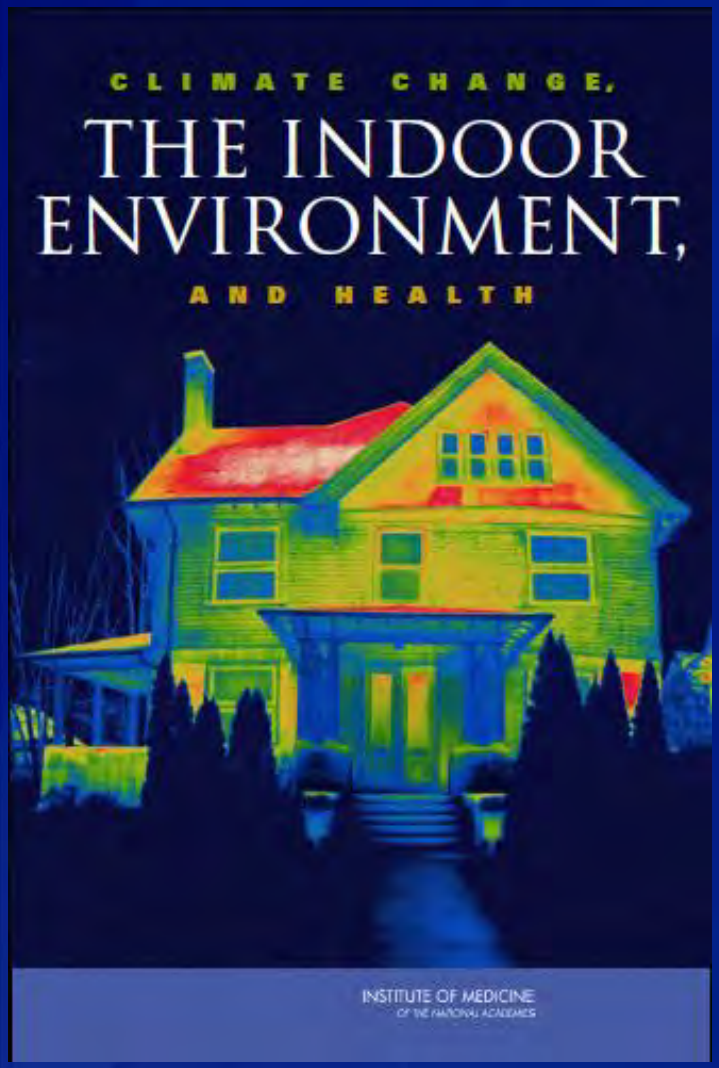
US EPA ARCHIVE DOCUMENT

Climate and housing factors that affect indoor allergens, mold, and asthma

Ginger L. Chew, ScD

National Center for Environmental Health
Air Pollution and Respiratory Health Branch



EPA commissioned a report from the Institute of Medicine (IOM) that:

- summarizes the state of scientific understanding of the effects of climate change on indoor air quality and public health.

*Published in 2011 http://www.nap.edu/catalog.php?record_id=13115

Committee on the Effect of Climate Change on Indoor Air Quality and Public Health

- **John D. Spengler, Ph.D.**
- *Chair*
- Harvard School of Public Health
- **John L. Adgate, Ph.D.**
- Colorado School of Public Health
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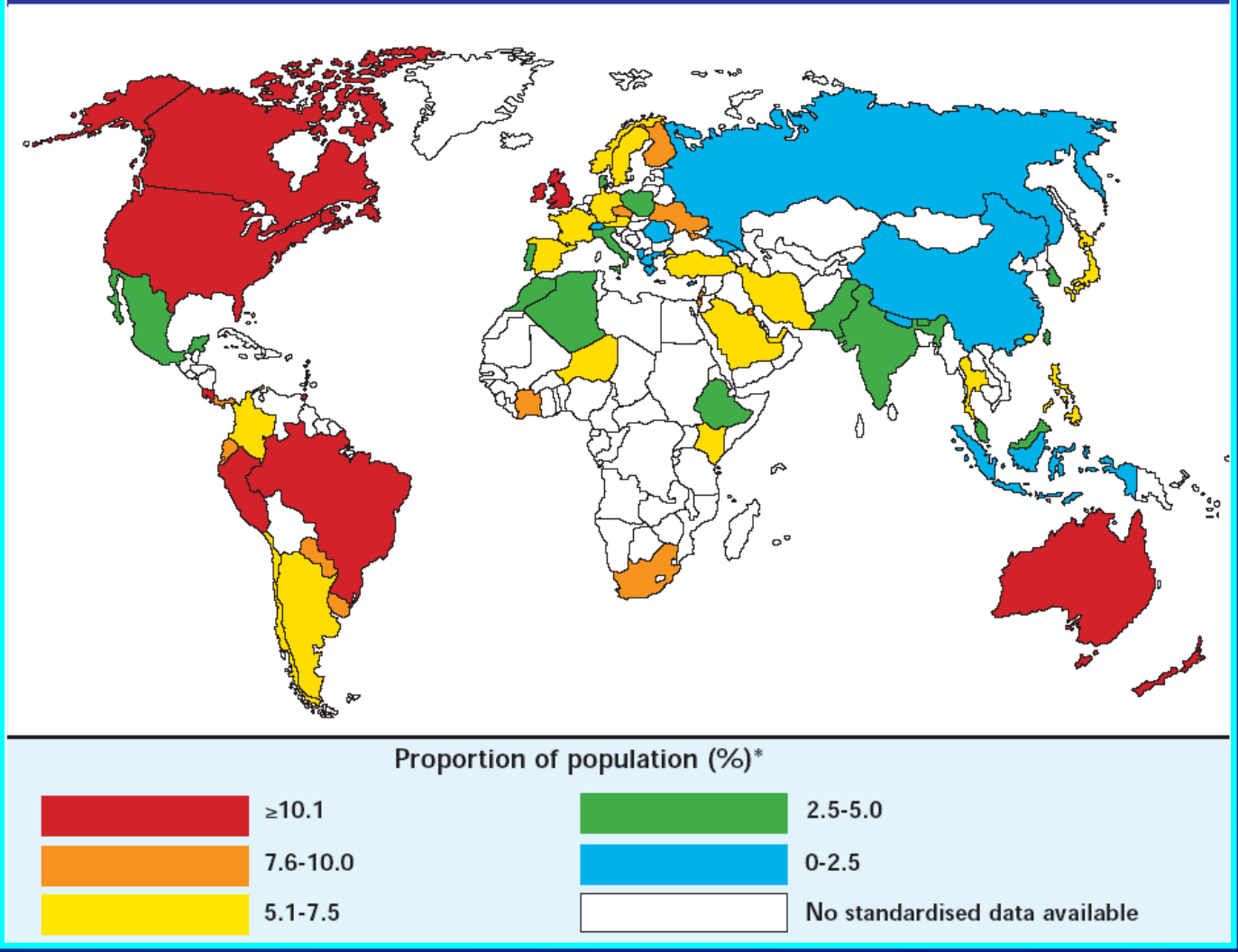
Division of Respiratory Disease Studies, NIOSH

World Map of the Prevalence of Clinical Asthma



Masoli et al., Global Initiative for Asthma (GINA) publication, 2004

Summary of Findings from the National Academy of Sciences (NAS)

Factor	Asthma Development	Asthma Exacerbation
<u>Biological agents</u>		
Dust mite allergen	✓+	✓+
Cockroach allergen	✓-	✓+
Fungi	-	✓
Rodent allergen	-	-
<u>Chemical agents</u>		
ETS (in preschool-aged children)	✓	✓+
NO2	-	✓
ETS (in school-aged and older children)	-	✓-
Formaldehyde	-	✓-
Pesticides	-	-
Plasticizers	-	-
VOCs	-	-
	-	-

✓+ = sufficient evidence of a causal relationship

✓ = sufficient evidence of an association

✓- = limited or suggestive evidence of an association

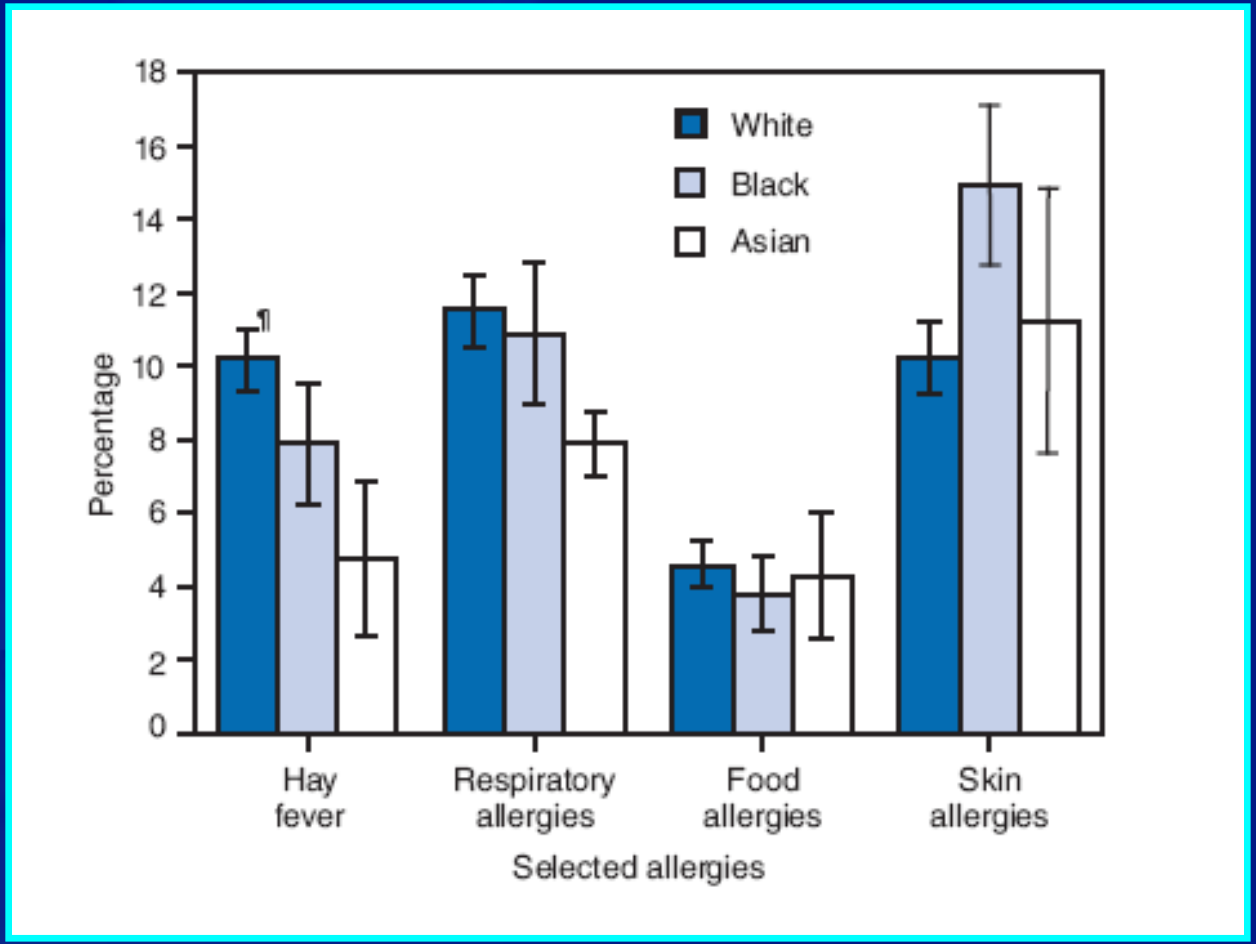
\- = inadequate or insufficient evidence to determine whether or not an associations exists

NAS, Institute of Medicine. Clearing the Air. 2000

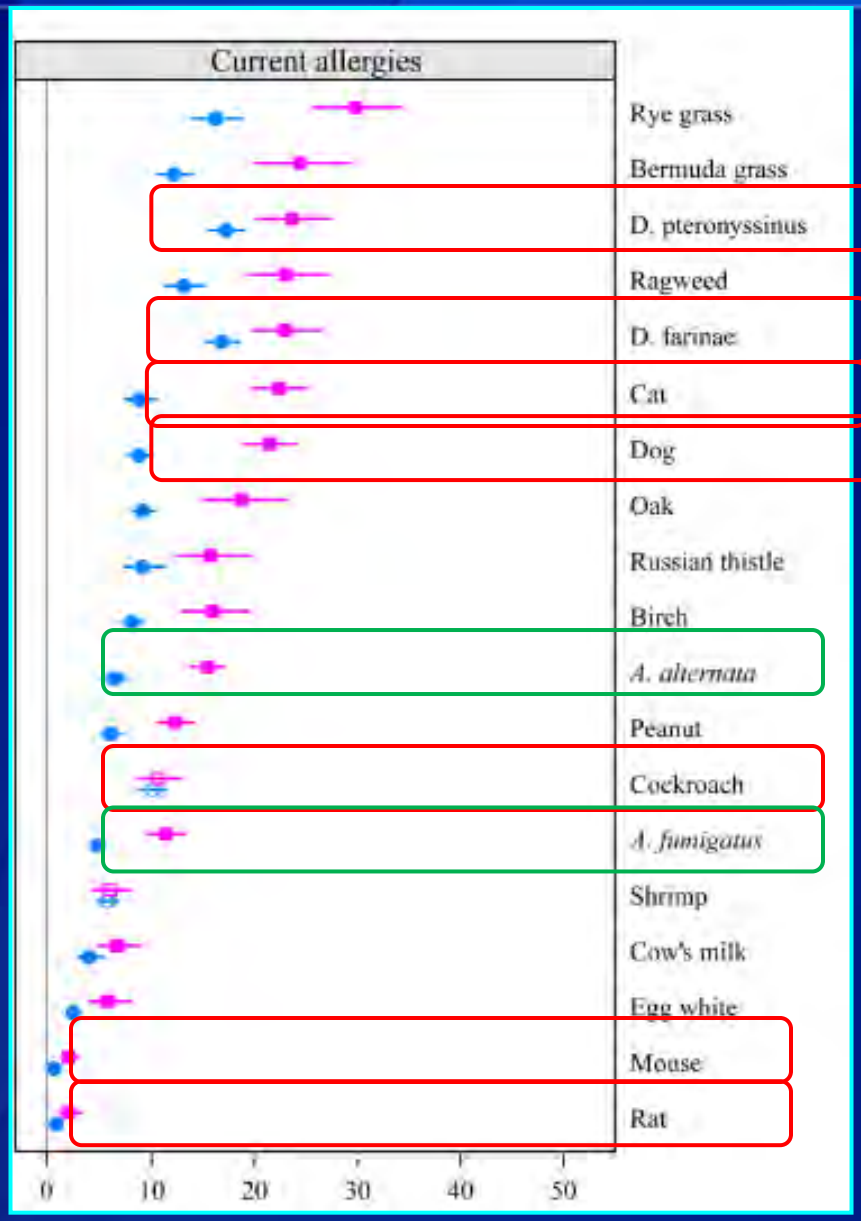
Newer findings

Factor	Asthma/ allergy references
Biological agents Fungi Rodent allergen	Jaakola et al., 2005 Matsui et al., 2006
Chemical agents Formaldehyde Pesticides Plasticizers VOCs (secondary chemical reactions) Antimicrobial agents (e.g.,Triclosan)	Mendell, 2007 Salam et al., 2004 Bornehag et al.,2004, Jaakola et al., 2008 Rumchev et al., 2004 Weschler, 2009 Clayton et al., 2012, Savage et al., 2012

Percentage of Children Aged <18 Years with Selected Allergies, by White, Black, or Asian Race (National Health Interview Survey), United States, 2008



MMWR (October 16, 2009)/ 58(40); 1127



Among general population, where are indoor allergens in the hierarchy?

*NHANES 2005-6 IgE data

Salo et al., J. Allergy Clin. Immunol, 2011

Allergy Prevalence - NHANES 1998-1994 Skin prick Test data (Children ages 6-16)

TABLE I. Sample characteristics and prevalence of allergen sensitivity

			Sensitive (%)				
	Sample (n)	Weighted (%)	Any allergen	Cockroach	Dust mite	Cat	*A altemata*
All children	4164	100.0	43	20	25	15	16
Sex							
Male	2057	52	48	22	29	17	19
Female	2107	48	37	18	21	13	12
Age (y)							
6-11	2520	53	38	17	22	11	13
12-16	1644	47	48	22	29	20	18
Race-ethnicity							
White NH	1116	73	41	16	24	16	14
Black NH	1502	17	52	33	29	15	22
Mexican American	1546	10	43	25	24	12	14

African American: OR = **2.5** [1.9-3.2]
Mexican American: OR = **1.9** [1.3-2.8]
White: reference category

Stevenson et al, J. Allergy Clin. Immunol. 2001

Dust mite sensitization and wheeze (Multi-site German study)

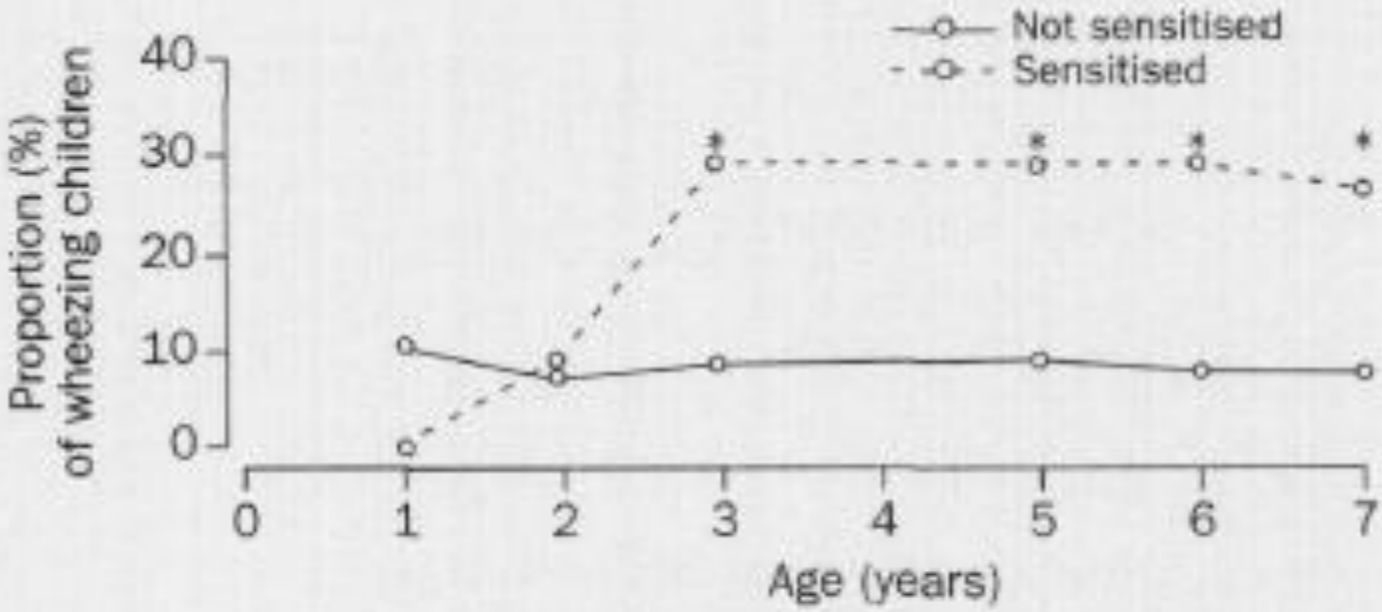


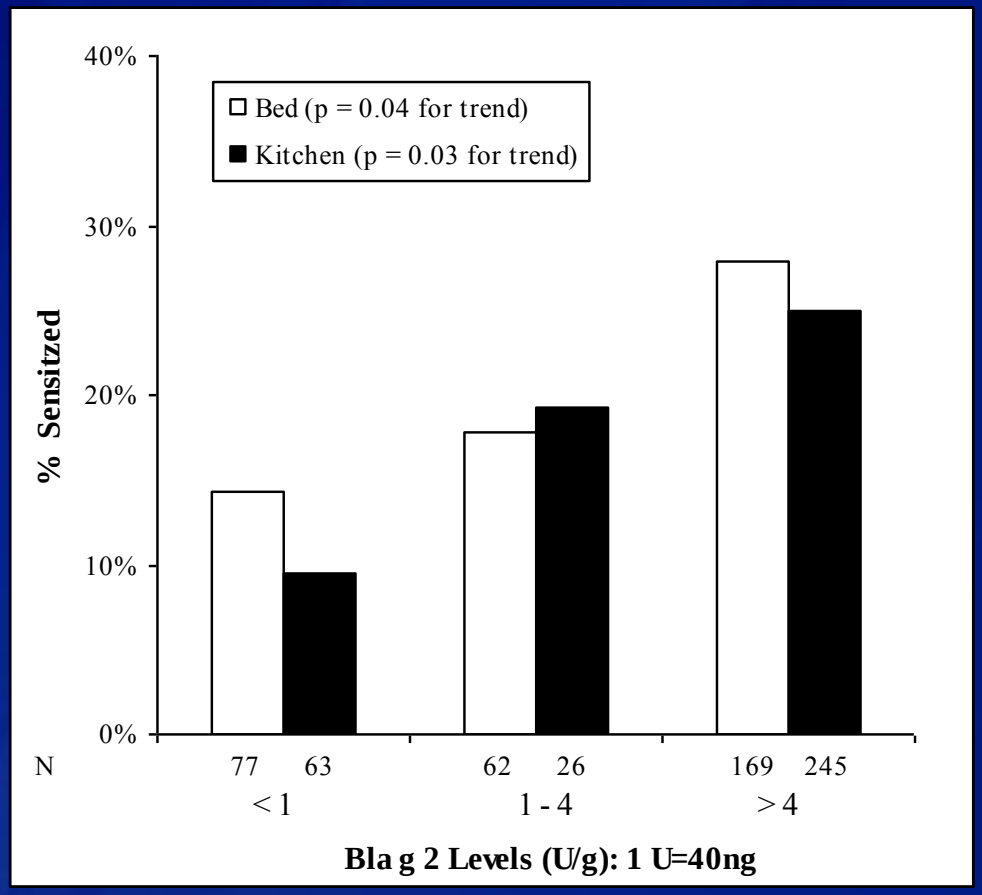
Figure 1: **Proportion of wheezing in children with and without sensitisation to mite allergen, by age**

*p<0·001.

Lau et al., Lancet 2000

Cockroach exposure associated with cockroach allergy

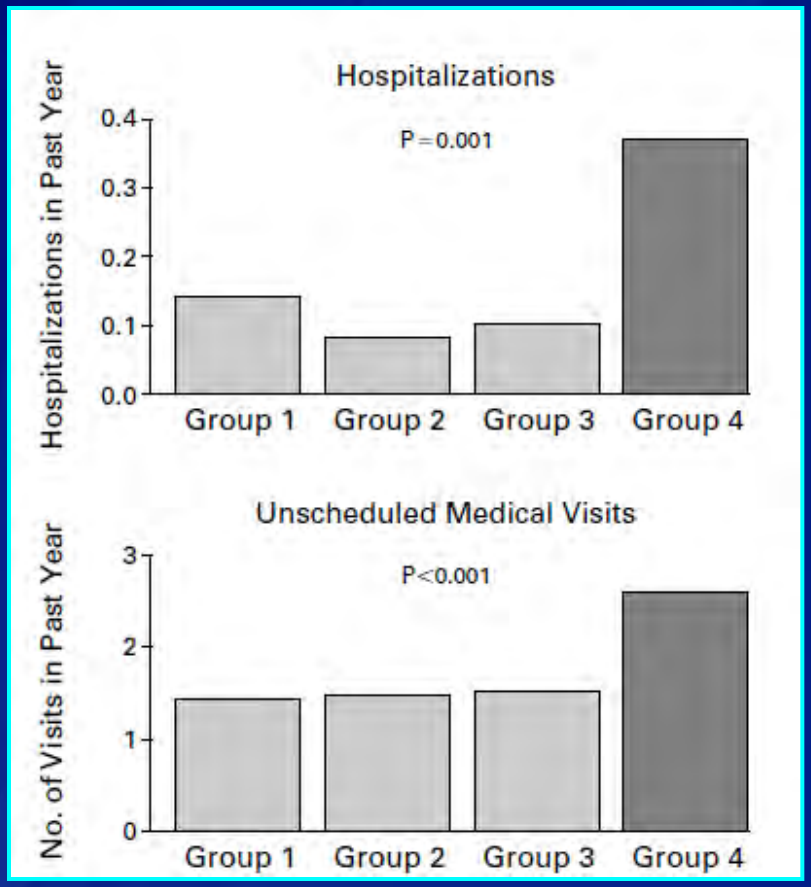
New York preschool children (n=341)



Bla g 2 levels >1U/g in children's bed and kitchen dust samples were independently associated with cockroach-specific IgE, adjusting for other covariates (such as asthma)

Chew, Perzanowski, Canfield et al, *JACI* 2008

Sensitization & Exposure to Cockroach allergen: Risk for Emergency Visits in the Inner Cities



Rosenstreich et al., New England J. Med., 1997

1 = SPT-/ Bla g 1 ≤ 8 U/g

2 = SPT-/ Bla g 1 > 8 U/g

3 = SPT+/ Bla g 1 ≤ 8 U/g

4 = SPT+/ Bla g 1 >8 U/g

Common indoor allergens

Dust mite
(Der f 1)

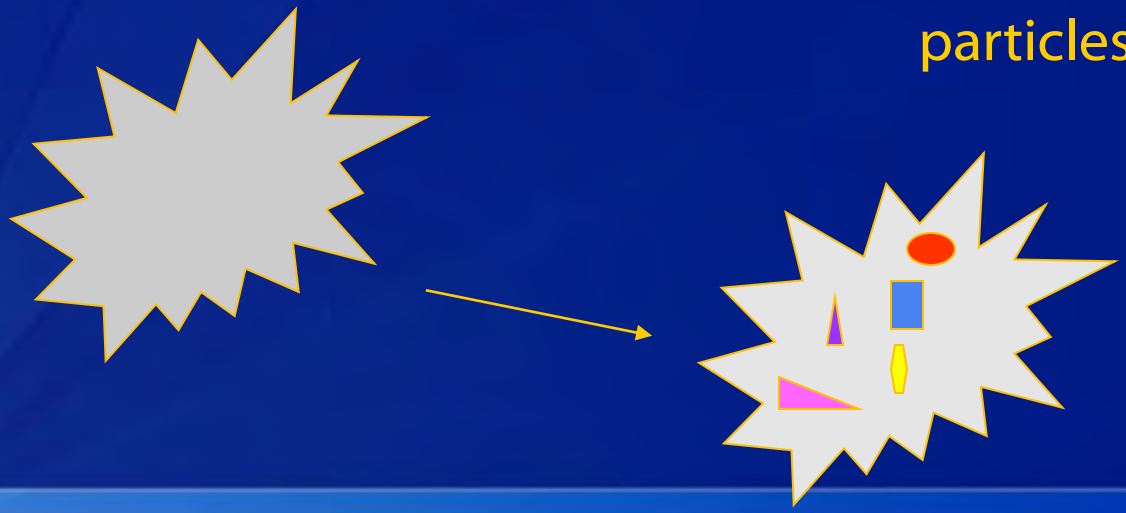
Cockroach
(Bla g 1 & 2)

Mouse
(Mus m 1)

Sources vs. Relevant Agent

Dust mite

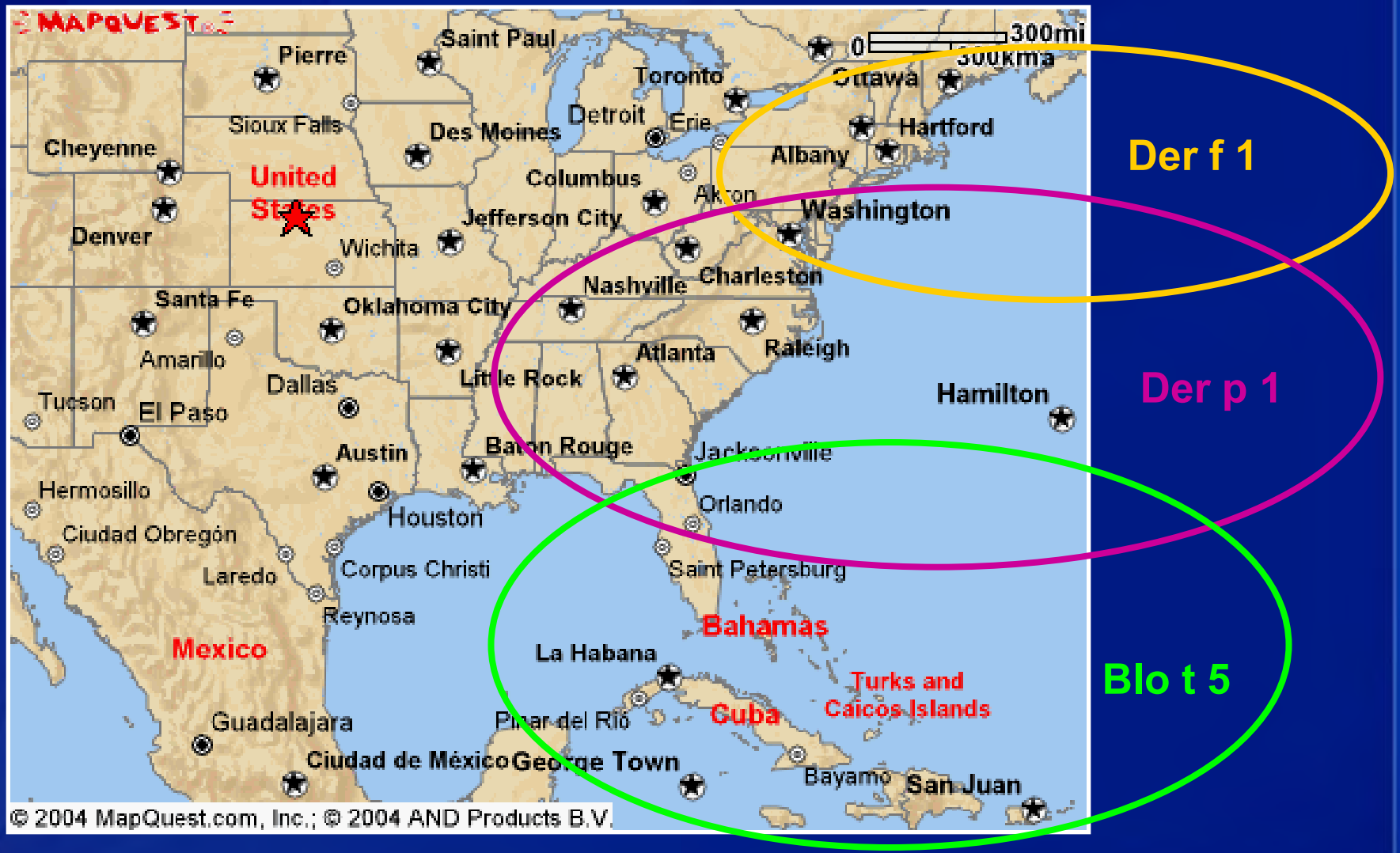
Fecal pellet



Allergens

- Dust mite size (200microns) vs. Particle size (10-40 microns)
- Particle size vs. Allergen size (25kD)
- Location of organism vs. Location of allergen-laden particles

Dust mite distribution



Are dust mites ubiquitous?

Clinical Experimental Allergy, 1992, Volume 22, pages 589–590

FM Kneist and JEMH van Bronswijk

Correspondence

House dust mite avoidance—the right way to go forward

Sirs, Allergy to house dust mite is a world-wide problem, compounded by more or less tightly closed houses with fitted carpets and soft furnishings which provide the ideal habitat for the house dust mite.

TABLE I. Prevalence of specific species of dust mites in 252 homes surveyed in eight locations

Location	No. mite positive homes	Homes with each mite species							
		DF		DP		EM		BT	
		No.	%	No.	%	No.	%	No.	%
Cincinnati, Ohio	48	46	95.8	39	81.3	0	0.0	0	0.0
New Orleans, La.	58	47	81.0	57	98.3	18	31.0	3	5.2
Memphis, Tenn.	31*	29	93.5	24	77.4	4	12.9	1	3.2
Galveston, Texas	32	30	93.8	31	96.9	14	43.8	6	18.8
Greenville, N.C.	36	36	100.0	34	94.4	0	0.0	0	0.0
Delray Beach, Fla.	8	8	100.0	6	75.0	1	12.5	2	25.0
San Diego, Calif.	25	21	84.0	25	100.0	2	8.0	11	44.0
Los Angeles, Calif.	13	12	92.3	12	92.3	0	0.0	0	0.0
Total	251*	229	91.2	228	90.8	39	15.5	23	9.2

*All 32 homes tested contained mites, but species could not be determined in one house because of lack of enough adult specimens, therefore 252 homes were mite positive.

Are dust mites important when allergen levels are low?

J ALLERGY CLIN IMMUNOL
VOLUME 96, NUMBER 4, 1995

TABLE I. Prevalence of IgE antibody to indoor allergens among middle-school children

Allergen	No. (%) of subjects with IgE antibody*			
	Subjects with symptoms			
	BHR$^+$ (n = 21)	BHR$^-$ (n = 36)	Control subjects (n = 54)	p Value†
Dust mite	1 (5)	6 (17)	2 (4)	0.38
Dog	14 (67)	7 (19)	8 (15)	<0.0001
Cat	13 (62)	10 (28)	9 (17)	<0.001
Cockroach	0 (0)	0 (0)	1 (2)	0.35
Russian thistle	10 (48)	10 (28)	12 (22)	0.045
Ryegrass	6 (29)	9 (25)	22 (41)	0.19

*Prevalence of at least 40 RU or CAP of at least grade II.
†Significance assessed by chi-square test for trends.

Maybe?

Indoor Air 2009; 19: 193–197
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Mite sensitization among Latina women in New York, where dust-mite allergen levels are typically low

G. L. Chew[1], A. M. Reardon[1], J. C. Correa[2], M. Young[1], L. Acosta[1], R. Mellins[3], F. T. Chew[4], M. S. Perzanowski[1]

Abstract In New York (NY), Latinos often have greater asthma morbidity than other ethnicities, and dust-mite sensitization is common despite low allergen levels. We investigated mite allergen exposure and sensitization in atopic and/or asthmatic women, the majority being Puerto Rican. Women (n = 274) recruited for a birth cohort study were visited postnatally. Dust from their homes was analyzed for mite allergens (Der f 1, Der p 1, and Blo t 5). Serum was analyzed for total and allergen-specific IgE. Thirty-seven percent were sensitized to *Dermatophagoides pteronyssinus*, 34% to *Dermatophagoides farinae*, and 21% to *Blomia tropicalis*. Only 5% of NY homes had levels of Der f 1 >2 μg/g; none had Blo t 5 or Der p 1 above this level. Caribbean or Latin American birthplace (a proxy for childhood exposure) was not associated with mite sensitization. Sensitization to *D. pteronyssinus* and *D. farinae* was associated with a report of doctor-diagnosed asthma [Odds ratio (OR) = 3.27, P = 0.003; OR = 2.81, P = 0.010, respectively]; sensitization to any mite was associated with asthma medication use in the past 12 months (OR = 3.12, P = 0.004). These associations held even after adjustment for cockroach, mouse, and cat sensitization.

Dust mite allergen is associated with increased probability of dust mite sensitization

Neighborhood differences in exposure and sensitization to cockroach, mouse, dust mite, cat, and dog allergens in New York City

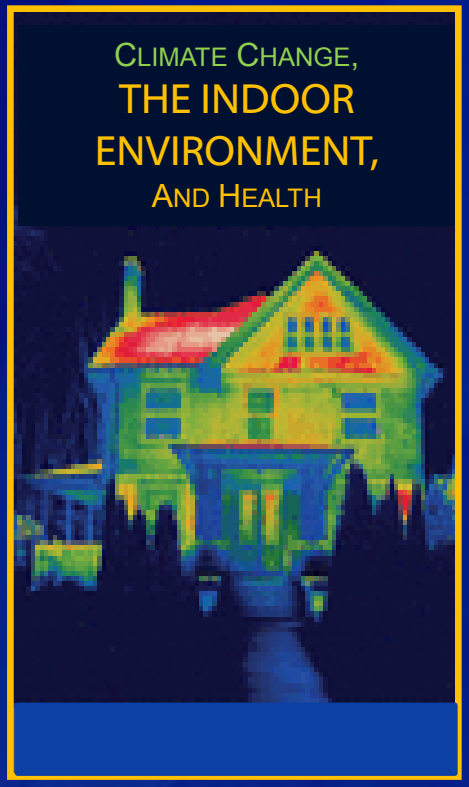
Omar Olmedo, BS,[a] Inge F. Goldstein, DrPH,[b] Luis Acosta, MD,[a] Adnan Divjan,[a] Andrew G. Rundle, DrPH,[b] Ginger L. Chew, ScD,[a] Robert B. Mellins, MD,[e] Lori Hoepner, MPH,[a,c] Howard Andrews, PhD,[c,d] Sara Lopez-Pintado, PhD,[d] James W. Quinn, MA,[g] Frederica P. Perera, DrPH,[a] Rachel L. Miller, MD,[a,e,f] Judith S. Jacobson, DrPH,[b] and Matthew S. Perzanowski, PhD[a] *New York, NY*

and asthma

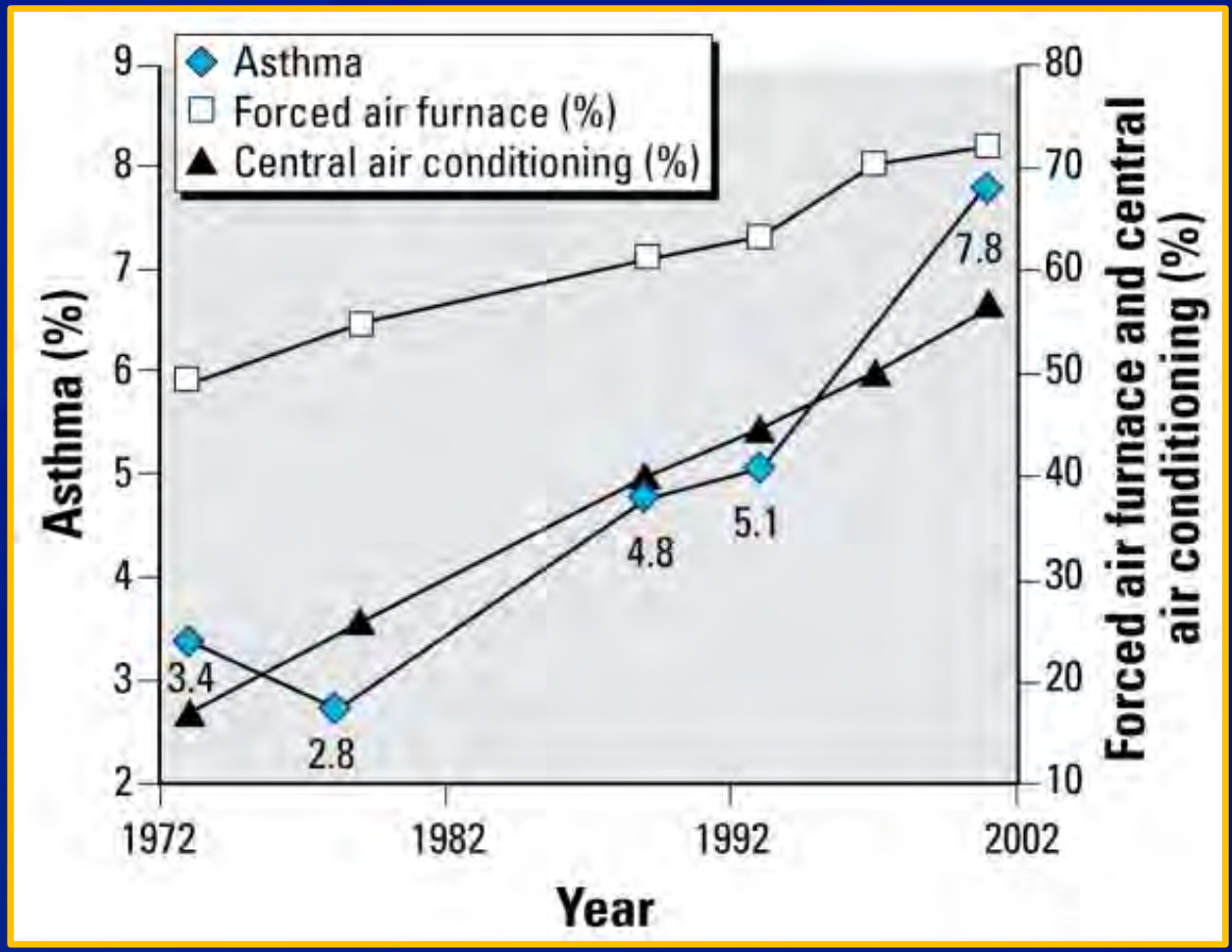
Odds ratio [95% confidence interval] = 2.55 [1.3 -5.1]

JACI, 128: 284-92, 2011

Increased Heating and Air Conditioning



Institute of Medicine (IOM) 2011



Jacobs, Wilson, Dixon, Smith, and Evens. EHP, 2009

The New York Times

The Cost of Cool

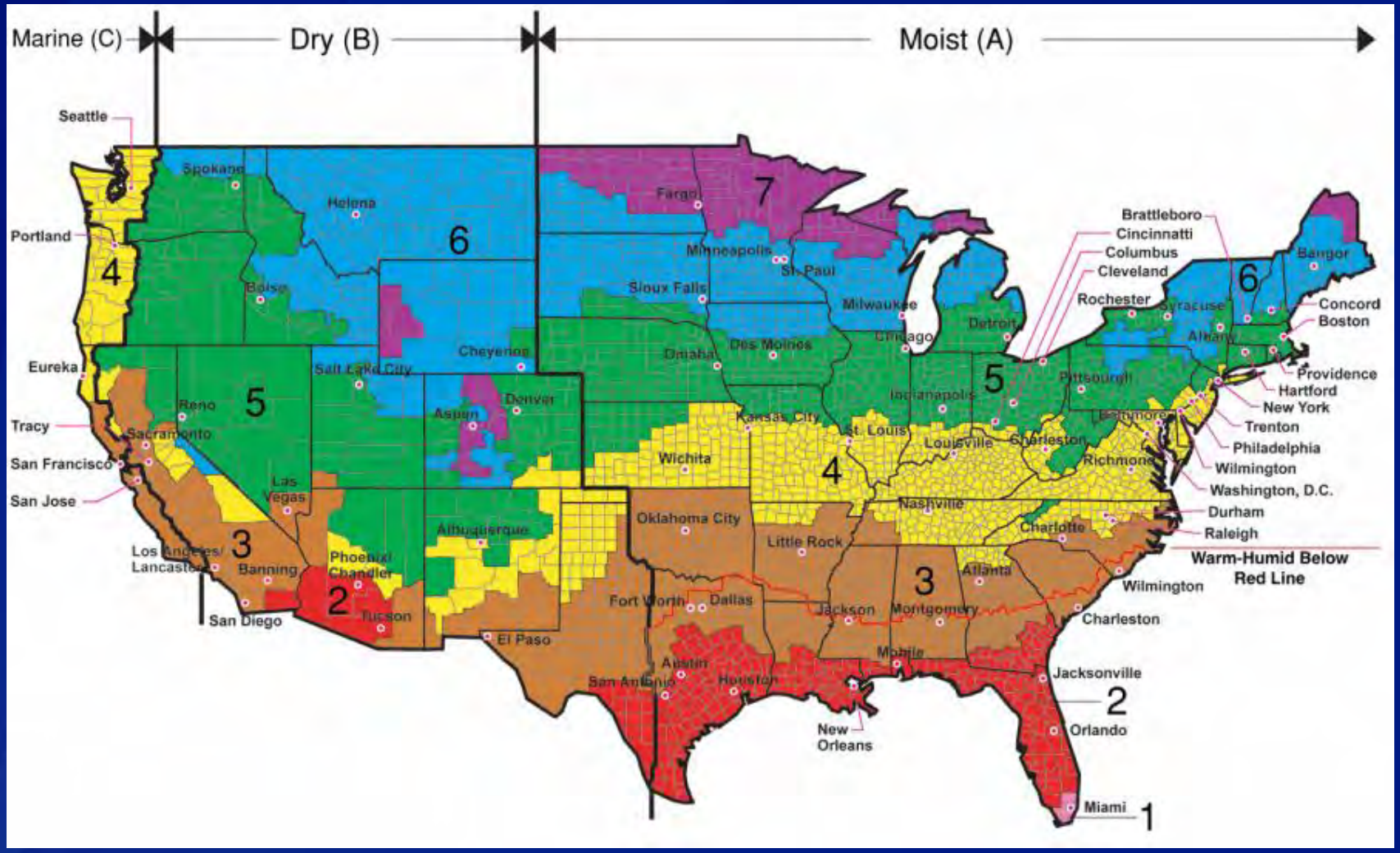
By Elisabeth Rosenthal
(August 18, 2012)

Victo Ngai

In 2007, only 11 percent of households in Brazil and 2 percent in India had air-conditioning, compared with 87 percent in the United States, which has a more temperate climate, said Michael Sivak, a research professor in energy at the University of Michigan.

"There is huge latent demand," Mr. Sivak said. "Current energy demand does not yet reflect what will happen when these countries have more money and more people can afford air-conditioning."

Climate Zone Map of United States



* from ASHRAE 90.1-2010 and Briggs RS, ZT Taylor, and RG Lucas. 2003. “Climate Classification for Building Energy Codes and Standards.

The Green Housing Study

Sample of scheduled renovations

The Green Housing Study Team

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Green Criteria

Optimized heating, ventilation and air conditioning (HVAC) system

Low/ no volatile organic compound (VOC) Carpets and paint

Recycled building materials

Integrated Pest Management

Energy efficient appliances

Improved Insulation

Integrated Pest Management (IPM)

Physical Changes

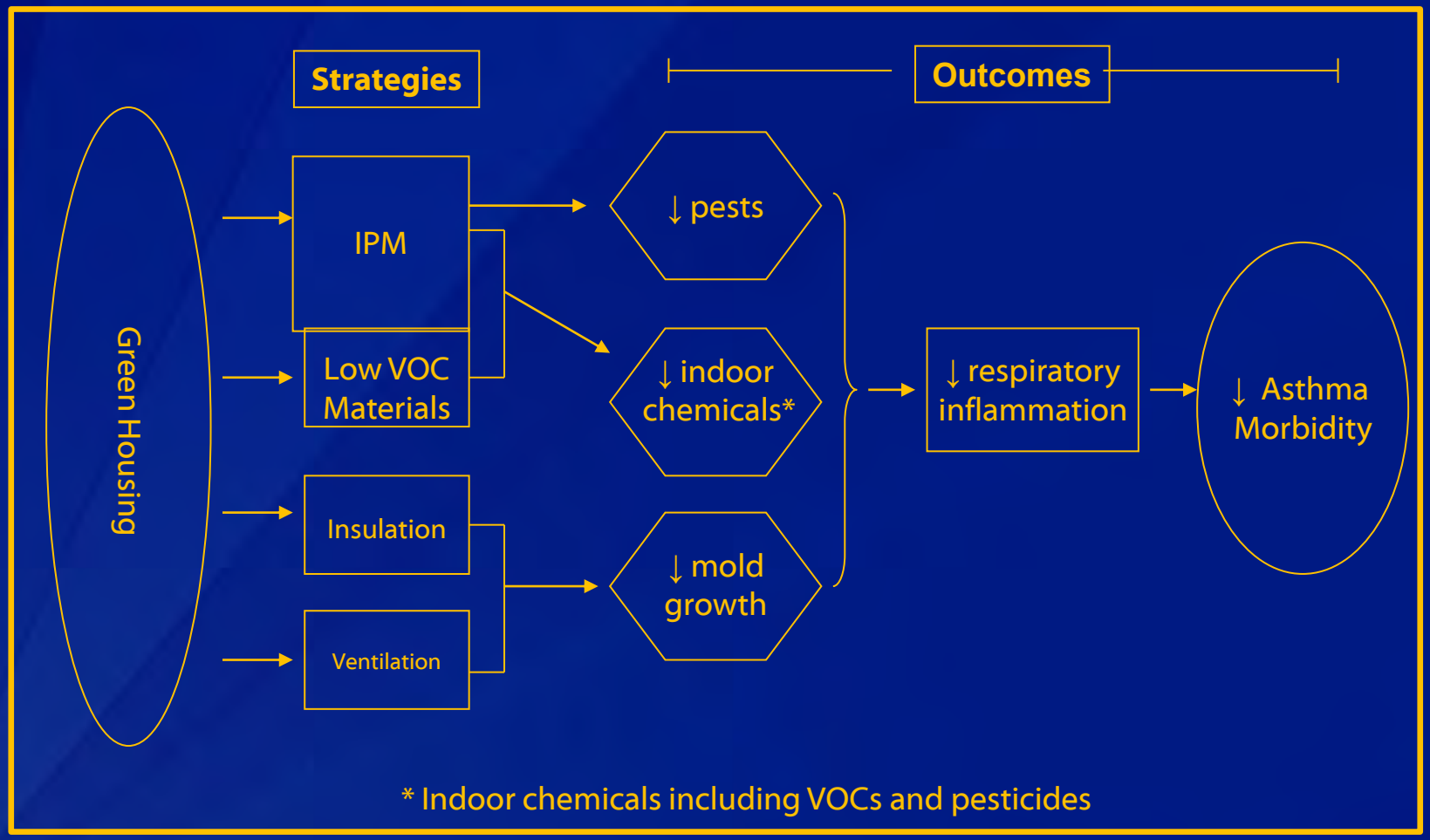
- Kitchen and Bathroom
  - Cleaning
  - Pesticide application (low toxicity)
  - Sealing cracks and holes
- Child's Bedroom
  - Cleaning
  - Pesticide (low toxicity)

Education

- Clean up spills
- Eat only in kitchen
- Use sealed food containers
- Dispose of trash frequently

* Cleaning to remove dead cockroaches and fecal pellets that could contain allergen

Asthma


Strategies
Outcomes
Green Housing
IPM
Low VOC Materials
Insulation
Ventilation
↓ pests
↓ indoor chemicals*
↓ mold growth
↓ respiratory inflammation
↓ Asthma Morbidity
* Indoor chemicals including VOCs and pesticides

Objective:

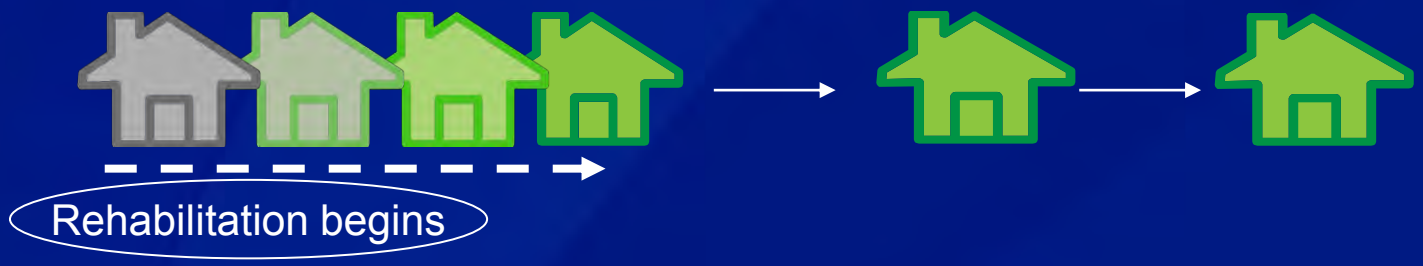
To quantify levels of mold, allergens, pesticides, particulates, and volatile organic compounds (VOCs) in Green and control housing.

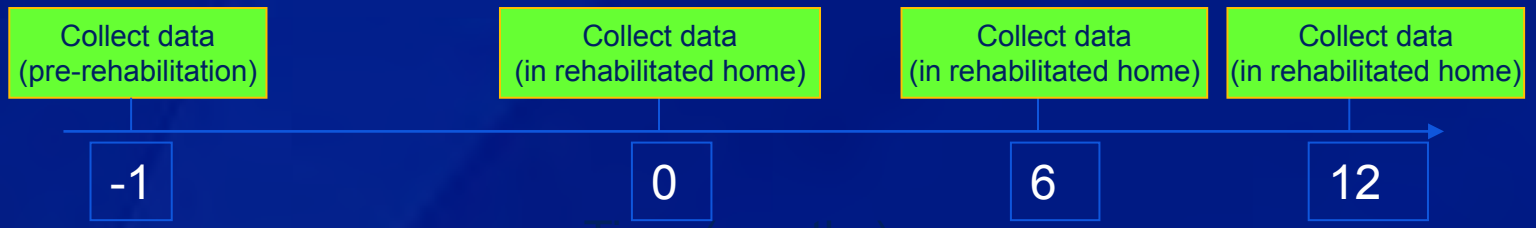
Study Design:

Repeated measures (started in Fall 2011)

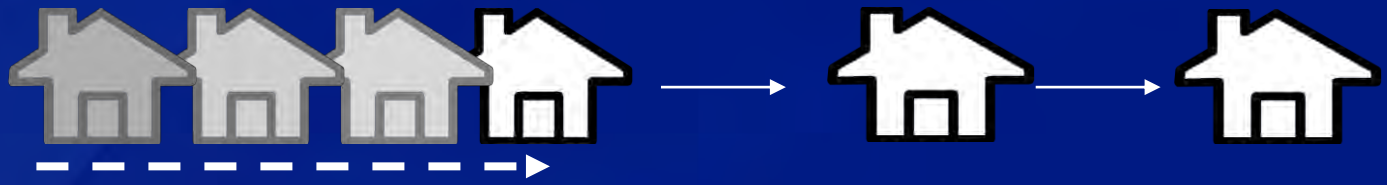
Boston
n = 51 apartments

Cincinnati
n = 51 apartments





Control #1



or

Control #2

Environmental Sampling

- Allergens and Fungi
  - Vacuum dust sampling
- Pesticides
  - Wipe samples from kitchen floor
- VOCs
  - Passive air diffusion badges

Vacuum cleaner

Chemical badges

Environmental Sampling (cont'd)

Novel Air Sampling

- ✔ *Wearable/pocket size*
- ✔ *Sensitive (ppb – ppm)*
- ✔ *Multiple analytes testing*
- ✔ *Selective (immune to common interferents)*
- ✔ *Real-time (sec. to min.)*
- ✔ *Low-cost (< a few hundred $)*
- ✔ *User-friendly / No expertise*
- ✔ *Robust for field testing*

Traditional Air Sampling

Chemical badges

Clinical Measurements

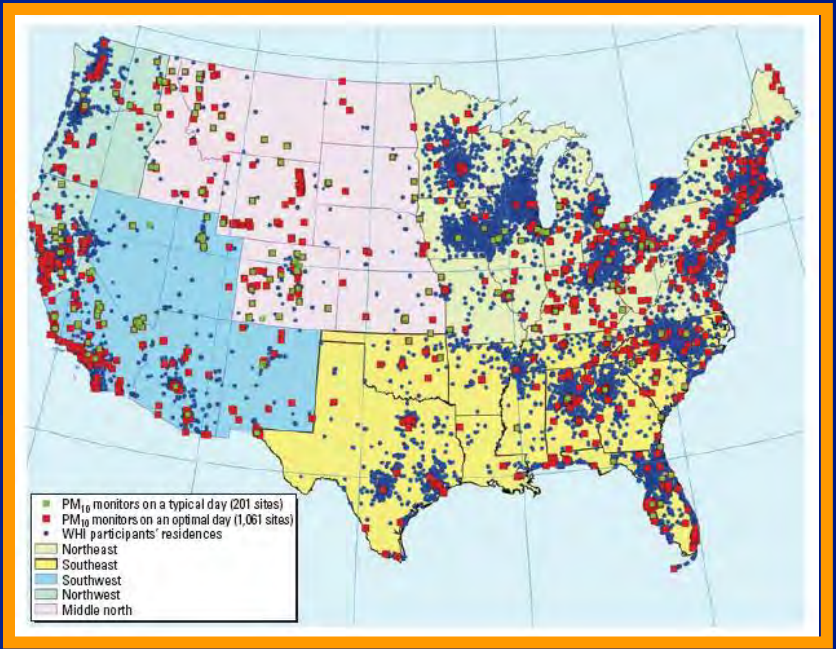
Factor	Child with asthma (Age 7-12)
Blood	
Baseline	✓
Urine	
Baseline	✓
Baseline (part 2)	✓
6-mo. follow-up	✓
12-mo. follow-up	✓
Pulmonary Function Test	
Baseline	✓
Baseline (part 2)	✓
6-mo. follow-up	✓
12-mo. follow-up	✓
Exhaled Nitric Oxide	
Baseline	✓
Baseline (part 2)	✓
6-mo. follow-up	✓
12-mo. follow-up	✓

Clinical Measurements (cont'd)

Factor	Child with asthma (Age 7-12)
Respiratory Symptoms Baseline Baseline (part 2) 3-mo. follow-up 6-mo. follow-up 9-mo. follow-up 12-mo. follow-up	 ✓ ✓ ✓ ✓ ✓ ✓
Flu /cold nasal swabs As needed	 ✓ ? ✓ ? ✓ ? ✓ ? ✓ ?
Text messaging for cold/flu symptoms Months 1, 2, 4, 5, 7,8, 10, 11	 ✓

Improved Exposure Assessment

- Air exchange rates
- Time/activity patterns
- Geographic Information Systems



Spatial relationships between residential locations and EPA monitoring sites for PM2.5 and PM10. Liao et al., EHP, 2006

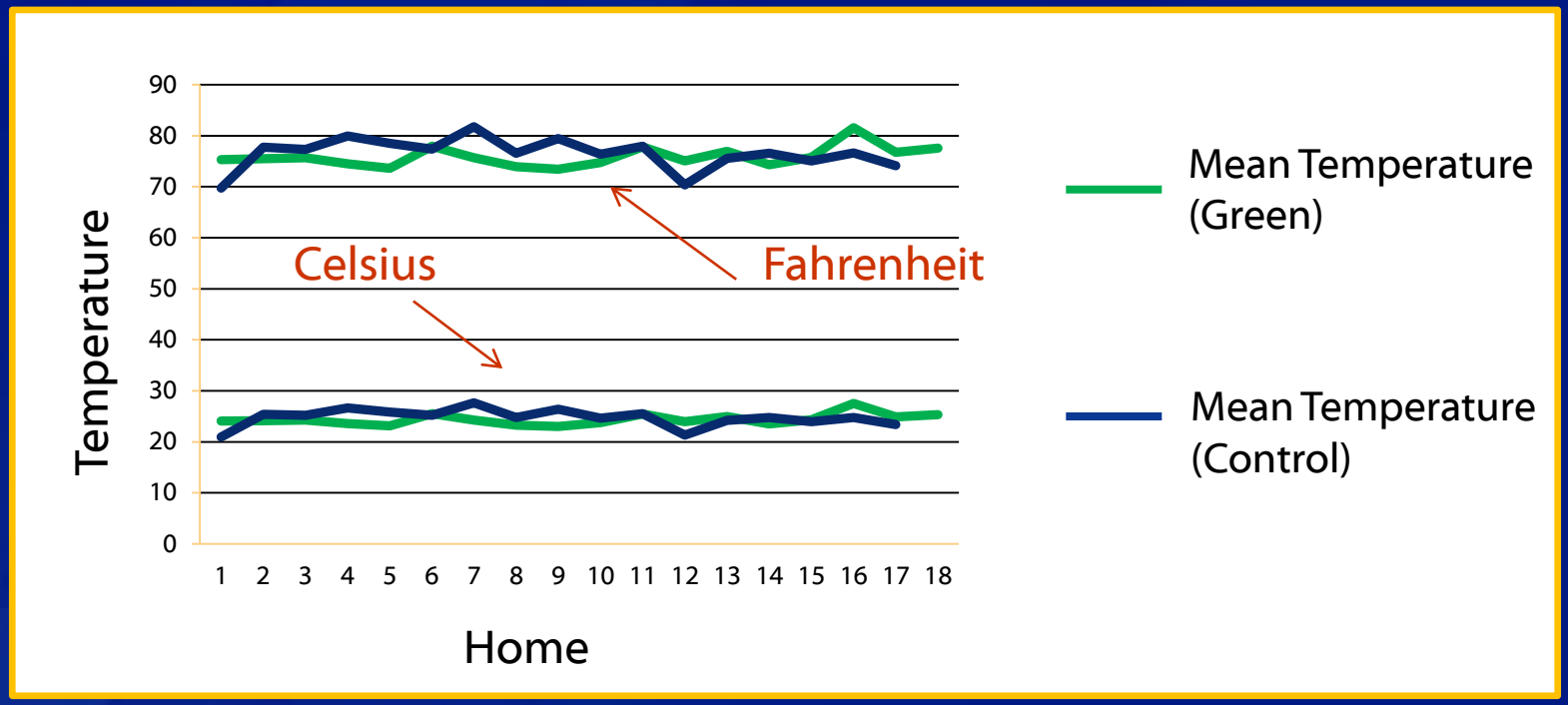
Preliminary Results (2011-2012)

Boston
n = 51 apartments

Cincinnati
n = 51 apartments

Green vs. Control homes in Cincinnati

(n=18 pairs of apartments)



No significant difference in temperature; however,

Relative Humidity

Control (37 %) vs. Green (43 %), p =0.03

Questions about variables that could affect dust mites

During the winter, do you add moisture to the air in your home?

Yes No

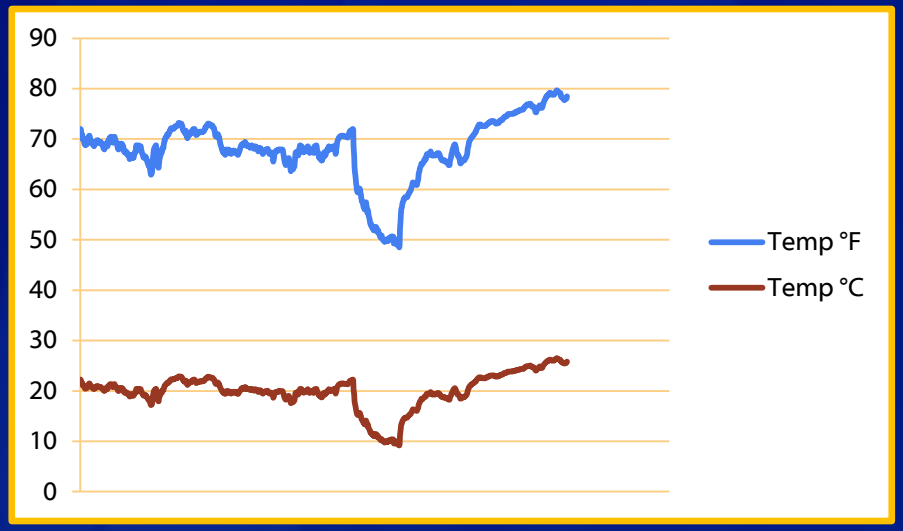
During the winter, how comfortable is the temperature in your home?

- About right
- Too hot
- Too cold

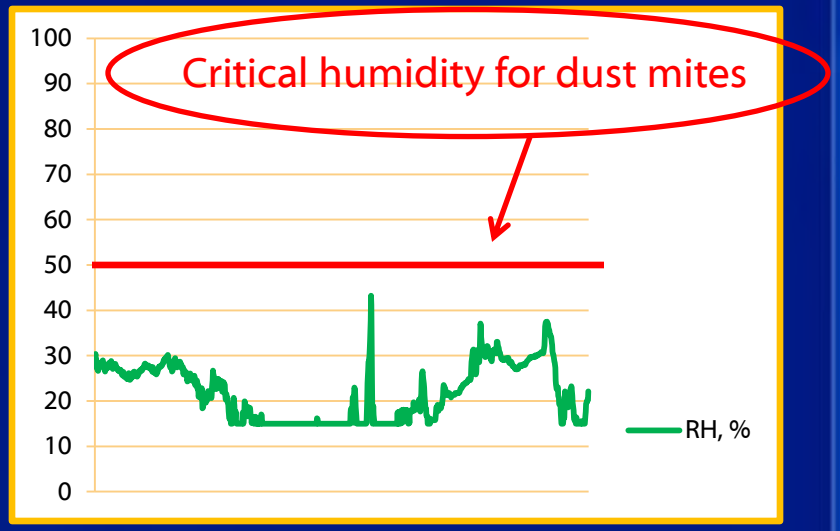
Green vs. Control homes in Boston

(examples of real-time data)

December (Control home)



4-day period



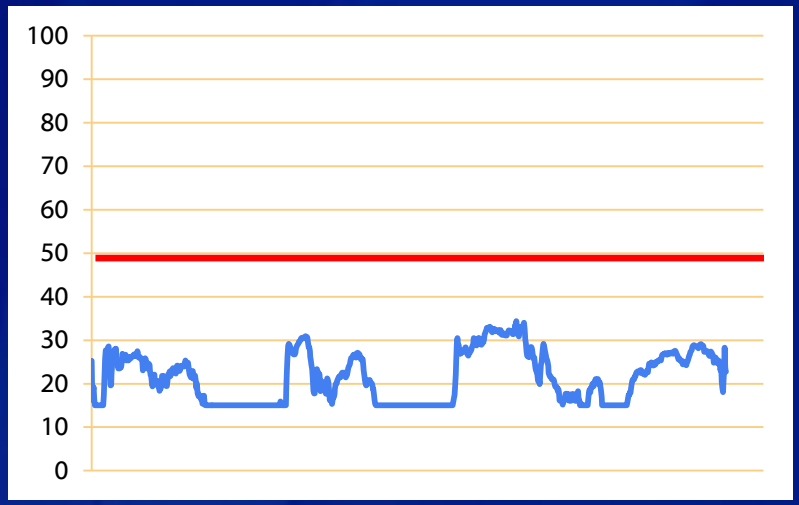
Same 4-day period

"Yes, it is too hot in my home during winter."

Green vs. Control homes in Boston

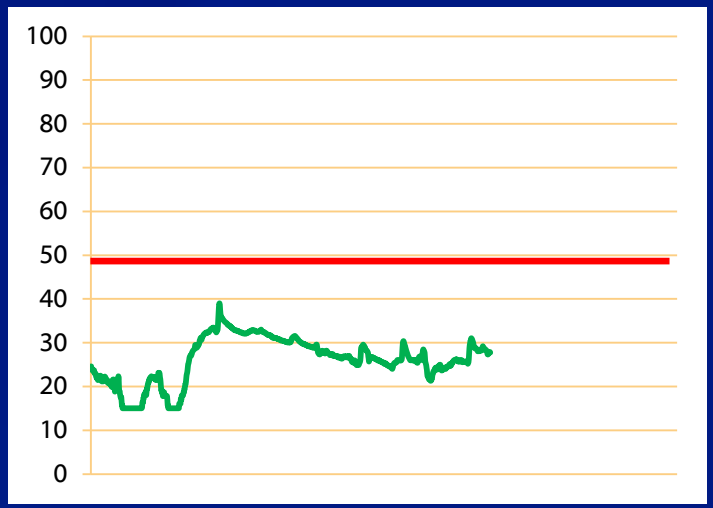
(Real-time Relative Humidity data)

Early Spring (**Control home**)



No

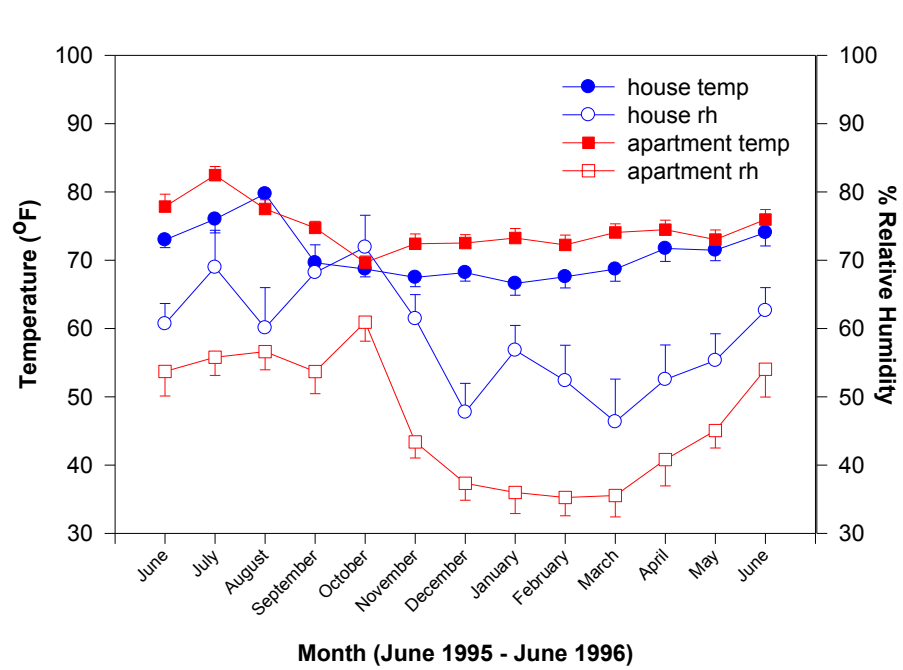
Early Spring (**Green home**)

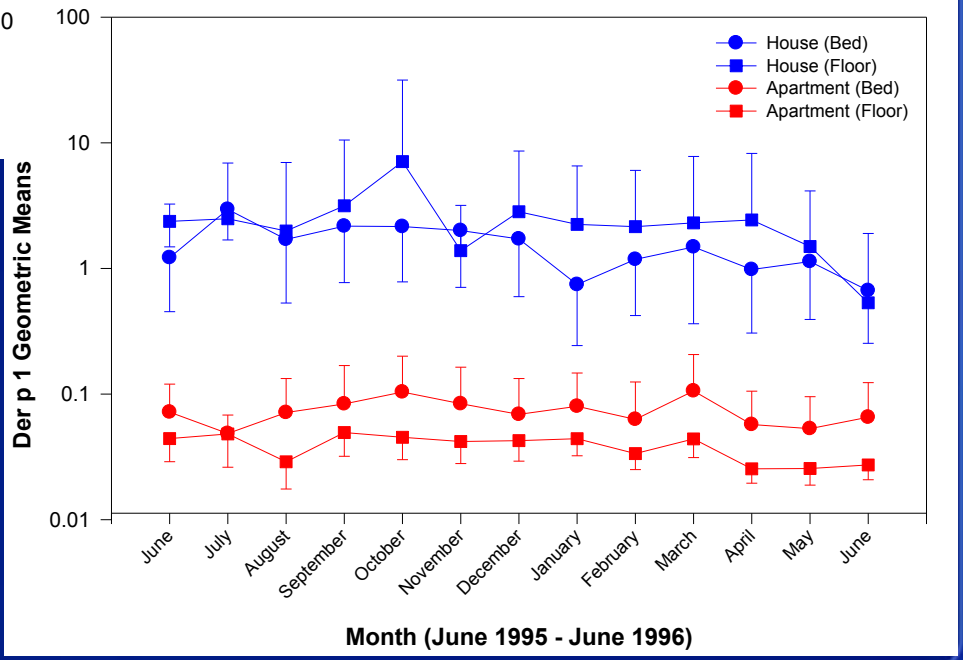


Yes

Do you add moisture to your home during winter?

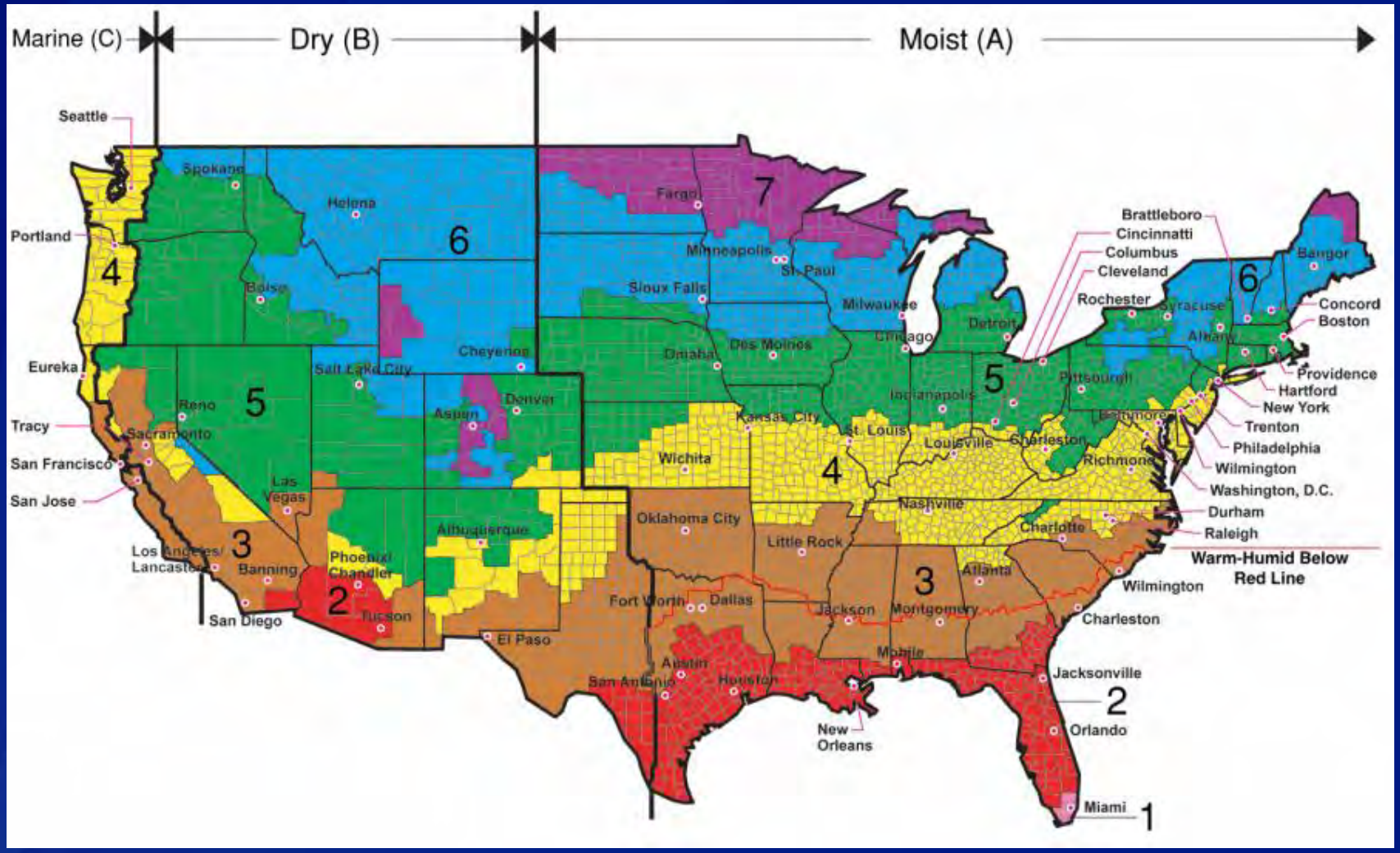
Is this déjà vu?





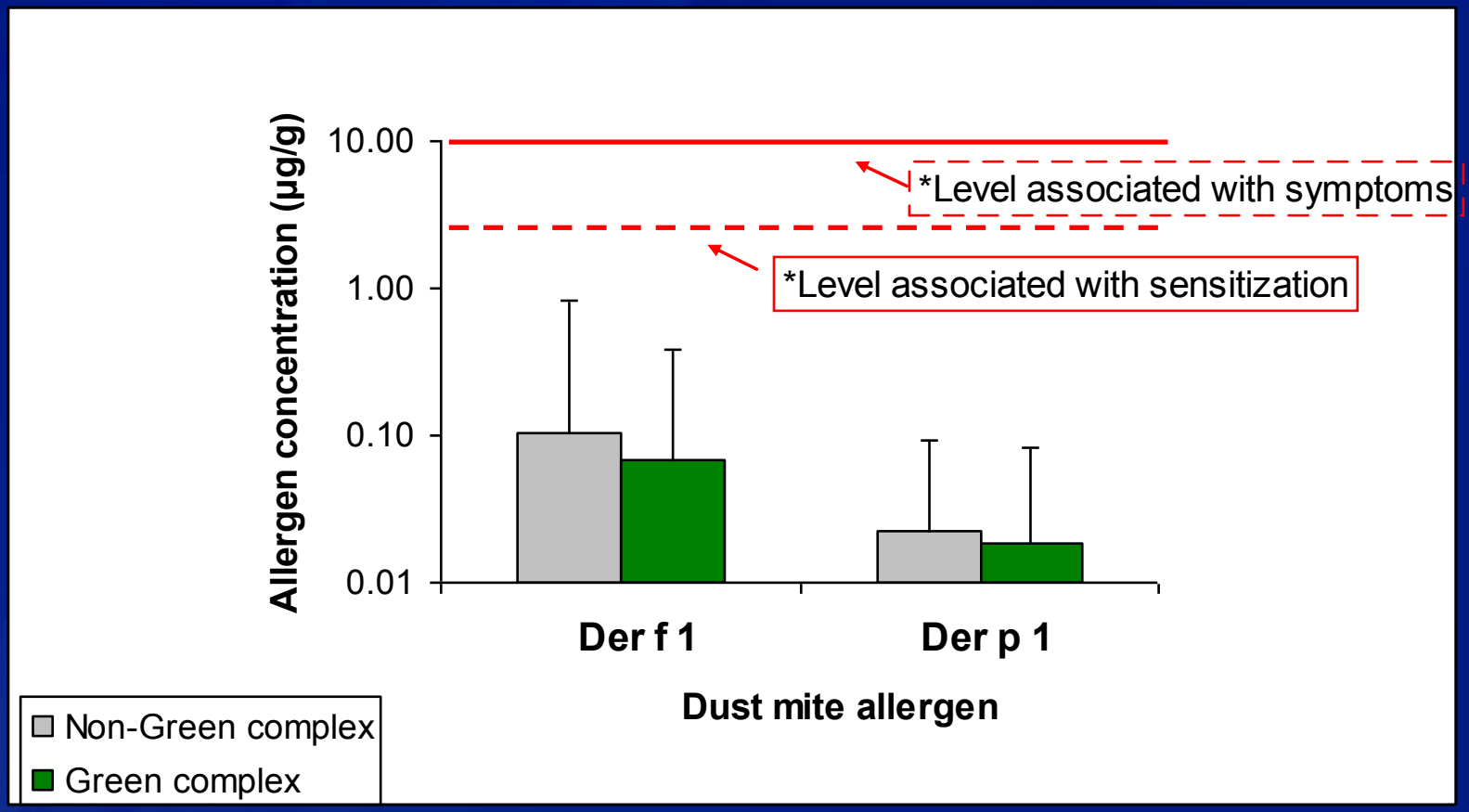
Chew, G.L., K.M. Higgins, M.L. Muilenberg, D.R. Gold, and H.A. Burge.
Monthly measurements of indoor allergens and the influence of housing type
in a northeastern US city. *Allergy.* 1999

Climate Zone Map of United States



* from ASHRAE 90.1-2010 and Briggs RS, ZT Taylor, and RG Lucas. 2003. “Climate Classification for Building Energy Codes and Standards.

Green Housing Study: Pilot data from Atlanta



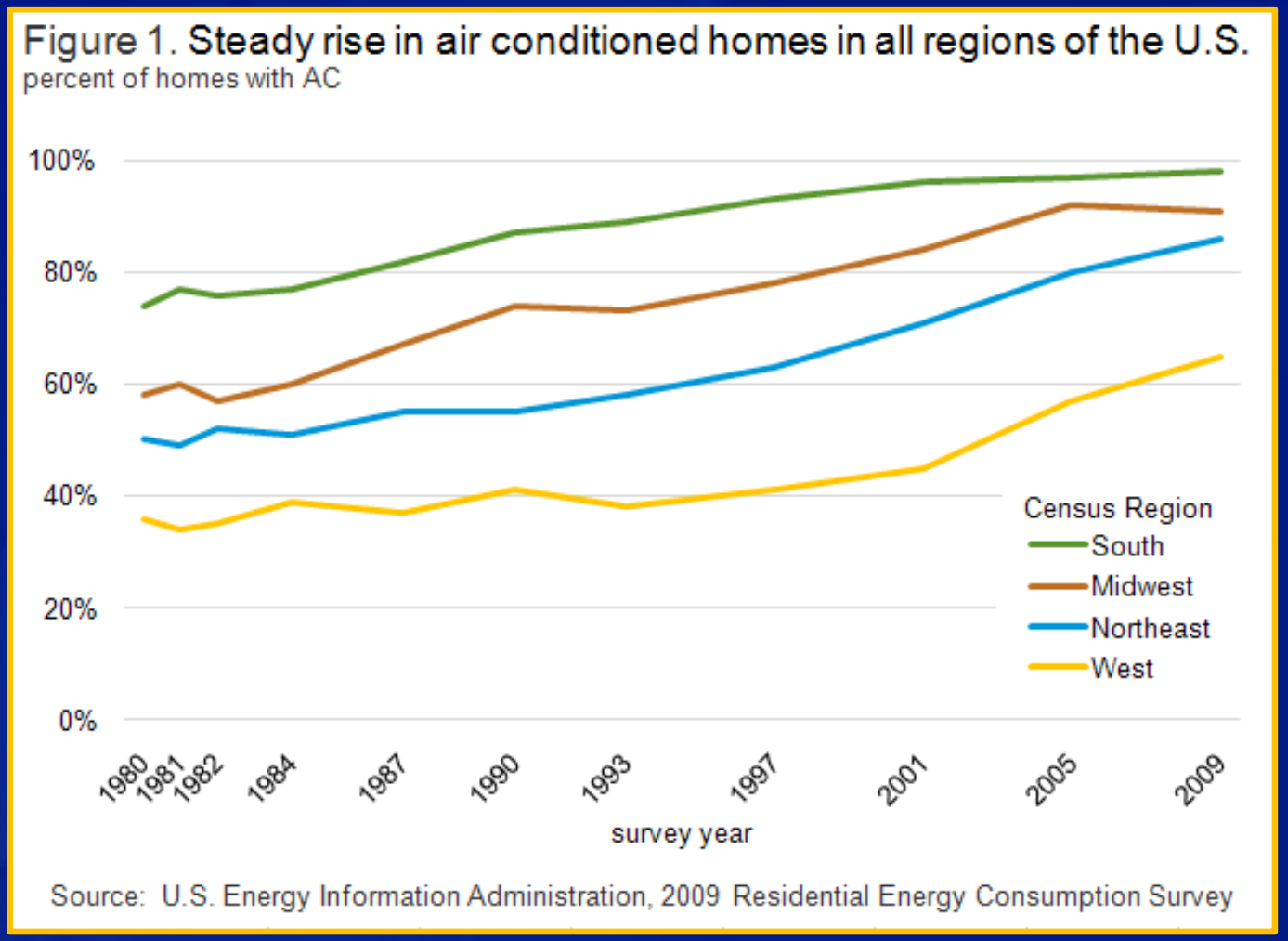
* Concentration displayed on log scale.

** Error bars represent 1 unit increase in geometric standard deviation.

Will this also lead to a decrease in mold growth?

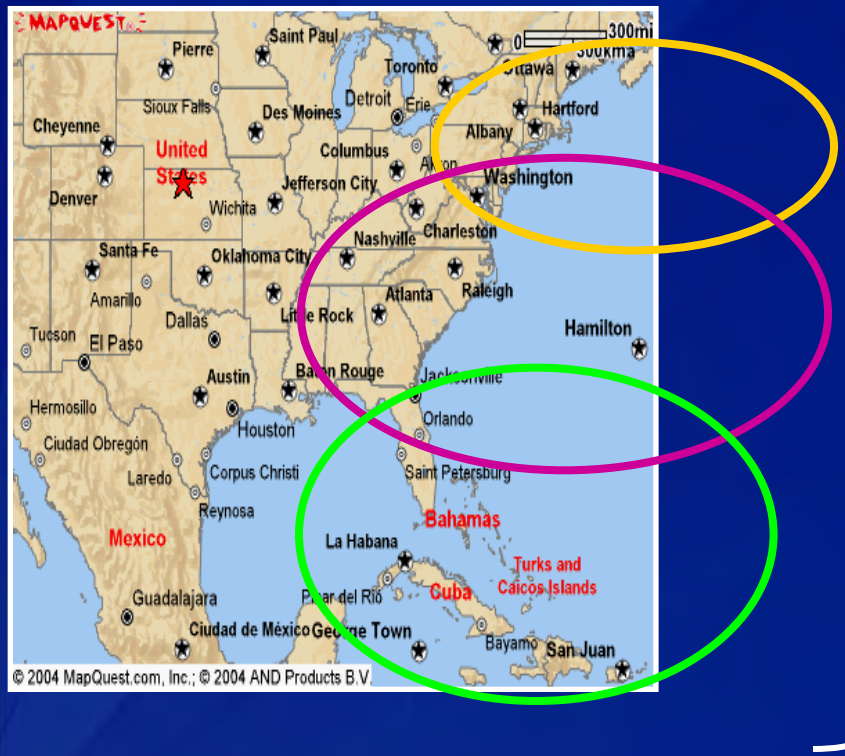
Probably not, because…

Photo by Ginger Chew (November 2005)



"...about 75% of households with incomes above $100,000 use central air conditioning compared to just 44% of households below the poverty line."

What about the other indoor allergens?



Shifts in species?

Similar to those of dust mites

IPM intervention: Inner-City Asthma Study (ICAS)

Significant decrease in Bla g 1 from baseline to 2-year follow-up, and….

Cost = $750-$1000 per child per year

Morgan et al., NEJM (2004)

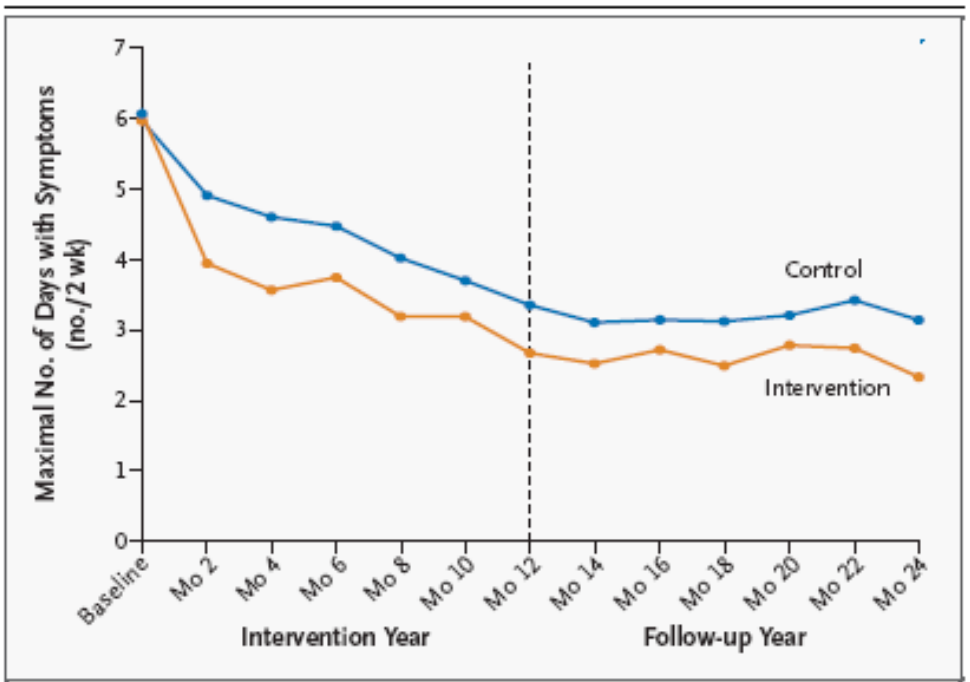


Figure 2. Mean Maximal Number of Days with Symptoms for Every Two-Week Period before a Follow-up Assessment during the Two Years of the Study.

The difference between the groups was significant in both the intervention year ($P<0.001$) and the follow-up year ($P<0.001$).

Multicomponent intervention

The Seattle-King County Healthy Homes Project: A Randomized, Controlled Trial of a Community Health Worker Intervention to Decrease Exposure to Indoor Asthma Triggers

James W. Krieger, MD, MPH, Tim K. Takaro, MD, MPH, MS, Lin Song, PhD, and Marcia Weaver, PhD

Community health workers:

- **reduced asthma symptom days**
- **reduced urgent health services**
- **Improved caregiver quality-of-life score**

American Journal of Public Health, 95:652-659, 2005.

Review articles: Multi-faceted interventions

Effectiveness of home-based, multi-trigger, multicomponent interventions with an environmental focus for reducing asthma morbidity

Crocker, Kinyotam Dumitru, Ligon, Herman, Ferdinands, Hopkins, Lawrence, Sipe, Task Force on Community Preventive Services, Am. J. Prev., Med., 41:S5-32, 2011.

Housing interventions and control of asthma-related indoor biologic agents: a review of the evidence.

Krieger, Jacobs, Ashley, Baeder, Chew, Dearborn, Hynes, Miller, Morley, Rabito, Zeldin. *J Public Health Manag Pract.* 16(5 Suppl):S11-20, 2010.

The Future of Interventions
(Better/safer building materials and practices)


Photo by Ginger Chew (January 2006)


Photo by Ginger Chew (January 2006)

Is it enough to remove just 4 feet of drywall?

Photo by Ginger Chew (November 2005)

The Future of Interventions (more resilient homes)

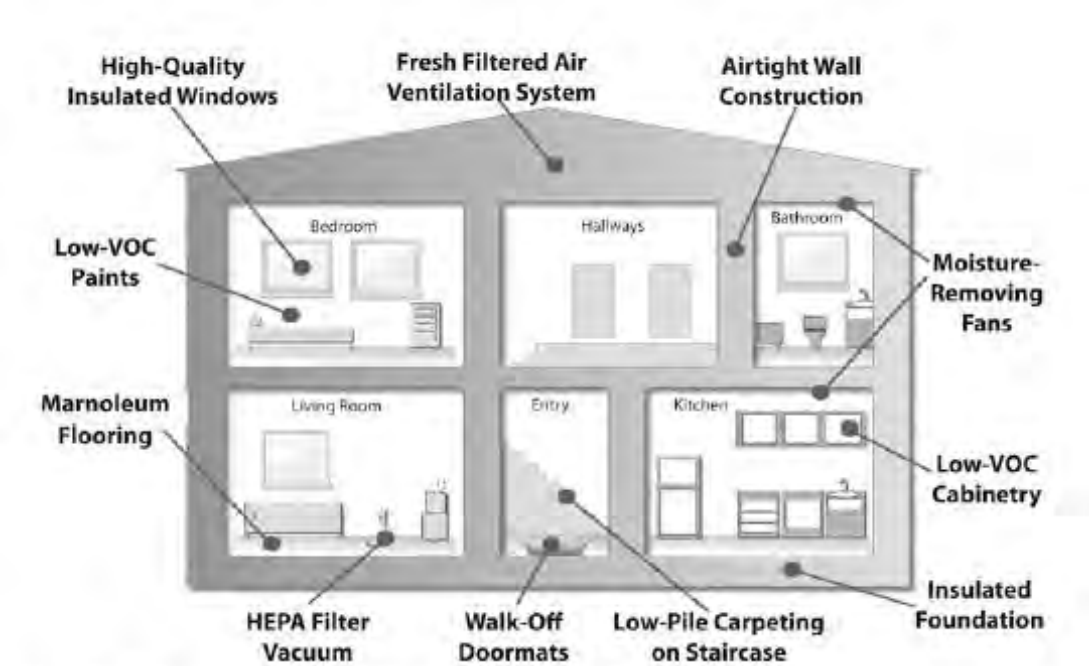
Before

After

The Future of Interventions
(Green/ Smart Homes)

Particulate sensors ?

Moisture sensors ?



Note. VOC = volatile organic compound; HEPA = high efficiency particulate air.

FIGURE 1—Features of the Hight Point Breathe-Easy Homes.

VOC sensors ?

Air exchange rate sensors ?

Takaro et al., Am. J. Public Health, 2011

Thank you

For more information please contact Centers for Disease Control and Prevention

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Telephone: 1-800-CDC-INFO (232-4636)/TTY: 1-888-232-6348
E-mail: cdcinfo@cdc.gov Web: http://www.cdc.gov

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

National Center for Environmental Health
Air Pollution and Respiratory Health Branch