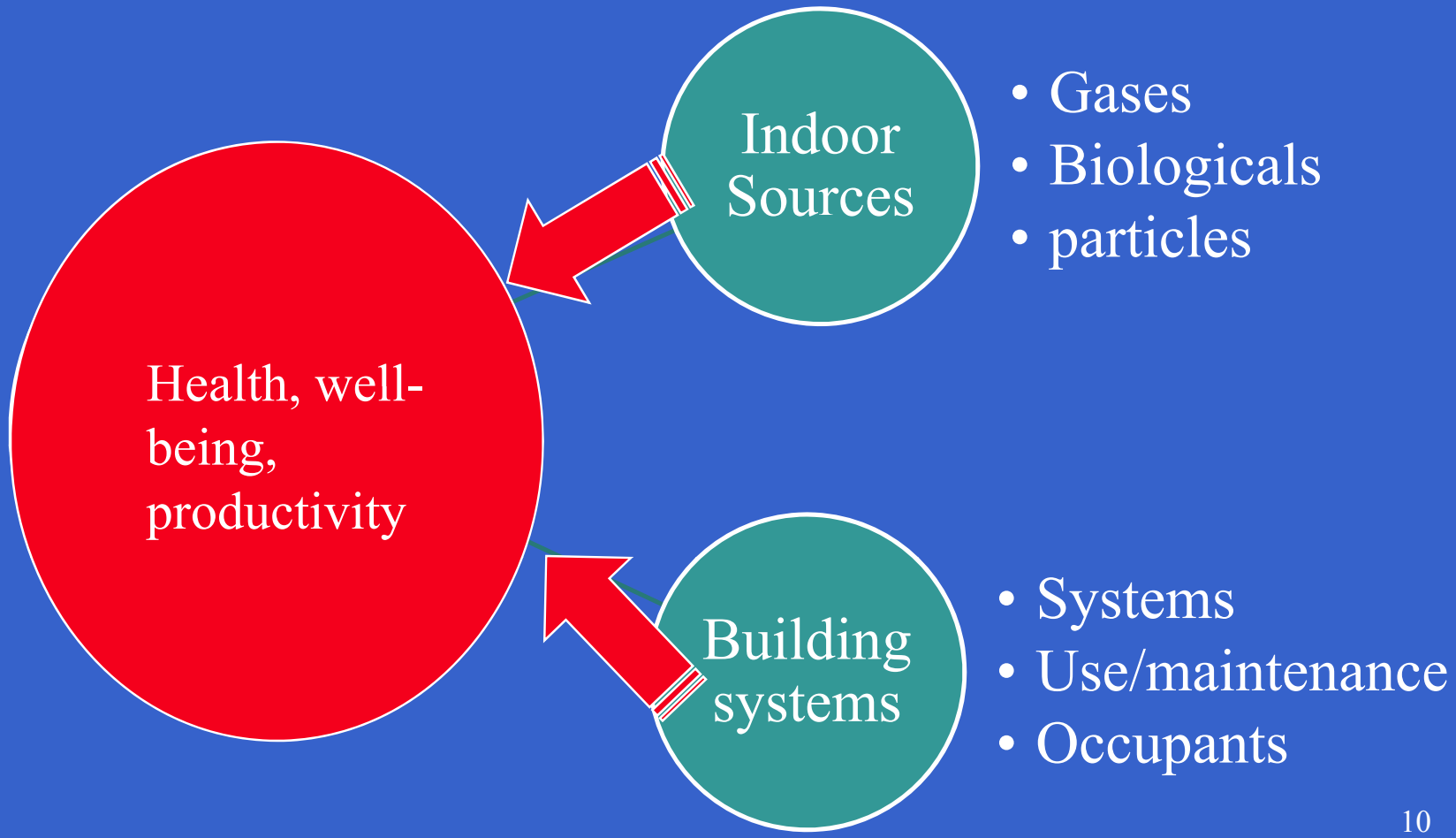
Goals of the Course

- **Identify and explain the major indoor air pollution sources and their health implications.**
- **Introduce students to building science themes (thermal comfort, HVAC systems, ventilation)**
- **Enable the students to develop the skills required to assess IEQ problems , identify their causes and recommend mitigation strategies**
- **Identify and describe the current regulations, standards and guidelines related to indoor air quality.**
- **Introduce students to indoor air research themes**

Context of the course

- Sources of indoor pollutants and health implications.
- Emerging pollutants and health implications
- The built environment: HVAC systems, building science matters (Energy, thermal comfort, ventilation, green buildings, sustainable design issues)
- IEQ investigations, mitigation of IEQ problems: Tools (IAQ modeling, instrumentation), case studies related to various microenvironments

Course Overview



Basic definitions for the Course

Pressure

- It is defined as the force per unit area.
- Standard atmospheric pressure at sea level is 29.92 inches of mercury or 760 mm of mercury or 14.7 lb/sq.inch.

Basic definitions for the Course

Air density (ρ)

- It can be defined as the mass per unit volume of air, (lbm/ft^3). at standard atmosphere (p=14.7 psfa, room temperature 70 F and zero water content.- ρ_{std}=0.075 lbm/ft$^{3)}$

- Specific enthalpy (h): A measure of energy for a system per mass. Units: KJ/kg, Kcal/hr

Basic definitions for the Course

Volumetric Flow Rate, Q, (i.e. in a pipe, duct) (m3/s, CFM)

The volume or quantity of air that flows through a given location (section) per unit time

$Q = U * A$

Where

Q = volumetric flow rate in cfm or m3/s

U = average velocity in fpm, or m/s

A = cross-sectional area in sq.ft, or sq.m

Mass Flow rate, M, (i.e. in a pipe, duct) (kg/s, lb/min)

The mass of air that flows through a given location (section) per unit time

Basic definitions for the Course

Conservation of Mass and energy:

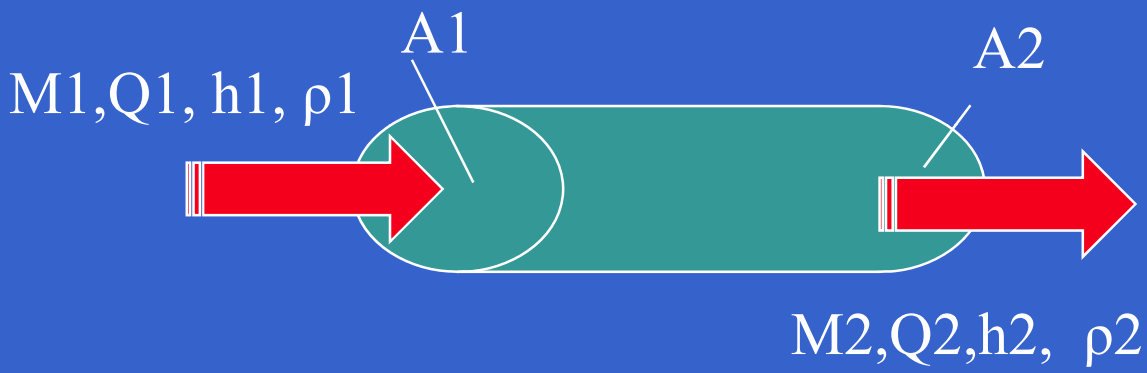
- Within some problem domain, the amount of mass remains constant--mass is neither created nor destroyed.

- The **first law of thermodynamics**, (conservation of energy), states that energy can be transformed (changed from one form to another), but cannot be created or destroyed

$M1=M2$

$\rho1 * Q1 = \rho2 * Q2$

$M1*h1=M2*h2$



Indoor Environmental Quality & Health

"**Health** is a state of complete physical, mental and social well-being, not merely the absence of disease or infirmity."

WHO, 1946

Indoor Environmental Quality

- indoor air temperature;
- mean radiant temperature;
- relative humidity;
- air movement;

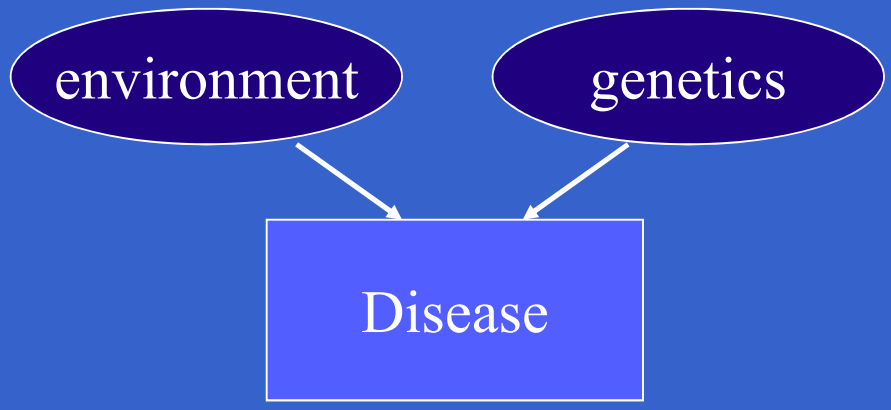
Thermal Comfort

- illumination (light level);
- sound;
- air quality;
- other factors (Furnishings, Psychological factors).

Health and Housing: A historical prospective

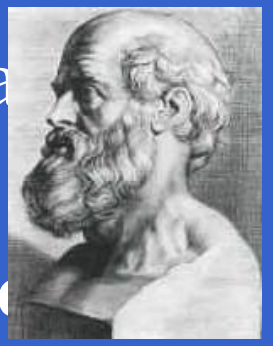
Perspective: Determinants of Health

- Genetics
- Environment
  - Behavior
    - Diet
    - Exercise
  - Occupation
  - Exposure profile
    - Pollutants
    - Infectious agents
  - Social determinants
    - Income
    - Social support
- Medical care



Historic overview: IEQ & Health

- Connection has been known for centuries
- Hippocrates, Greek philosopher and "fa
  of medicine"
- In his treatise, **On Air, Water and Pla**
  ".. disease is a direct manifestation of an unhealthy site rather than a form of punishment cast down by angry gods…."
- Similarly the Romans made the same connection..



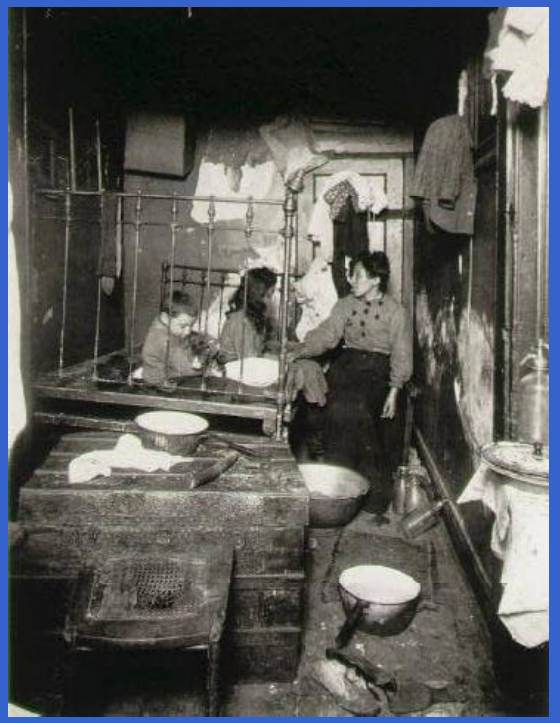
Florence Nightingale
the founder of the nursing profession.

In the 18th and 19th century, link focused on where you live…..

"The connection between the health and the dwelling of the population is one of the most important that exists."

Florence Nightingale, 1856

Urbanization– 19th century

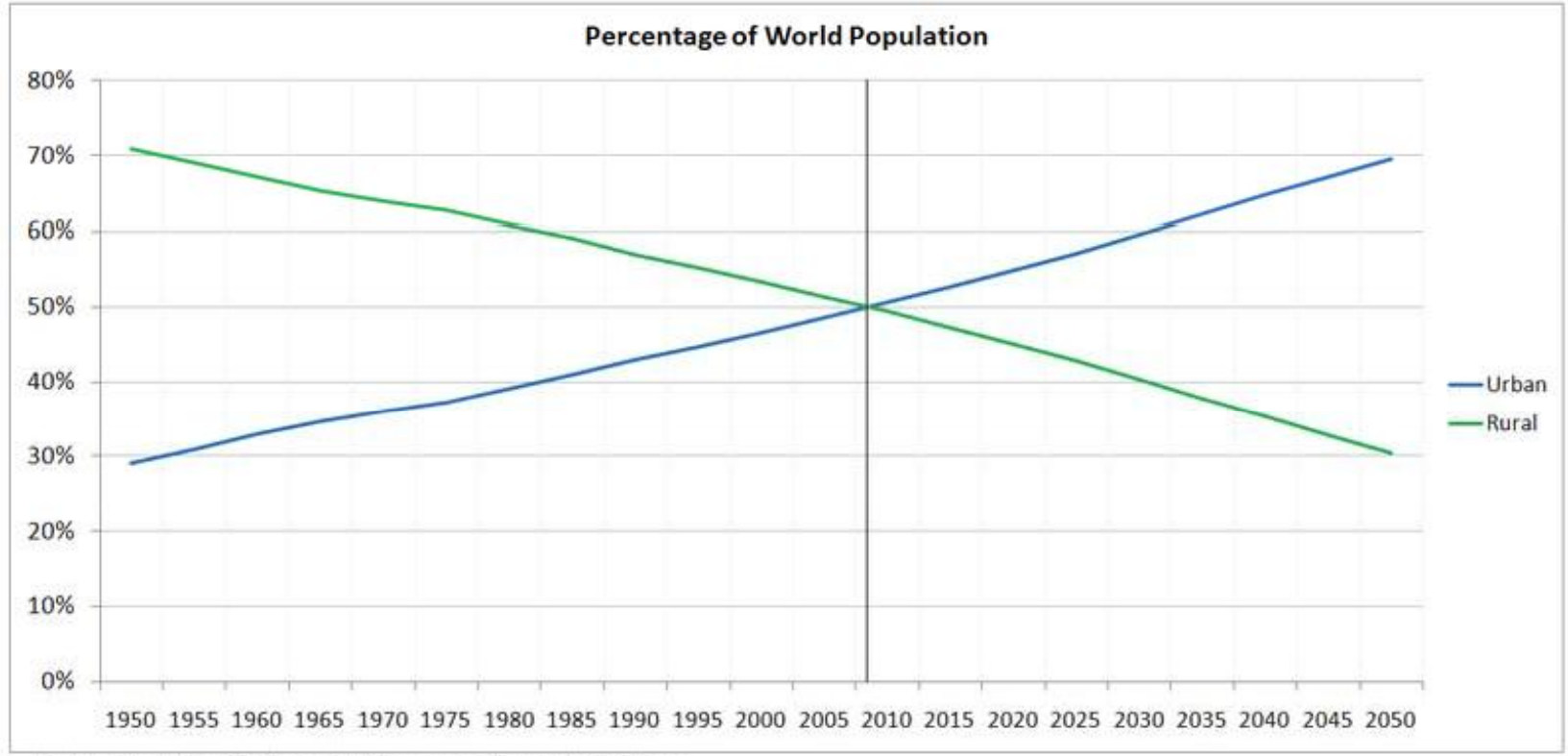


By 1900, New York had the highest population density on earth

Urban Housing – 19th century

- Urbanization- Overcrowding
- High rates of infectious disease (epidemics)
  - Cholera
  - Tuberculosis
  - Typhoid fever
- Poor sanitation
- Fire hazards
- Poor lighting
- No ventilation
- HOUSING laws started being implemented.

Urban Housing – 21st century
A turning point



What has changed in the indoor microenvironments over the last 50 years?

(Weschler Atmos. Envir. 2008)

www.cpluv.com/www/medias/prideparanoia/pridep

www.getmarquishomes.com

http://i.treehugger.com/files/th_images/dell_computers.jpg

Personal habit changes…..

Personal habit changes

- Time spend Indoors 
- Smoking 
- Pet ownership 

"…We spend over 90% of our time indoors…"

- Demographic shift from rural to urban lifestyles.

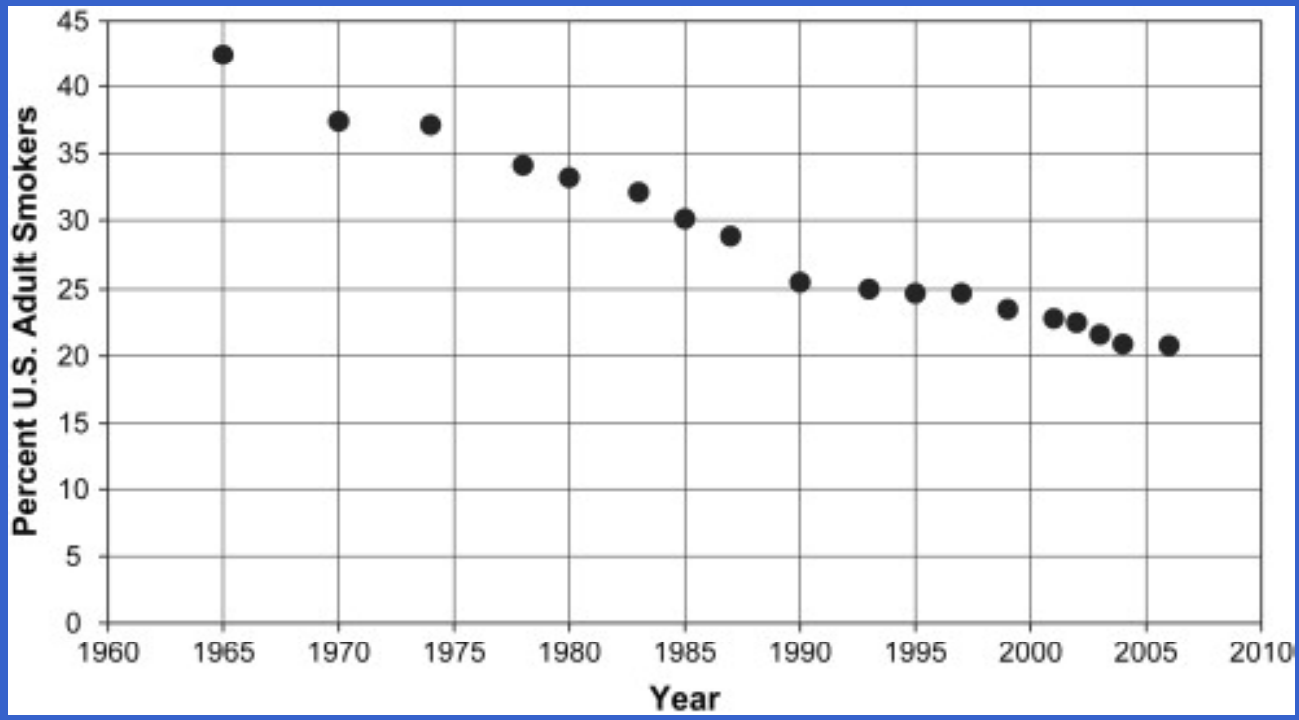
- Increase of indoor activities (work, webbased activities, shopping, etc)

- Increased dependence on the automobile – commuting to work

THE HUMAN IS AN INDOOR SPECIES

✓ More than 94% of a person's time is spent indoors or in a vehicle

Smoking trend in the US



Percent of U.S. adult smokers for the period from 1965 to 2006 (CDC, 2007).

Building factors…..

Modern Construction

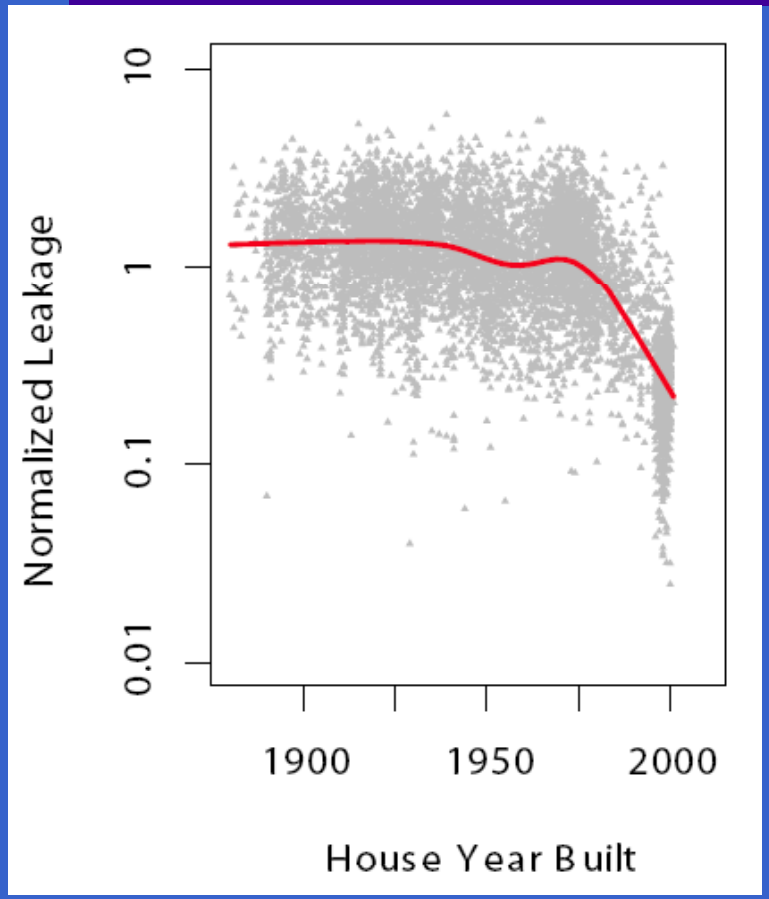
Synthetic Materials

VOC Sources

Office Machines

> 40% of US Homes Have Gas

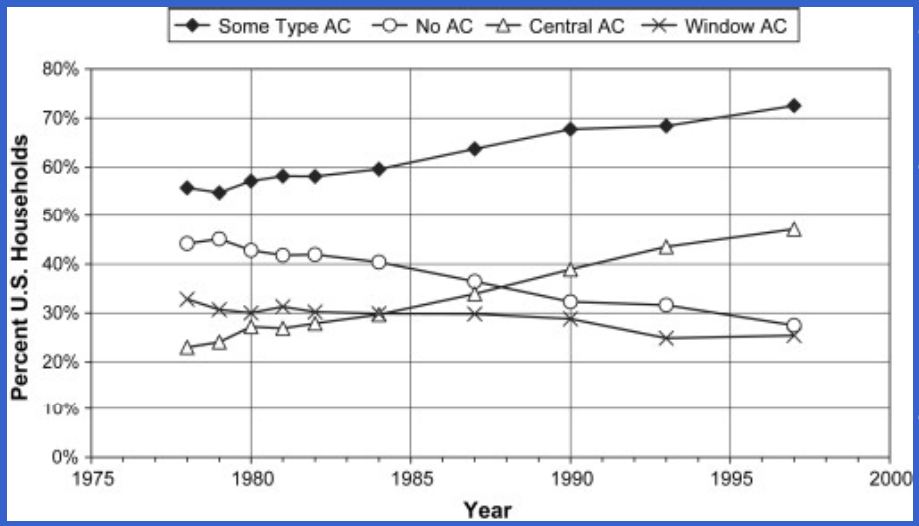
Tighter buildings…



(From Chan et al. 2003, LBL)

- Why we have tighter buildings today?
- Challenge: Acceptable IEQ and Energy balance
- Low ventilation and health implications

AC use in the US….



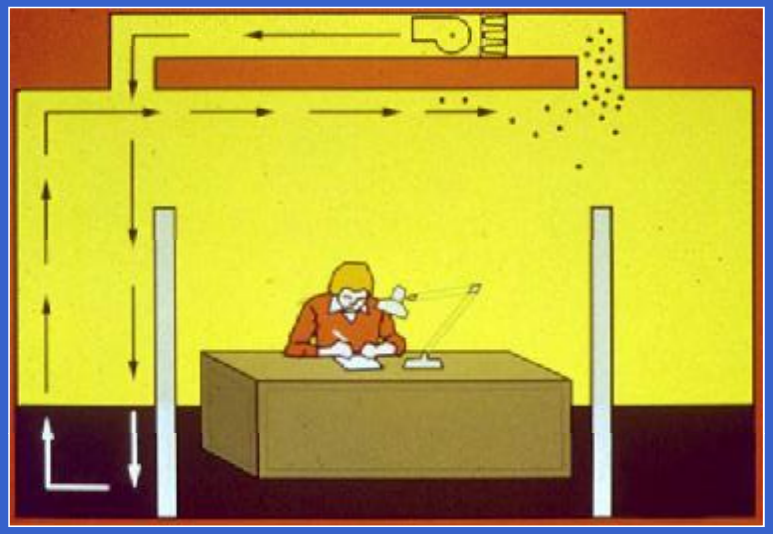
(Source,: Weschler,2008

- Central AC systems
- Mostly recirculation of air (90%)
- Less ventilation
- Less air pollutants from OA ???

Ventilation Effectiveness?

Good mixing

Poor mixing



IAQ problems over the years…?

IAQ of the 1980's

RADON	HCHO
ETS	VOC'S
ASBESTOS	NO_2

IAQ of the 1990's

SBS	MOLDS
PESTICIDES	ALLERGENS
Particulate Matter	LATEX

IAQ of the 21st century ….more challenges ahead

PHTHALATES	METALS
PERSISTENT POLLUTANTS PBDE,PCB's	ENDOTOXINS MYCOTOXINS and ACTINOMYCETES
CHEMICAL SENSITIZERS	INFECTIONS C/BW

Chemicals in our homes…

- USEPA reports 3000 chemicals produced or imported in USA per year with >1M pounds/yr
- 43% No testing for basic toxicity
- 7% Complete basic toxicity testing but not for endocrine activity
- Bisphenol A & Phthalates ~ 1B pounds/yr

m.htm 1999

Modern Chemicals

- Phthalates
- Bisphenol A
- Polytetrafluoroethylene (PTFE)
- Polychlorinated biphenyl (PCB)
- Polybrominated diphenyl ethers (PBDE)
- Triclosan

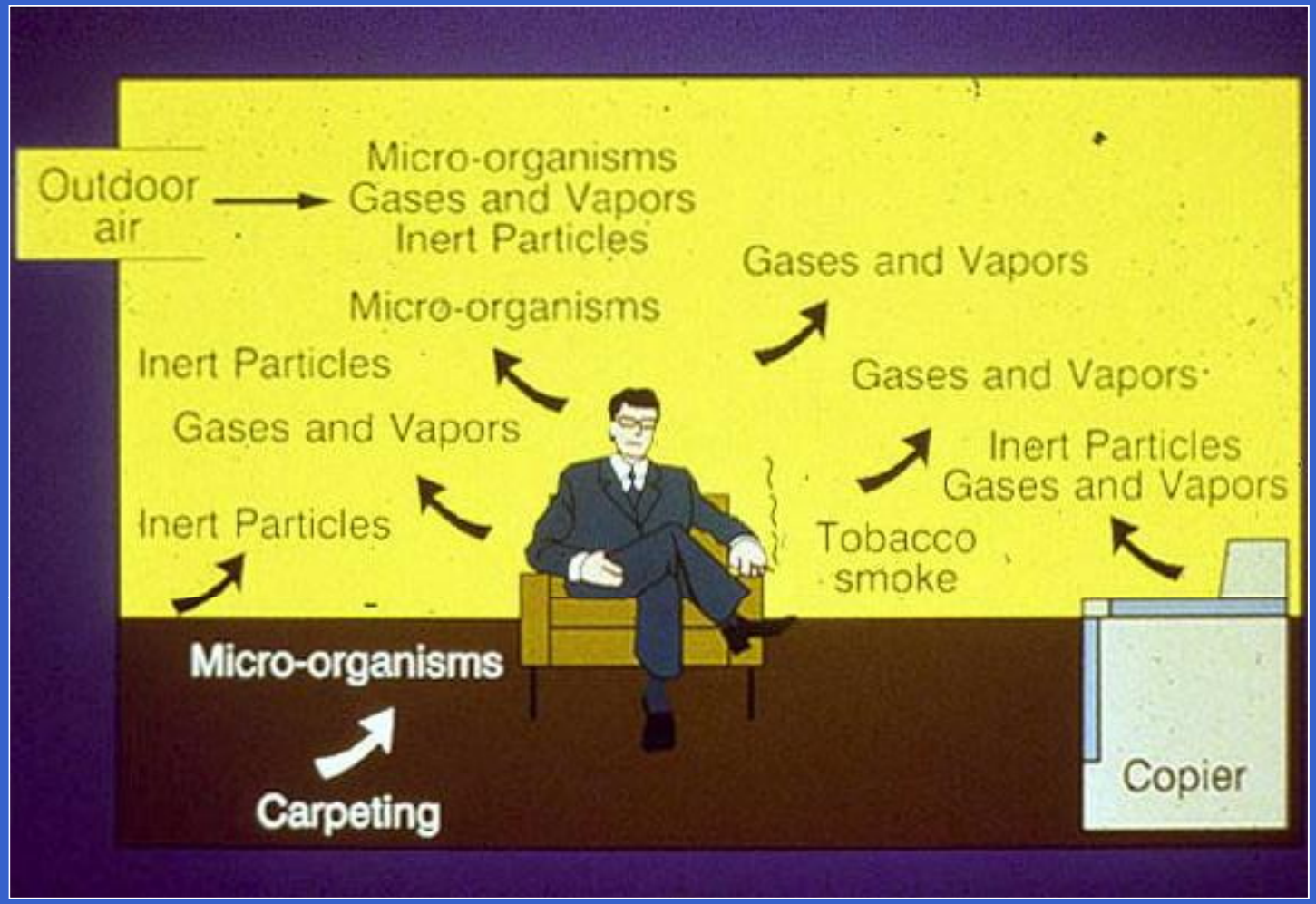
Environmental Laws?

Table 1: Content Analysis of Major Environmental Laws

Name of Law	"exposure"	"ambient air"	"indoor air"	"outdoor air"
Clean Air Act (CAA)	23	175	0	0
Clean Air Act Amendments	10	11	0	0
Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)	41	2	0	0
Superfund Amendments and Reauthorization Act (SARA)	14	0	18	0
Consumer Products Safety Act (CPSA)	4	0	0	0
Clean Water Act (CWA)	2	0	0	0
Federal Food, Drug, and Cosmetic Act (FFDCA)	35	0	0	0
Food Quality Protection Act (FQPA)	33	0	0	0
Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)	35	0	0	0
National Environmental Policy Act (NEPA)	0	0	0	0
Occupational Safety and Health Act (OSH Act)	20	0	0	0
Resource Conservation and Recovery Act (RCRA)	27	2	0	0
Safe Drinking Water Act (SDWA)	13	0	5	1
Toxic Substances Control Act (TSCA)	63	2	0	0
TOTAL:	**326**	**192**	**23**	

Indoor Environment

Indoor Environment



Indoor vs ambient Environment

- Limited volume of air
- Pollutants: higher indoor than OA concentrations, indoor sources
- Indoor chemistry
- personal habits, susceptible people

"RULE OF A THOUSAND"

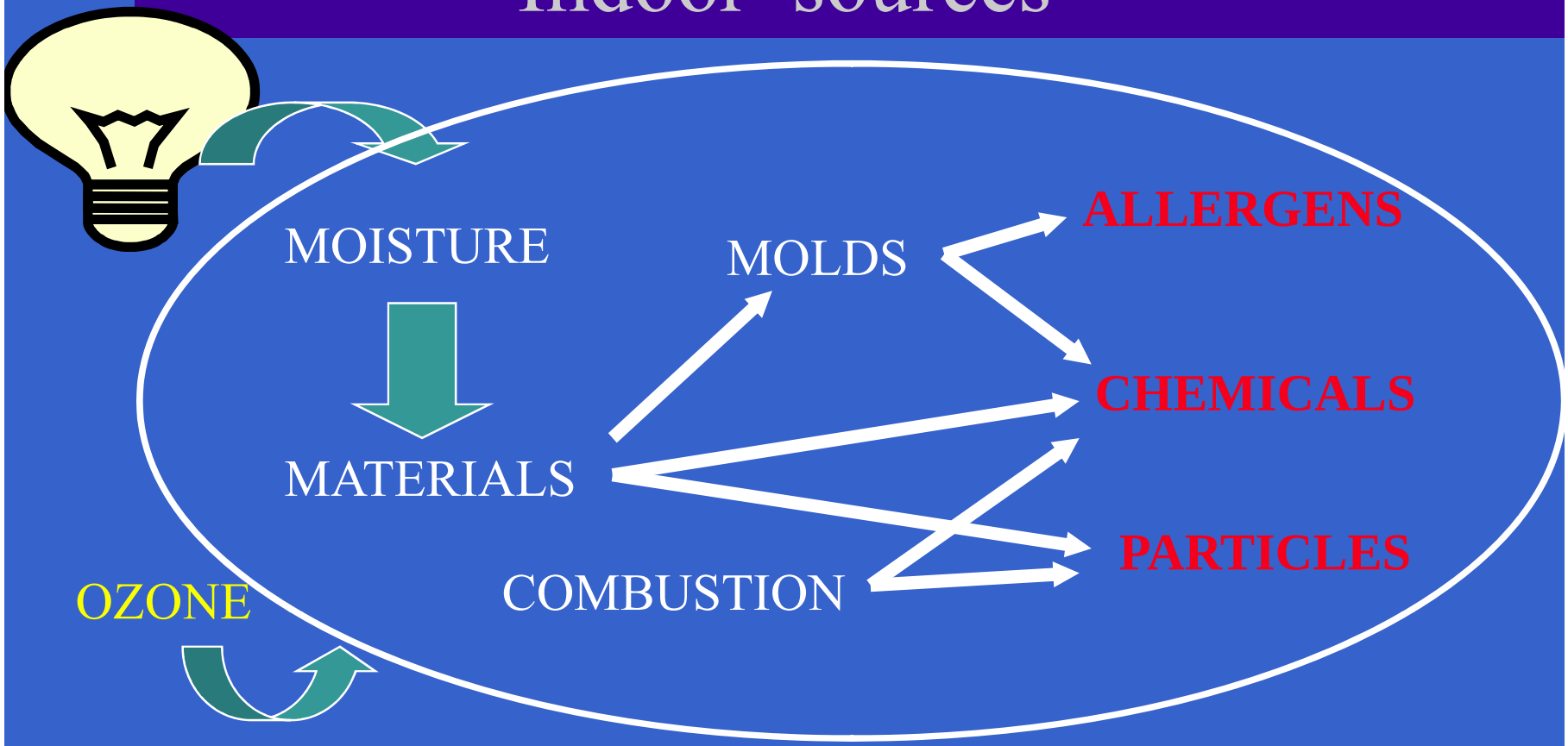
A pollutant released indoors is about 1000 times more likely to be inhaled than that same amount released outdoors

(Nazaroff, 2000)

Why are we concerned about IEQ?

- Indoor sources
- Many contaminants higher indoors and strongly influence exposures
- Spend over 90% of our time indoors
- Health, comfort and productivity are effected by indoor environmental conditions

Indoor sources



MAINTENANCE: Ventilation, Filtration, Cleaning

Air Pollutants with Higher levels indoors

Air Pollutants
(Higher Indoors than Outdoors)

- Criteria Air Pollutants
  - Carbon Monoxide*
  - Nitrogen Dioxide
  - Particulates
- Noncriteria (Toxic) Air Pollutants
  - Volatile Organic Compounds (VOCs)
  - Pesticides
  - Respirable Suspended Particles (RSP)
  - House Dust (lead*, ...)
  - Radon
  - Asbestos
  - Acid Aerosols

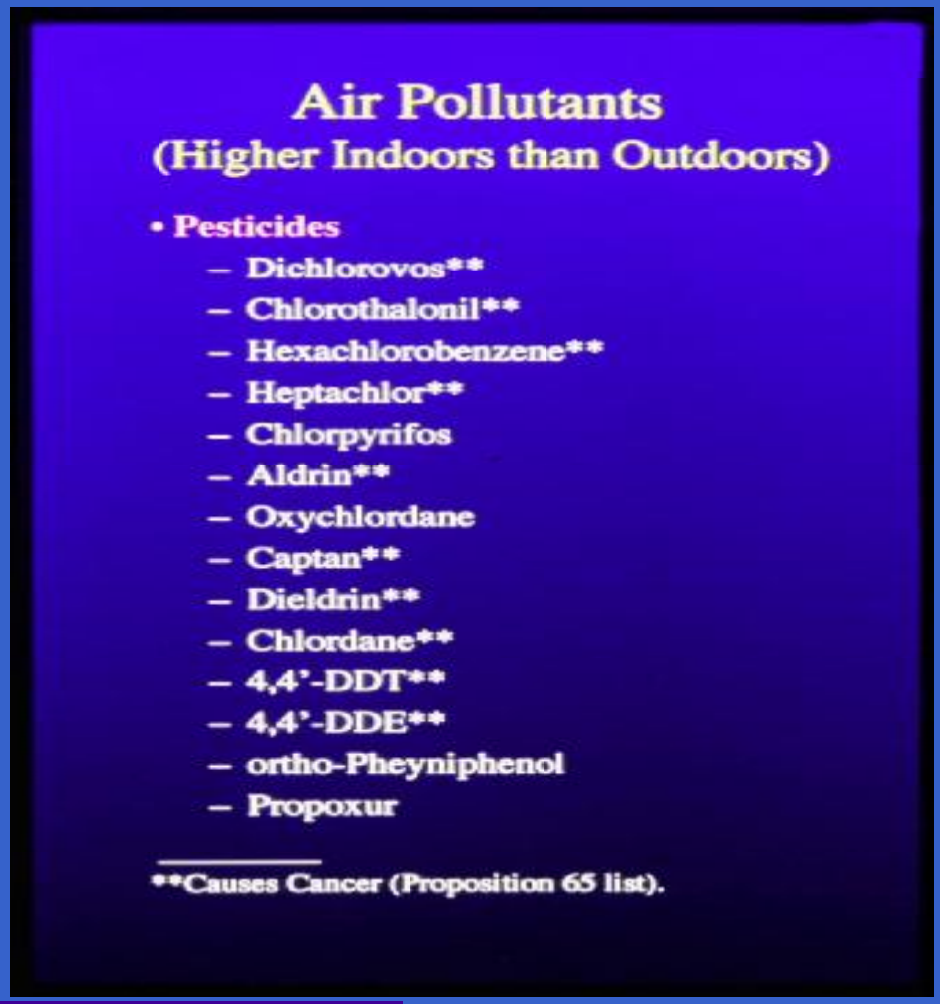
*Causes reproductive toxicity (Proposition 65 list) or direct health effects.

Toxic Air Pollutants
(Higher Indoors than Outdoors)

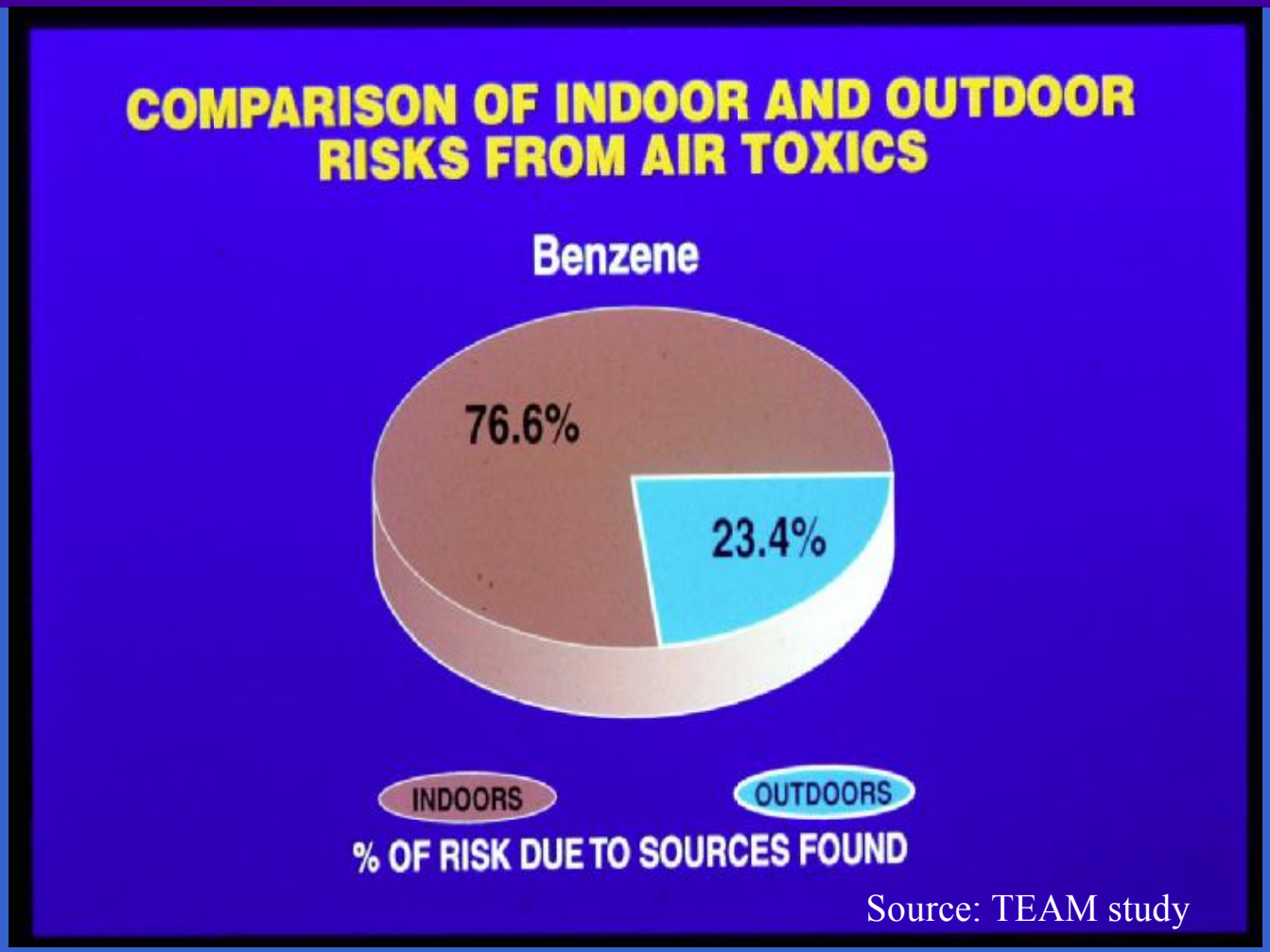
- Volatile Organic Compounds (VOCs)
  - Chloroform**
  - 1,1,1-Trichloroethane
  - Benzene**
  - Carbon Tetrachloride**
  - Trichloroethylene**
  - Tetrachloroethylene**
  - Styrene
  - meta, para-Dichlorobenzene**
  - Ethylbenzene
  - ortho-Xylene
  - meta, para-Xylene
  - Formaldehyde**
  - Methylene Chloride
- Environmental Tobacco Smoke**
  - Nicotine
  - Respirable Suspended Particles
  - Polycyclic Aromatic Hydrocarbons
  - Benzene**

**Causes Cancer (Proposition 65 list).

Air Pollutants with Higher levels indoors



Higher Health Risks for indoor sources



Indoor Environmental Quality (IEQ), productivity & Health related economic benefits ????

Improved Work Performance

- Higher ventilation rate
- Better temperature control
- Better lighting quality?
- Improved acoustics ?

Health-Related Economic Benefits

- **Higher ventilation rate**
- **Reduced allergens and chemicals**
- **No indoor smoking**
- **Reduced moisture problems**

IEQ and Health link – the global picture

- WHO Global Burden of Disease Project (2002)

- Conservative estimates of 2 – 3% of global DALY

POTENTIAL INDOOR AIR HEALTH EFFECTS

- Allergic Reactions (Molds, Particles)
- Angina (CO)
- Asbestosis
- Asthma (Particles, Mold)
- Brain Damage (CO)
- Burning Lung (Molds, Particles)
- Chronic Cough (Molds, Particles)
- Chronic Pulmonary Obstructive Lung Disease (CPOD)
- Dizziness (CO, VOCs, Molds)
- Headache (CO, Molds)
- Fatigue (VOCs)
- Fluid in Throat (Particles, Mold)
- Immunosuppression (VOCs, Pesticides, Molds)
- Lung Cancer (Particles, Radon)
- Leukemia (Benzene, VOCs)
- Multiple Chemical Sensitivity (VOCs)
- Neural Effects (Molds, VOCs, Pesticides)
- Shortness of Breath (Molds, Particles)
- Seizures (Molds, Pesticides)
- Sudden Death (CO)
- Tightness in Chest (Molds, Particles)

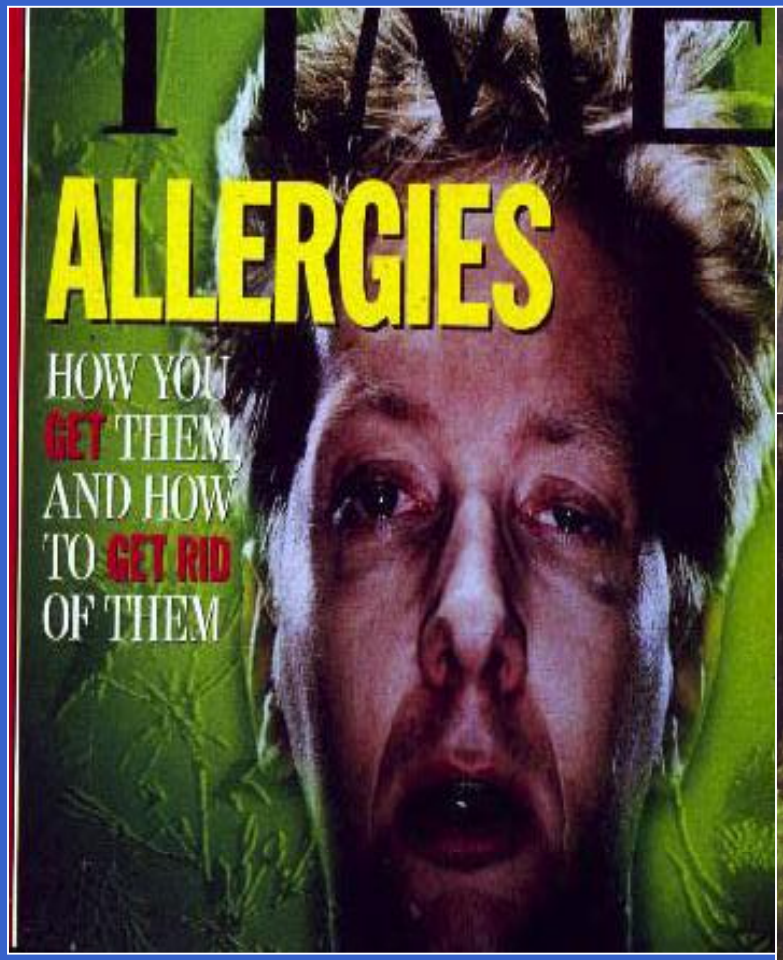
Sick Building Syndrome

SYMPTOMS:

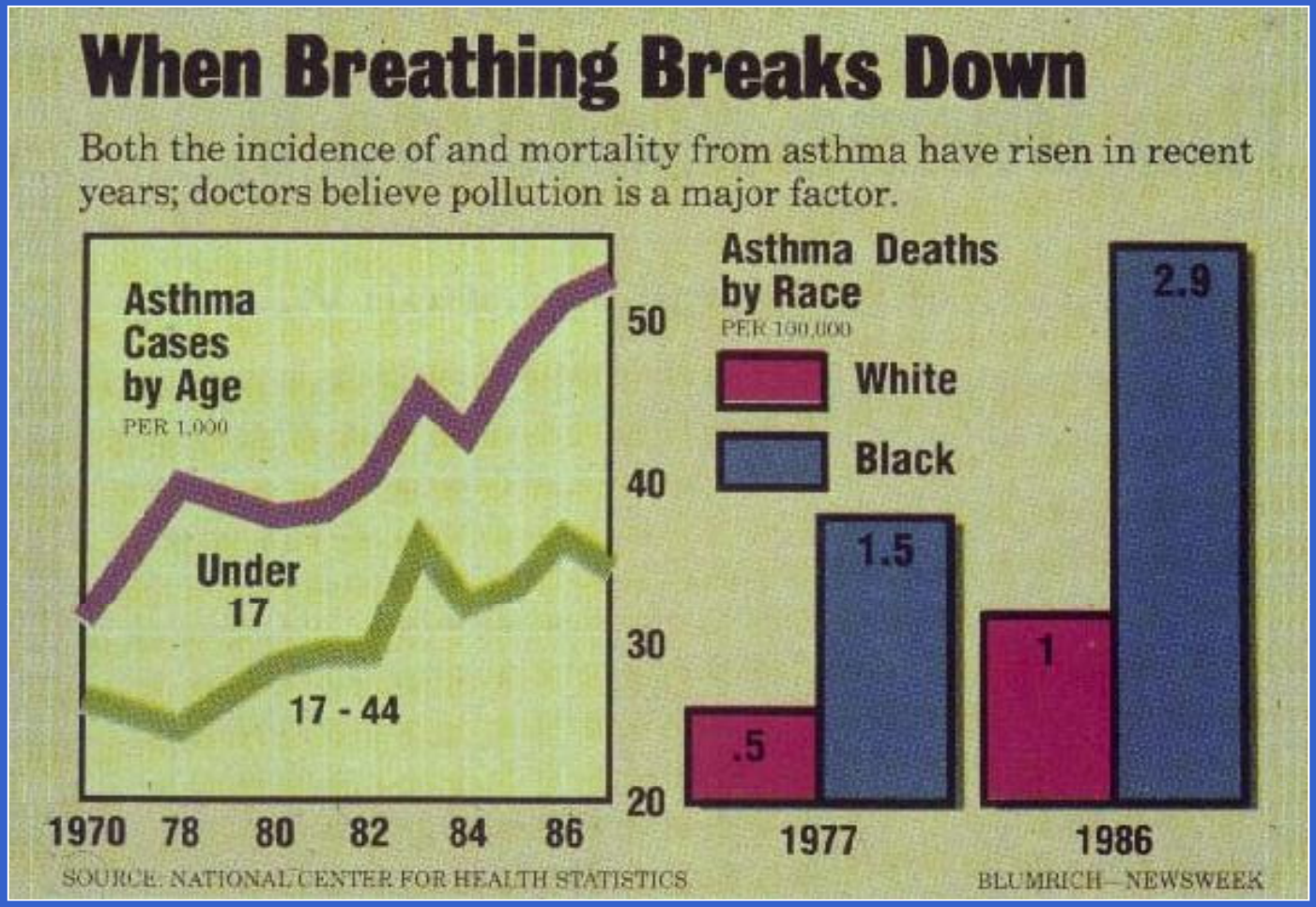
- Dry - Itchy Eyes
- Nasal Irritation
- Hoarseness, Irritated Throat, Laryngitis
- Skin Problems
- Fuzzy Thinking, Memory
- Irritability, Sleep Disruption, Fatigue
- Headaches, Nausea

- Symptoms Linked to Building
- Resolve When not in Building
- Affect a Substantial Fraction of Occupants

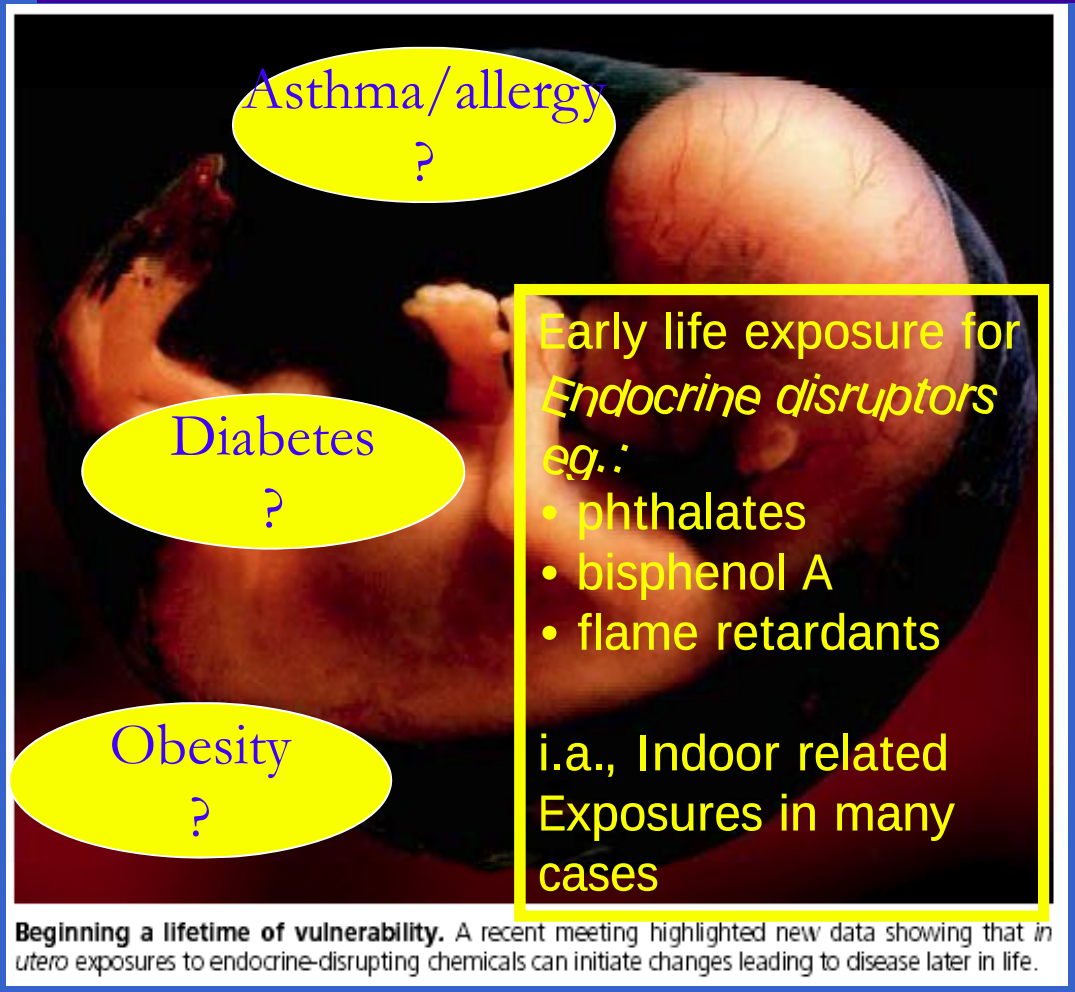
> 30% of Americans Have Allergies



Asthma Up 75% [1980-1994]



Health Concerns from new chemicals?

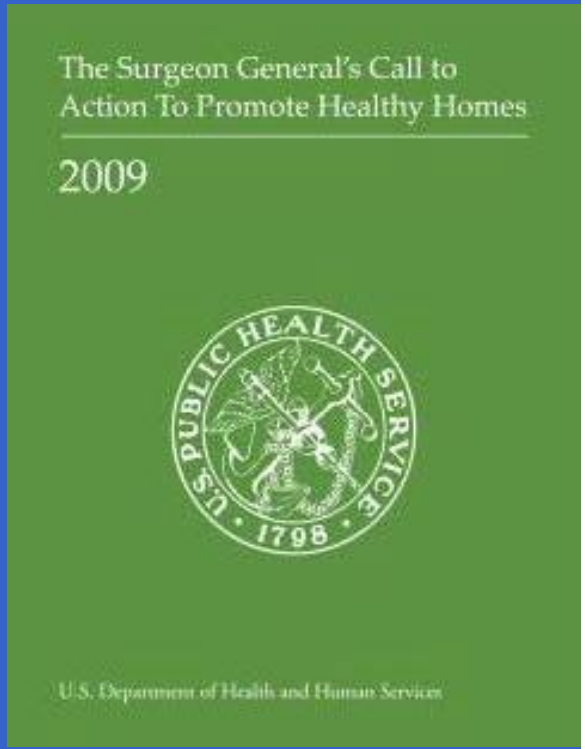


Beginning a lifetime of vulnerability. A recent meeting highlighted new data showing that *in utero* exposures to endocrine-disrupting chemicals can initiate changes leading to disease later in life.

US Surgeon General's Call to Action to Promote Healthy Homes

On June 9, 2009, Acting Surgeon General Steven K. Galson released *The Surgeon General's Call to Action to Promote Healthy Homes*.

> "***A healthy home is sited, designed, built, renovated, and maintained in ways that support the health of residents***"
> i



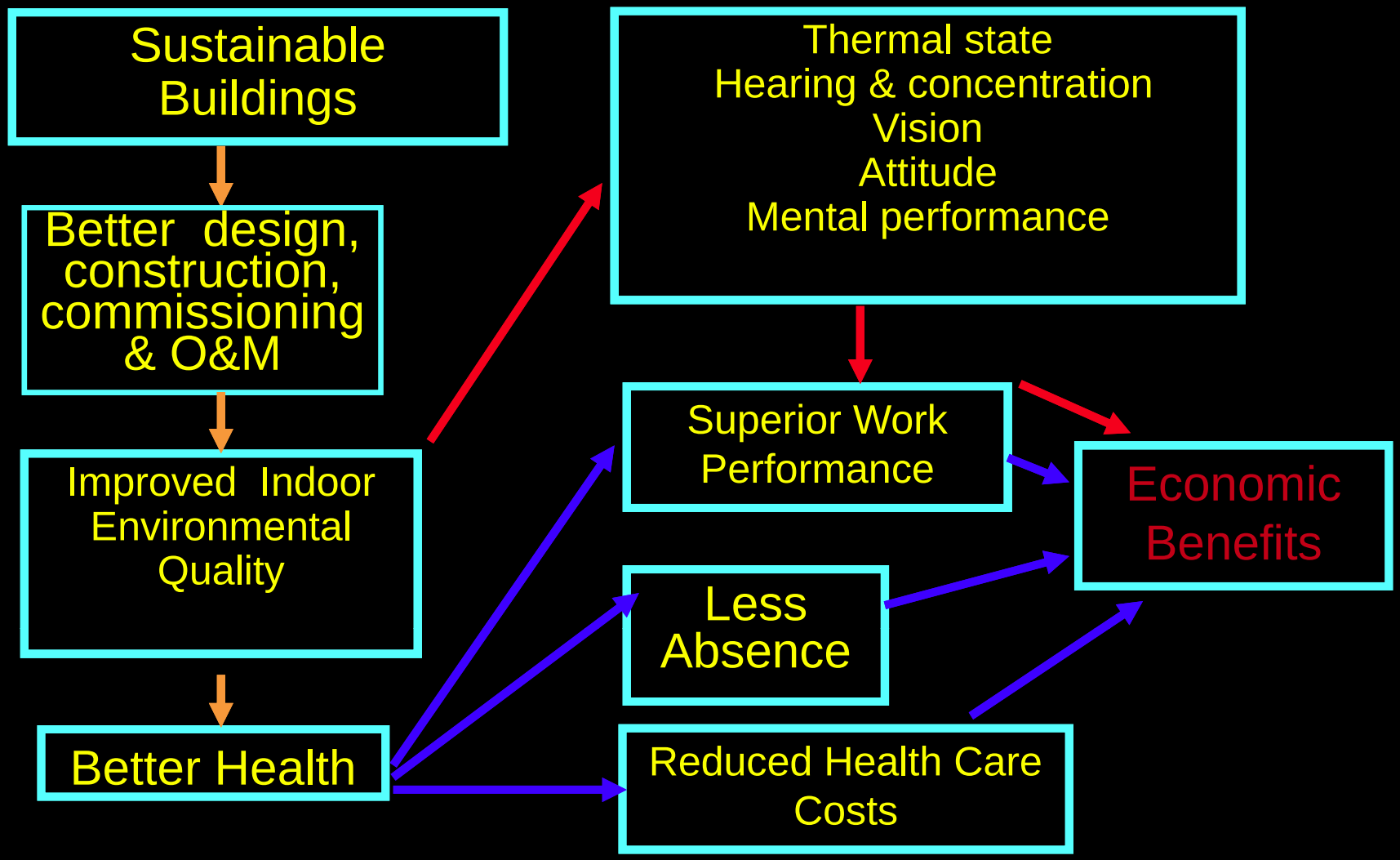
Buildings for the Future…

- Green Buildings
- Sustainable buildings
- Energy Efficient buildings
- Healthy buildings

Top Ten Characteristics of a Healthy Building

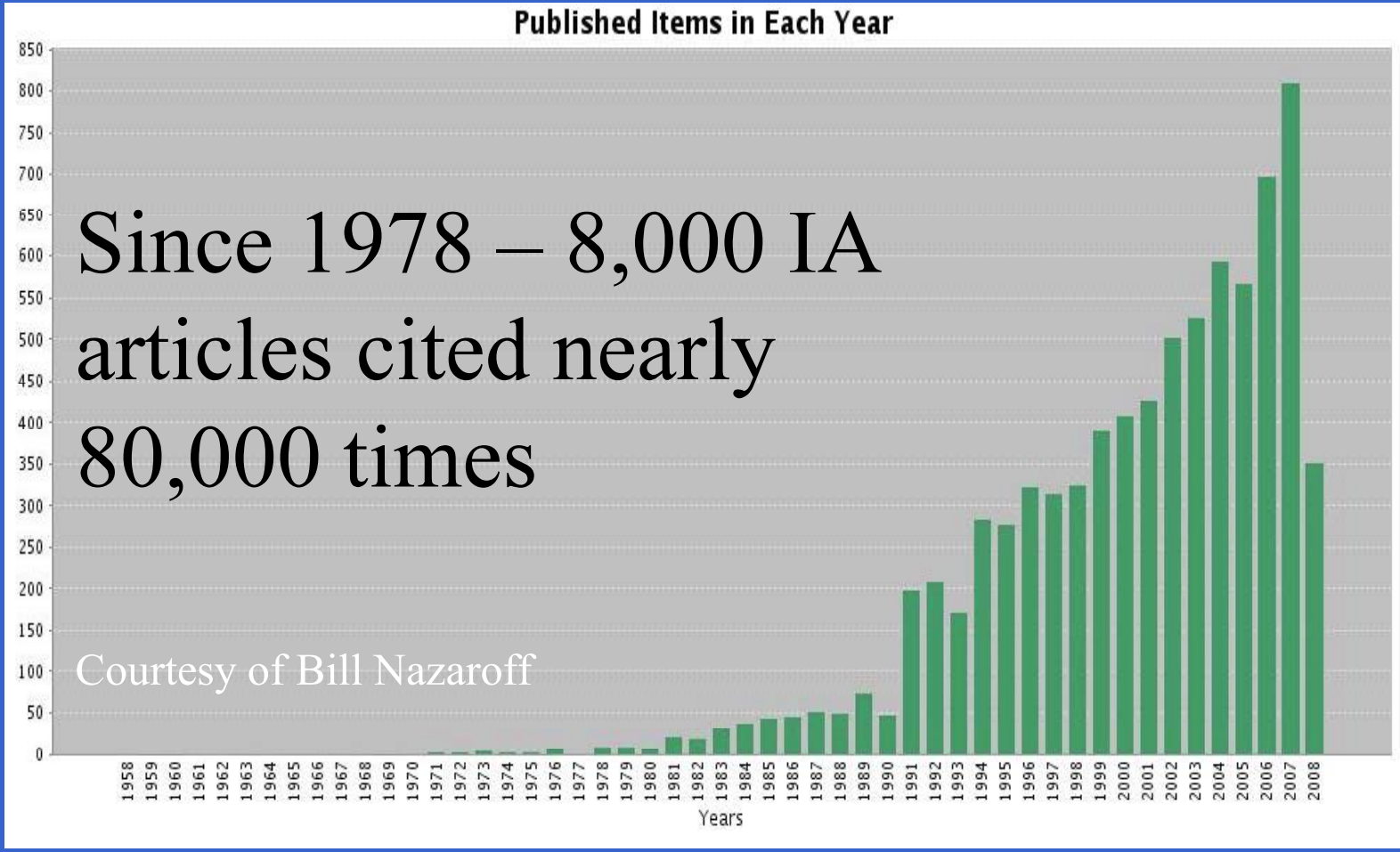
- Dry
- Clean
- Ventilated
- Thermal control
- Acoustic quality
- Glare control
- Odor control
- Air quality
  - VOCs
  - Biologicals
  - Ozone
  - Particles
- Space equity
- Manage workplace stress

How Sustainable Buildings Could Improve Health & Productivity



W. Fisk, LBNL, White House Conference, Jan. 2006

A Generation of Indoor Air Science: 1978 - 2008



Since 1978 – 8,000 IA articles cited nearly 80,000 times

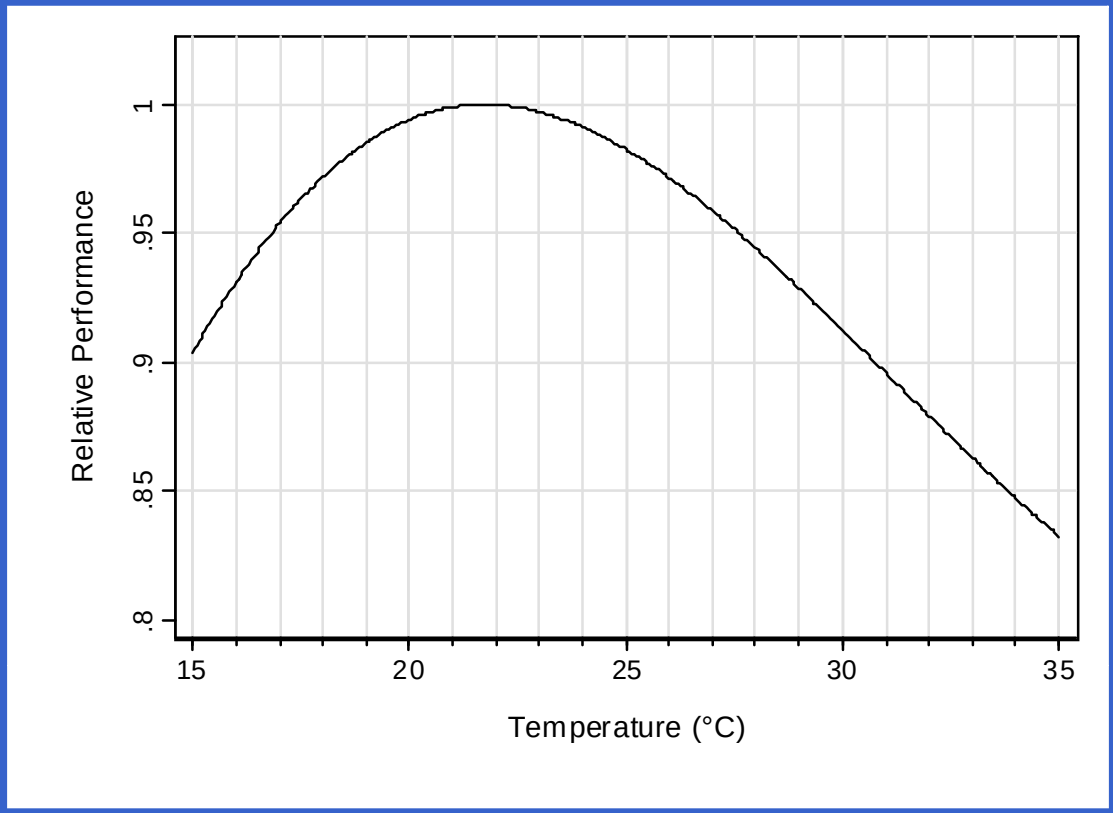
Courtesy of Bill Nazaroff

Thank you for your attention

International Building Guidance

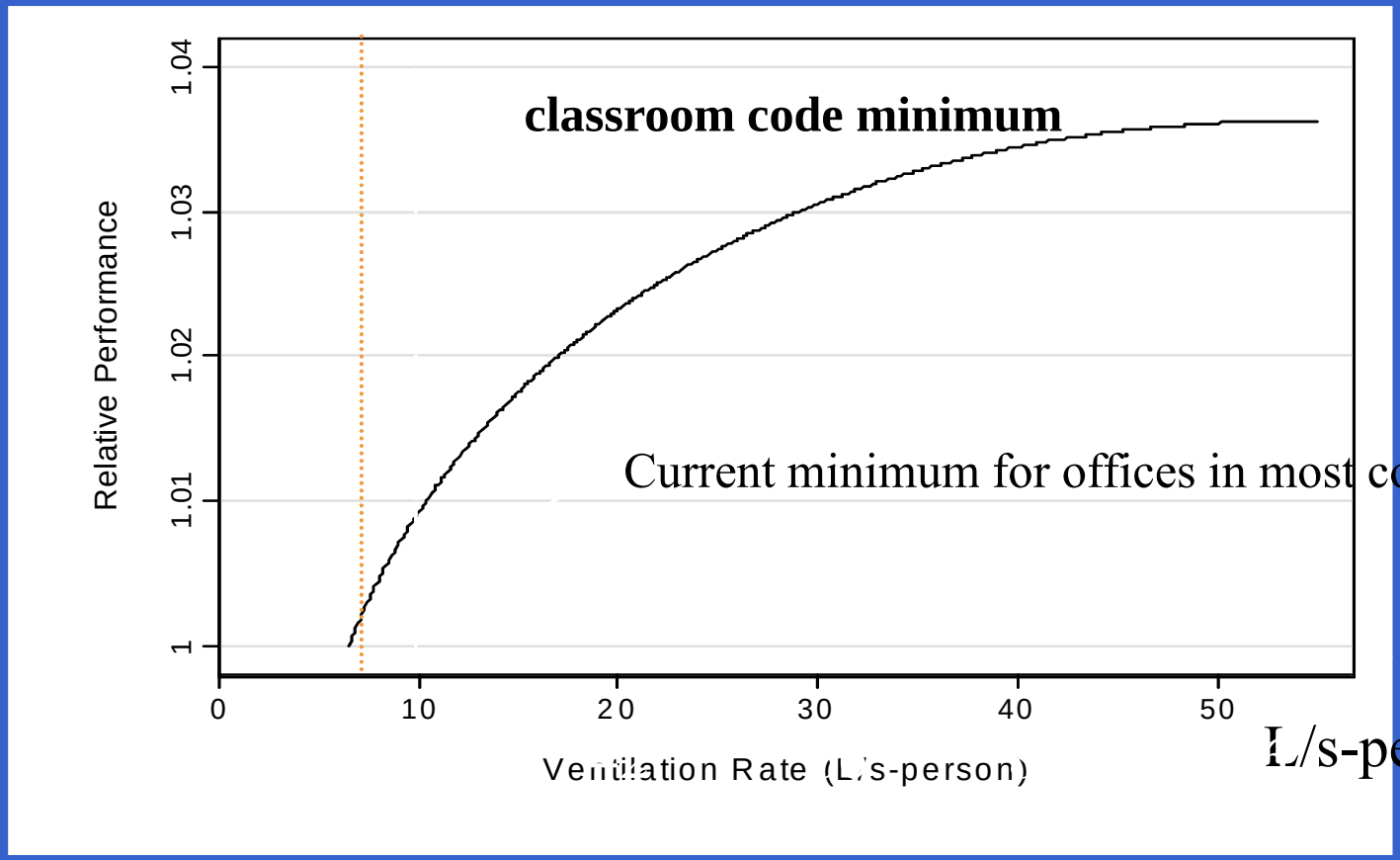
- USGBC – *LEED*
- UK – *BREEAMS*
- JAPAN – *CASBEE*
- AUSTRALIA - *GREEN STAR*
- GERMANY – new system being introduced

Relative Work Performance vs. Temperature (maximum performance at at 21.8 ºC, 72 ºF)



Source:
Seppanen and Fisk (2005)

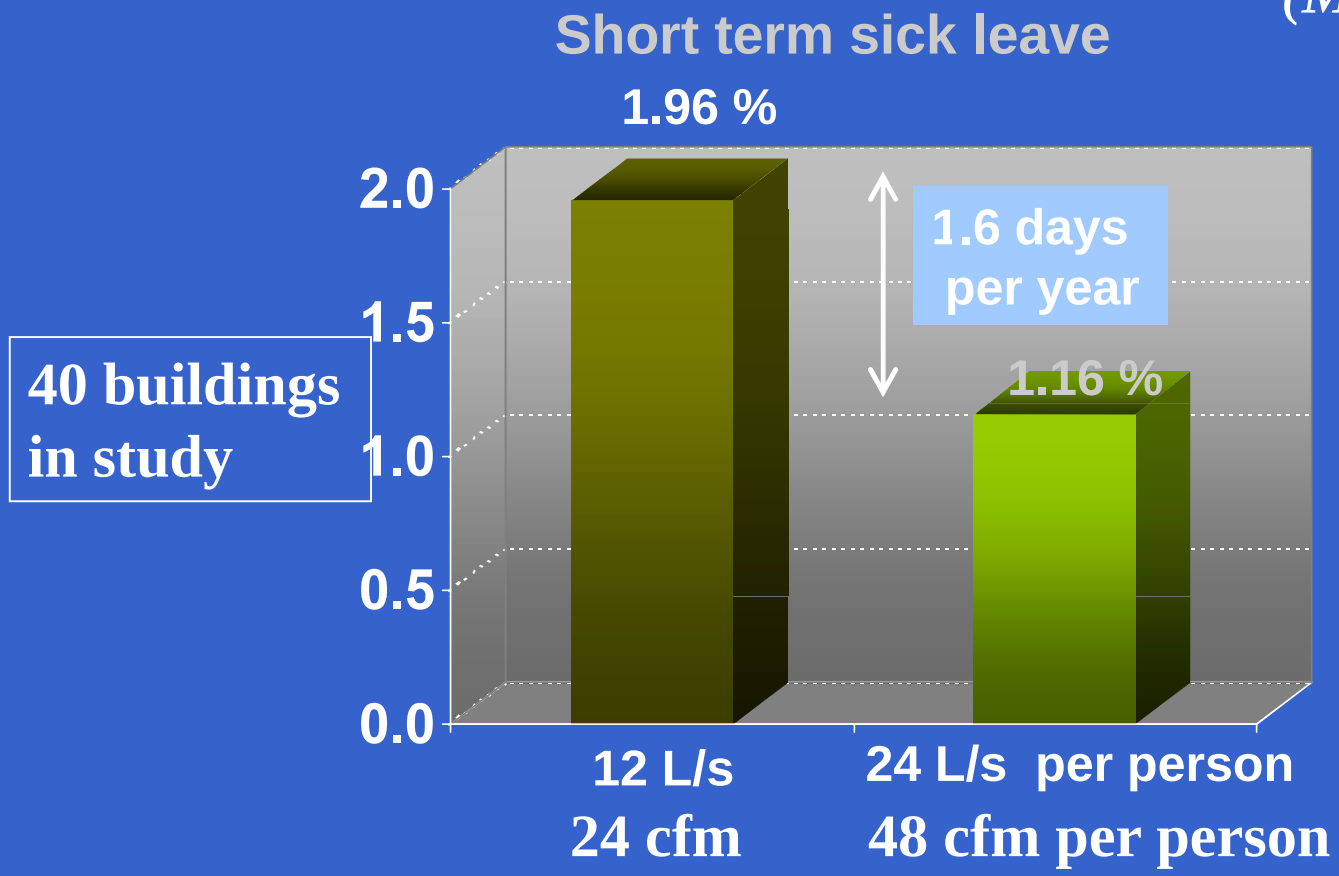
Ventilation and Productivity



Seppanen, Fisk, Lei-Gomez (Indoor Air Journal 2005)

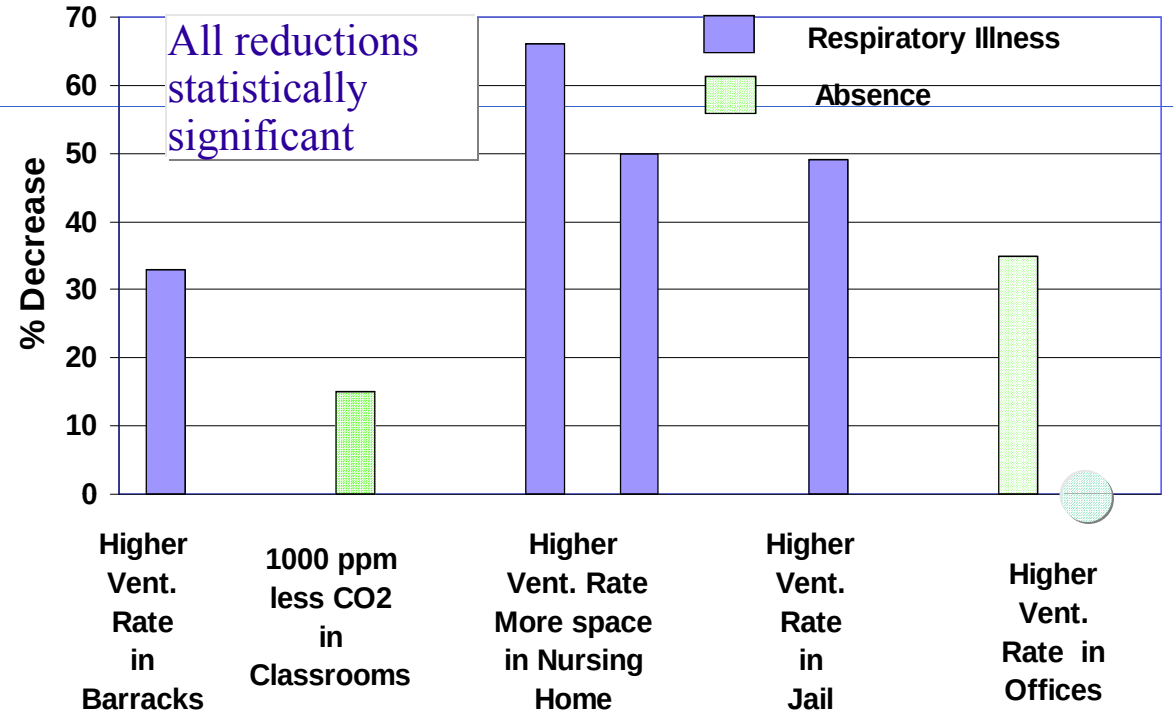
Ventilation and short term sick leave

(Milton et al. 2000)



Ventilation and Respiratory illness

Decrease in Respiratory Illness or Absence With Increased Ventilation Rates



Source: Fisk Annual Rev. E&E 2000

IAQ Problems

THE FRONTLINE

One Player Lifeflighted; Zamboni Under Investigation

Mystery Malady Strikes Hockey Players During Game

Zamboni fumes felling skaters

Ice-surfacing vehicle, poor ventilation cited

stronaut

Birth

WISCONSIN STATE JOURNAL

Bad air linked to hockey game illnesses

At least 20 fans, players affected

Ice-cleaning machines may harm players

Carbon monoxide buildup raises heart-attack risk, study shows

Media frenzy?

Boston Globe
April 13, 1995