

2017 Winter Conference

Las Vegas, Nevada

The logo for Kansas State University, featuring the words "KANSAS STATE" in a large, bold, serif font, with "UNIVERSITY" in a smaller, bold, sans-serif font below it, separated by a horizontal line. The entire logo is set against a dark purple rectangular background.

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Seminar 1: Updating Scientific Evidence about the Effects of Low Humidity on People

RP–1630, “Update the Scientific Evidence for Specifying Lower Limit Relative Humidity Levels for Comfort, Health and IEQ in Occupied Spaces”

Learning Objectives

1. Understand the effects of humidity on health, comfort, IAQ and on elderly people
2. Understand that healthcare associated infections increase when the humidity decreases too much
3. Understand the human physiological reactions to low humidity
4. Understand the effects of low humidity on working performance

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Acknowledgements

- Maryam Hamehkasi and Ronaldo Maghirang, Department of Biological and Agricultural Engineering, KSU
- Steven Eckels and Byron Jones, Department of Mechanical and Nuclear Engineering, KSU
- Grace M. Hwang, Johns Hopkins University Applied Physics Laboratory
- David Shulan, M.D., Allergist (retired), FL
- TC 5.11 and PMS (Roger Pasch, chair)

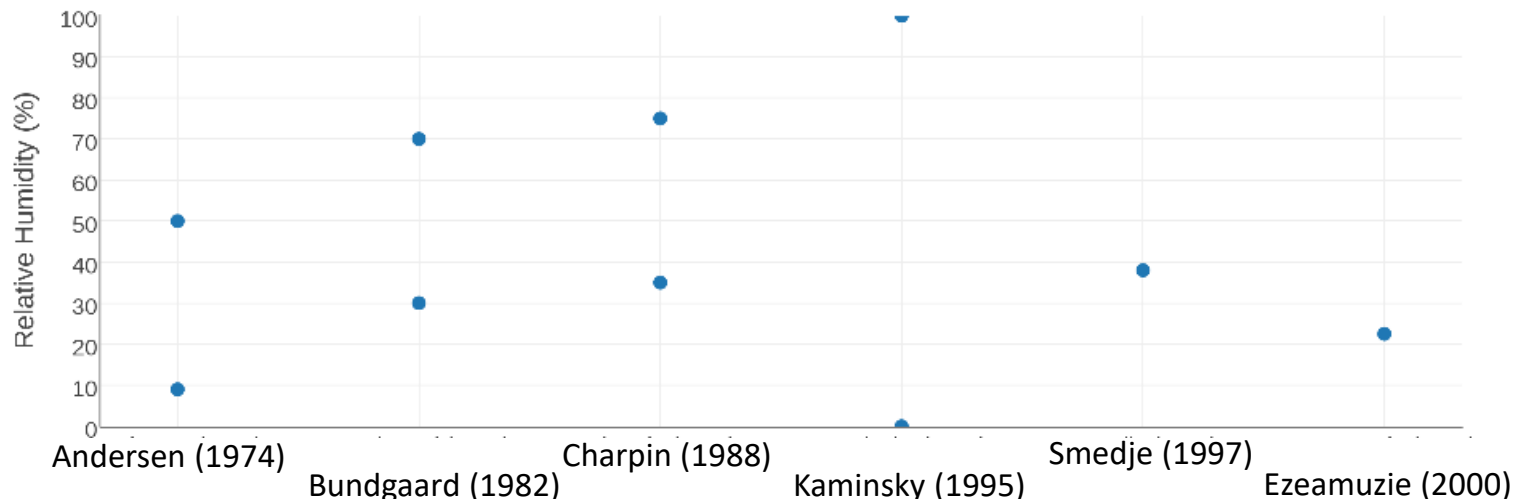
Literature Search Approach

- Update Sterling (1985) paper; focus on post-1985 papers
- Keyword and citation searches
- Around 600 papers located
- General criteria for further paper analysis included:
 - At least one data point where $RH \leq 40\%$
 - New data
 - Report temperature
 - Controlled study
 - Focus on healthy, human subjects
 - Residences and workplaces
- Papers categorized in Health, Comfort, Indoor Environmental Quality (IEQ) categories

Health

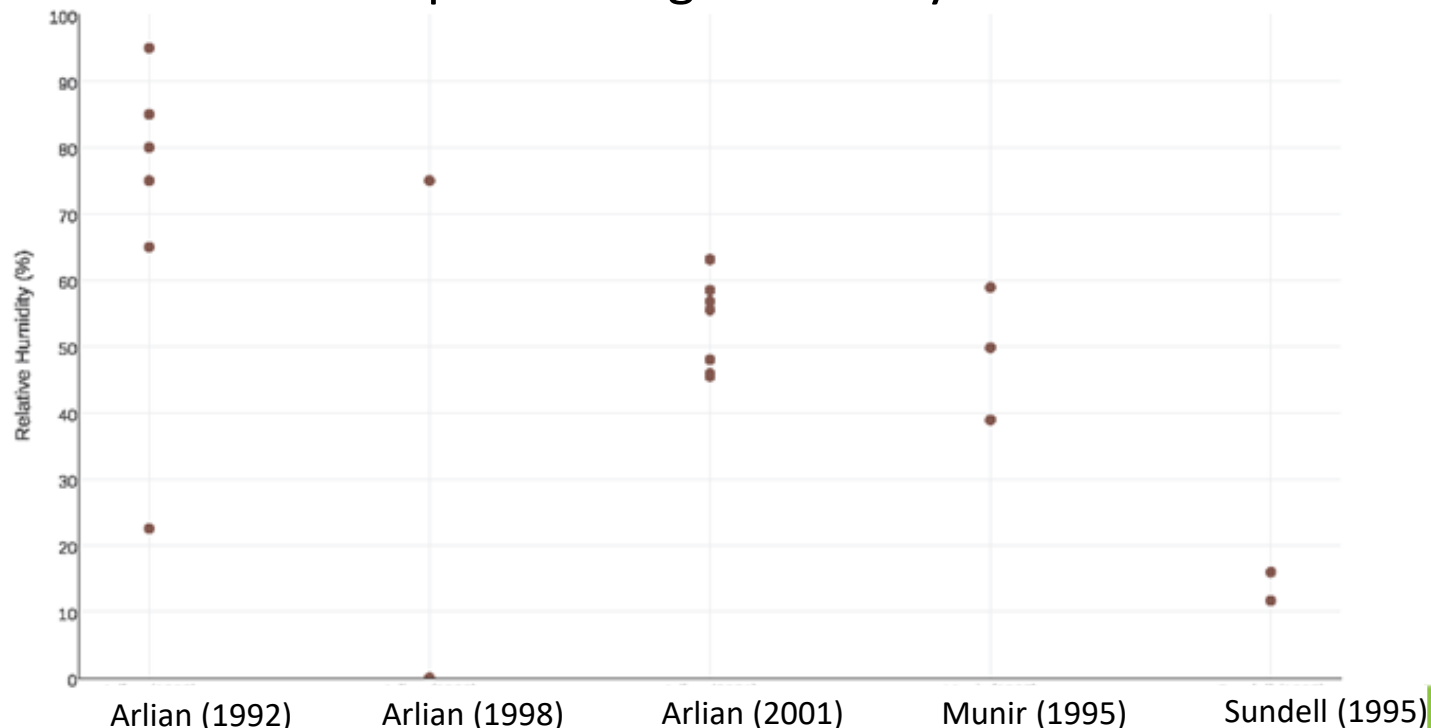
Asthma and Respiratory

- Few laboratory studies [Andersen(1974), Bundgaard (1982), Kaminsky (1995)]
 - Warm, moist air and cold, dry air to determine mechanisms of exercise-induced asthma
- Environmental studies regarding the allergy/asthma link [Smedje(1997), Ezeamuzie (2000)]
- Very limited data available regarding low humidity



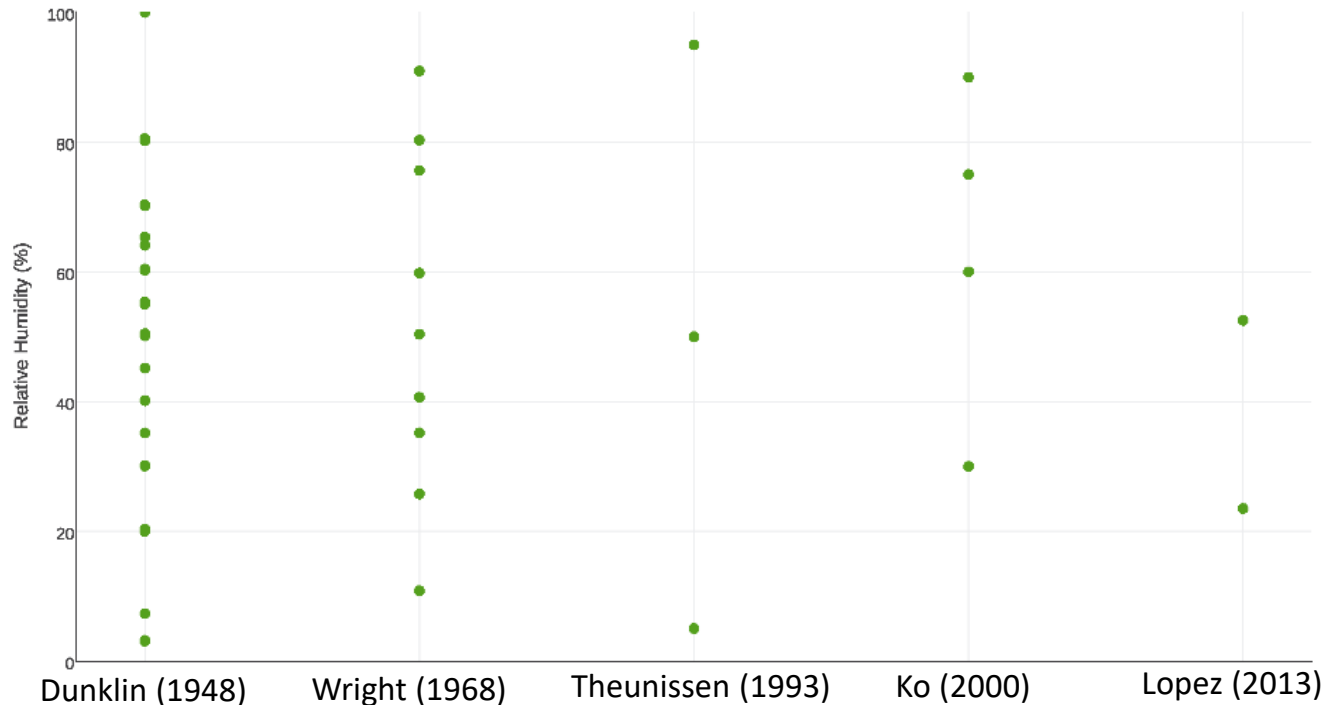
House Dust Mites (HDM)

- Laboratory tests [Arlian (1992), Arlian (1998)]
 - Dust mites
- Controlled tests in homes [Arlian (2001)]
- Environmental tests [Munir (1995), Sundell (1995)]
 - Sundell (1995)- ventilation is a confounding variable
- Low humidity ($RH < 60\%$) beneficial for reducing dust mite allergens; dust mites can survive with spikes of high humidity



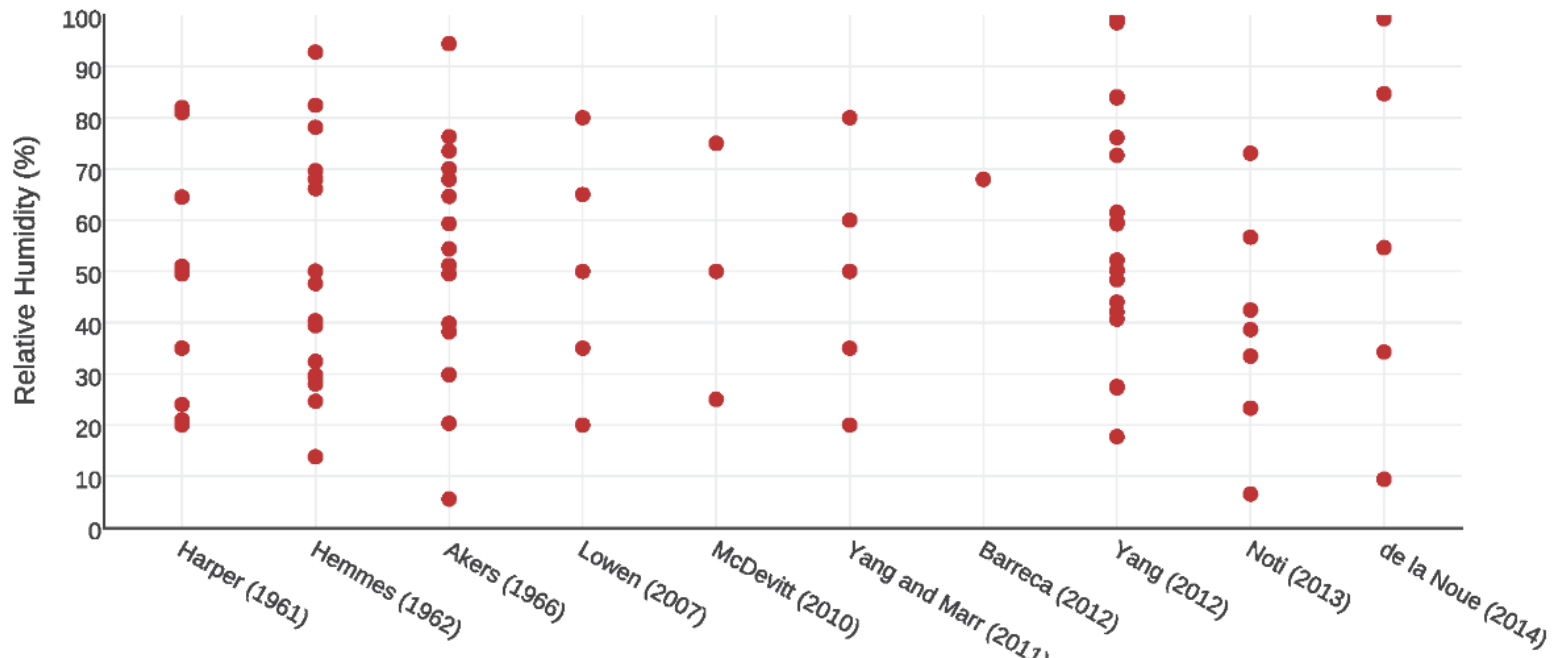
Bacteria

- Lab tests
 - Aerosol viability [Dunklin (1948), Wright (1968), Theunissen (1993), and Ko (2000)] and fomites [Lopez (2013)]
- Challenging to compare across studies
- What is the relationship between survival and infection?
- A few older studies still cited in literature



Viruses

- Majority of data on influenza virus aerosol survival and transmission
- Laboratory testing [Akers (1966), de la Noue (2014), Lowen (2007), Noti (2013), Yang (2012)]
- Epidemiology [Barreca (2012), Jaakkola (2014), van Noort (2012)]
- Modeling [Yang (2011), Shaman (2009)]
- Influenza survival was a strong function of humidity and exhibited a canonical dip between 40%–80% RH



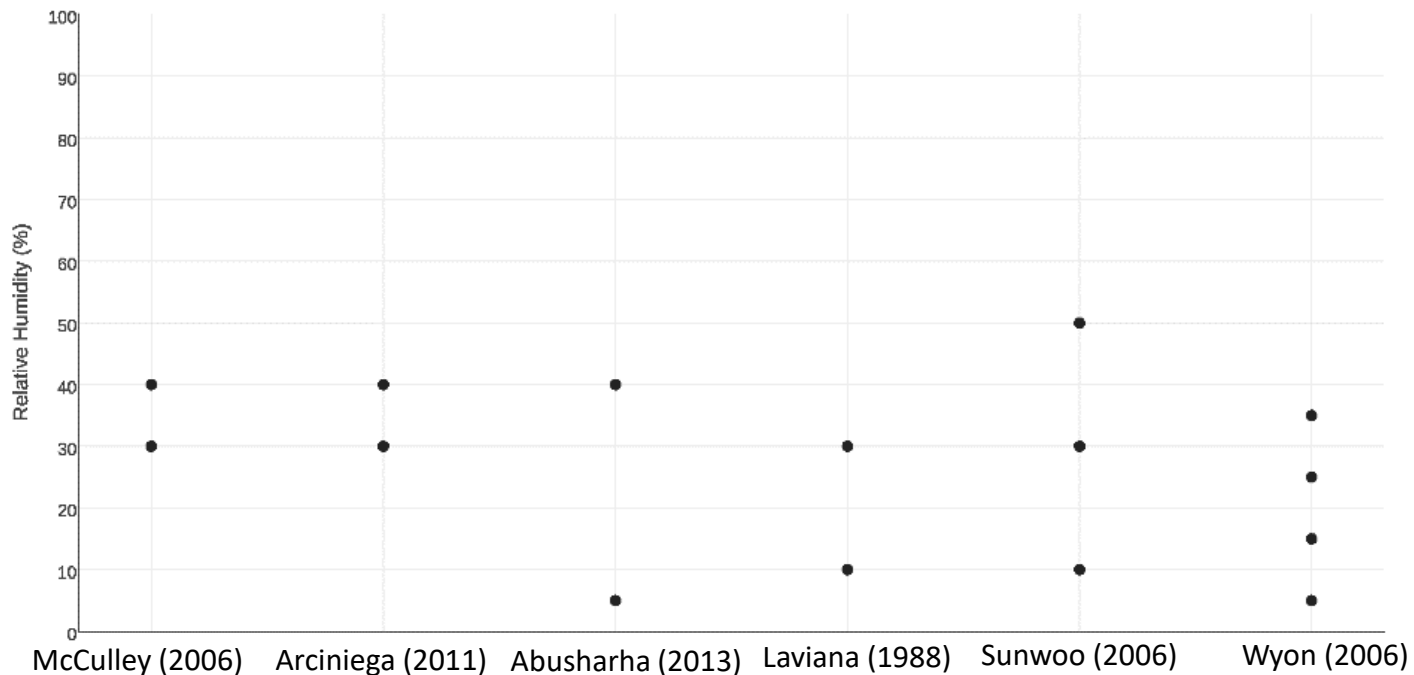
Health Knowledge and Gaps

- Influenza and dust mite survival are strong functions of RH
- Limited asthma data
- Several routes of bacterial/virus transmission and infection hypothesized
 - Direct contact, fomite, droplet, droplet nuclei
 - Relative humidity can uniquely affect each of these transmission modes.
 - Bacteria envelope (Gram-positive or Gram-negative) affects RH, but even in these subcategories, the behavior at low humidities varies
- Many confounding variables
 - Air exchange rate, length of organism exposure, variation in the biological structure and routes of entry, variation of pathogen survival on different fomites, and variances in human host response
 - Several studies assumed that detection correlates with infection, while other studies were based on transmission rates

Comfort

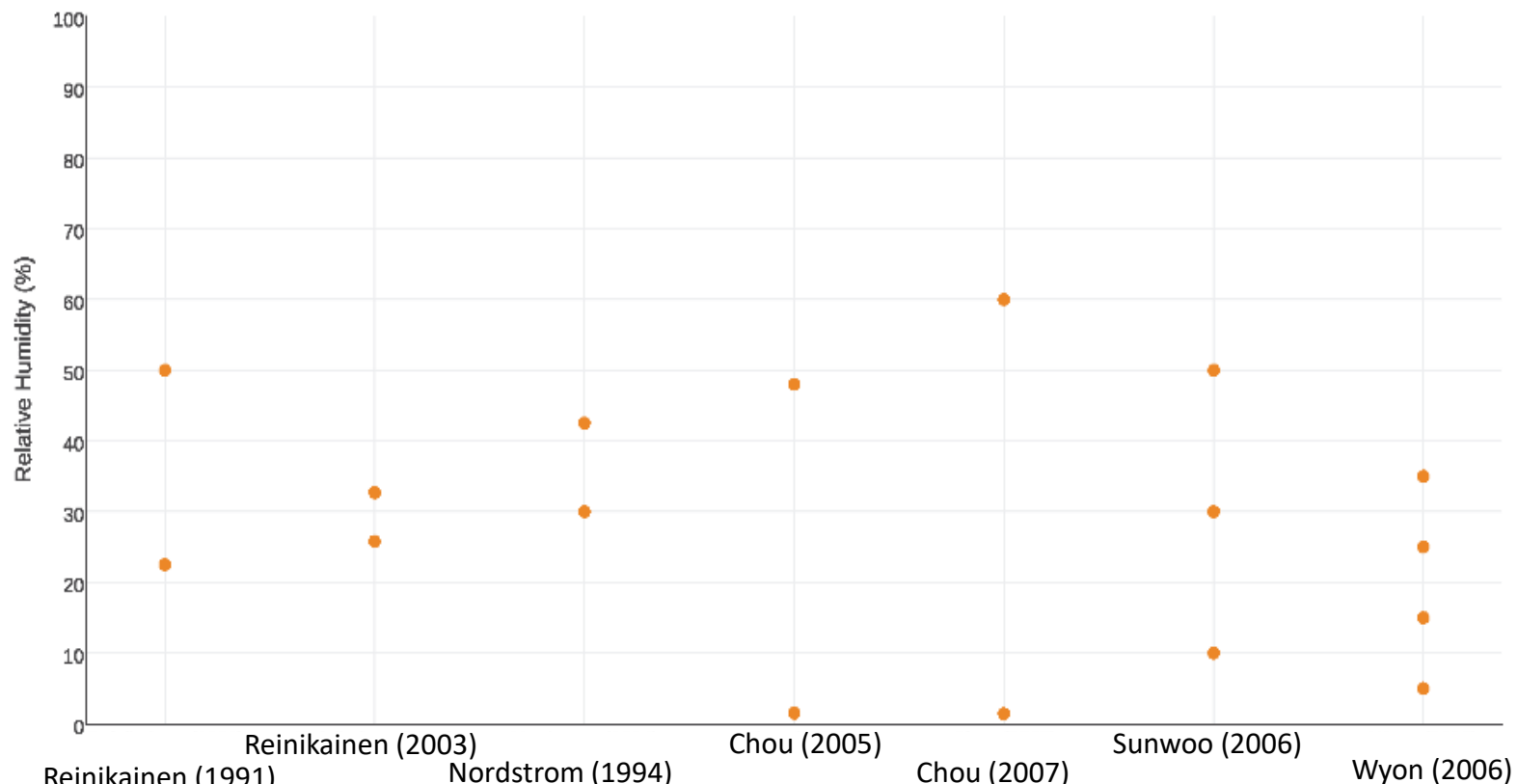
Eye Irritation

- Focus on healthy patients
- Eye goggles [e.g., Arciniega (2011) and McCulley (2006)] and environmental chamber [e.g., Abusharha (2013), Laviana (1988), Sunwoo (2006), Wyon (2006)]
- Wyon (2006): eyes were drier at 5% RH than 35% RH although subjects did not perceive it; small but significant decrease in performance of office tasks at low RH



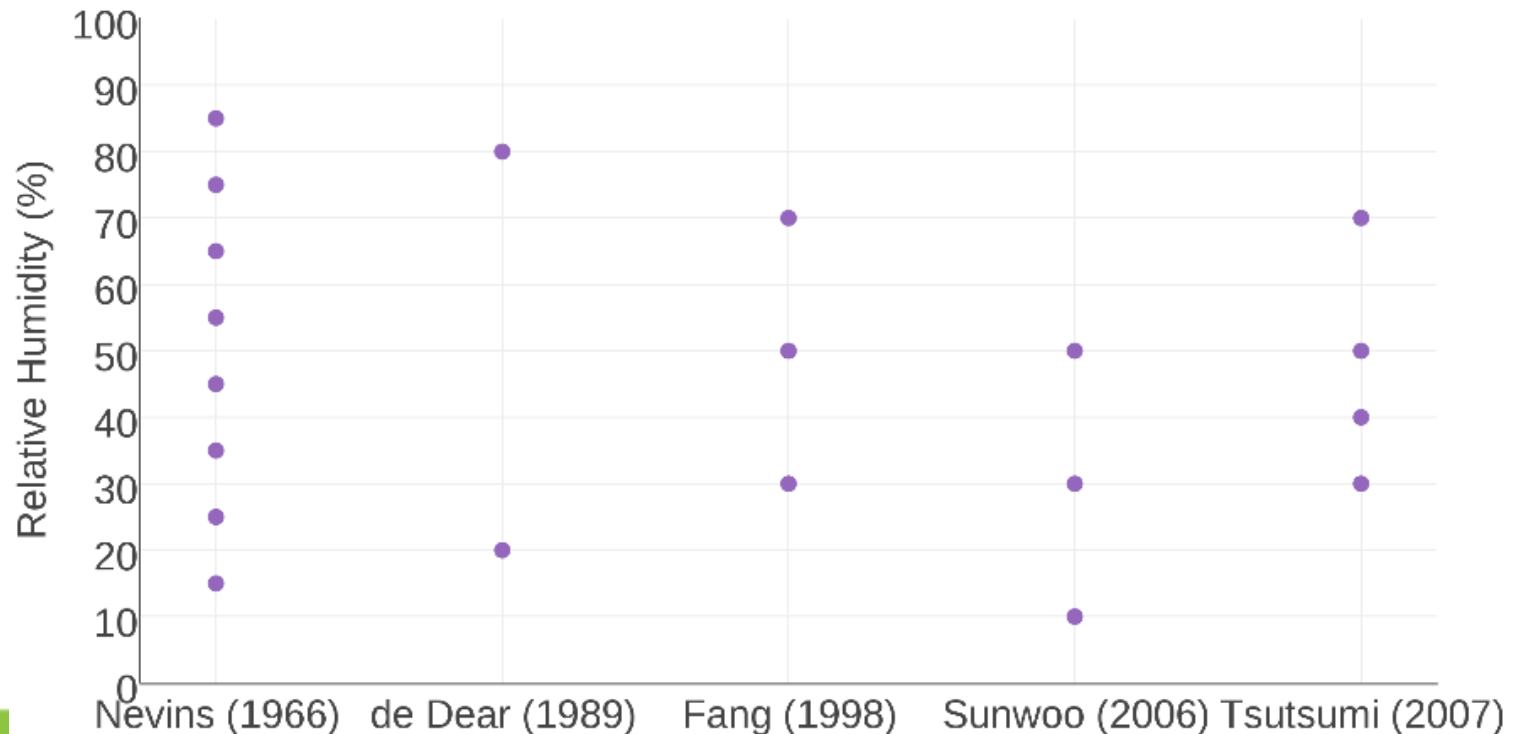
Skin Irritation

- Focus on healthy patients
- Testing in offices/workplaces [e.g., Reinikainen (1991), Reinikainen (2003), Nordstrom (1994), Chou (2005), Chou (2007)] and environmental chambers [e.g., Sunwoo (2006) and Wyon (2006)]
- Increased transepidermal water loss (TEWL) at lower RH, but changes with time are not known. How does the body adapt?



Thermal Comfort

- Extensive testing in environmental chambers [e.g., Nevins (1966), de Dear (1989), Fang (1998), Sunwoo (2006), Tsutsumi (2007)]
- Few effects of low RH on thermal comfort as long as temperature is suitably adjusted for the humidity effect



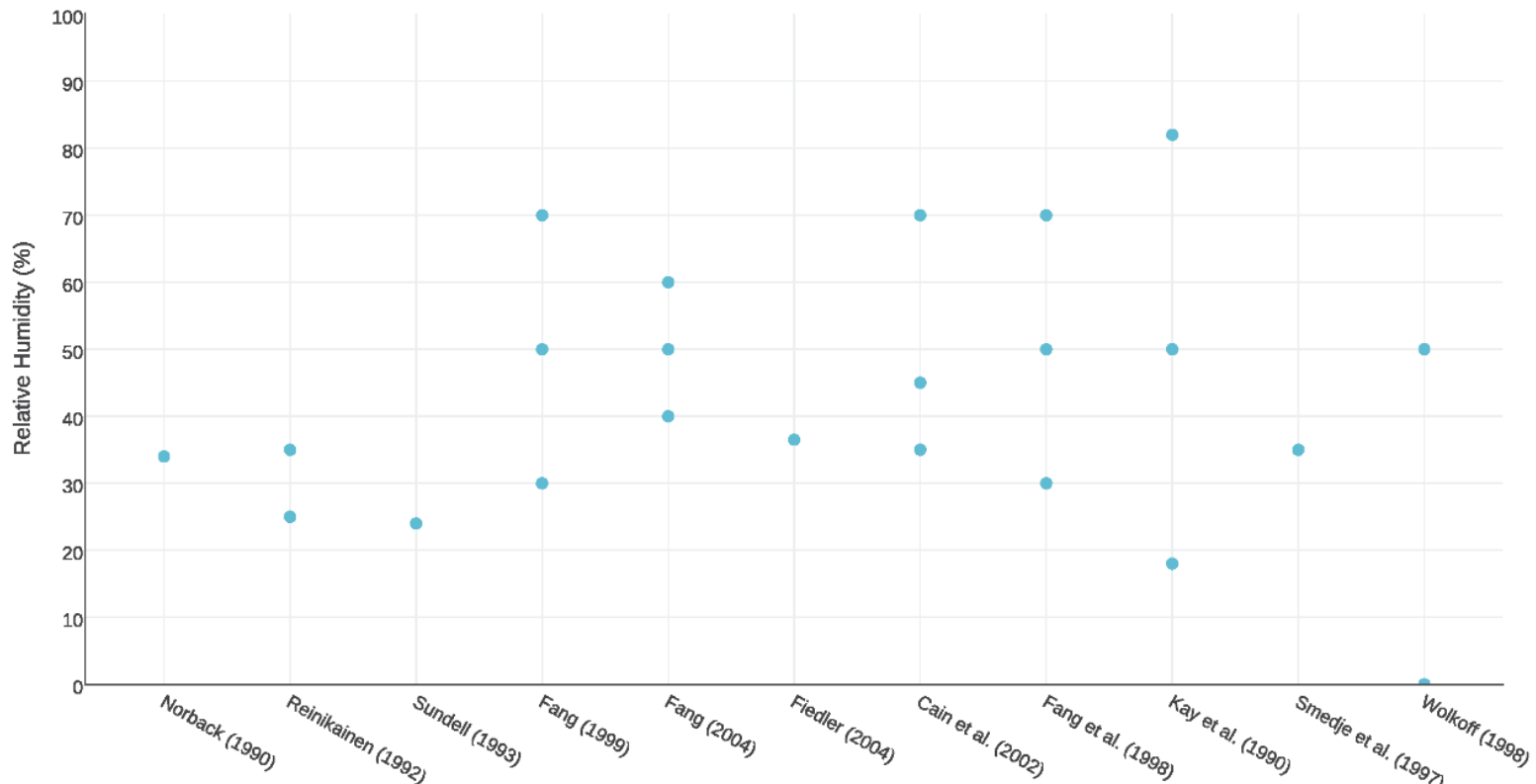
Comfort Knowledge and Gaps

- Low humidity does not cause thermal discomfort in terms of thermal sensation
- Comfort effects of low humidity attributed to skin, eye, and mucous membrane irritation.
 - Evaporative tear losses increase and blink frequencies are higher in healthy eyes (minutes to hours)
 - What are the long term effects of low RH on vision, eye comfort, and eye health?
 - Increased skin discomfort and itching was observed at ultra-low humidity levels (1.5–2.5% RH)
 - Mild skin discomfort effects were observed for healthy patients in humidity $\leq 30\%$ RH
 - Data suggest that initial TEWL was when a subject entered a low humidity condition, after which the skin adapted (in a time scale of 30–60 minutes) in order to conserve water in the short term.

IEQ

Indoor Air Quality (IAQ)

- Human subjects [e.g., Kay (1990), Fang (1998), Cain (2002), Fang (2004)], emissions from building materials [e.g., Wolkoff (1998), Fang (1999), Cain (2002)], and surveys [e.g., Norback (1990), Reinikainen (1992), Sundell (1993), Smedje (1997), Fiedler (2005)]
- Few conclusions can be drawn regarding the IEQ literature



IEQ Knowledge and Gaps

- Limited data
- Results on the effects of RH on volatile organic compound (VOC) emissions from building materials were inconclusive
 - Depended on the type of material and type of VOC.
- Emissions from materials may or may not change with changes in temperature and humidity
- In general, increases in temperature and humidity decreased the perceived quality or acceptability of the air
- In the study by Cain et al. (2002), dilution (concentration) and temperature had far stronger effect than RH on TVOC emissions and perceived air quality

Human Subjects

- Human subjects in surveys and laboratory tests

Category	Children (0-13)	Adolescents (13-18)	University students only	Adults (18-65)	Elderly (>65)
Asthma/ Respiratory	3	1	1	3	1
House Dust Mites	1	0	0	0	0
Viruses/ Bacteria	1	2	0	4	1
Comfort	0	0	8	5	1
IEQ	0	0	4	8	0

- Few studies addressed adults > 65 [e.g., Sunwoo (2006)- 8 college age men, 8 men (avg age 72)]

Conclusions and Future Work

- Most studies involving human subjects conducted tests at a limited number of humidity levels (e.g., 2-3)
- Few studies identified the direct benefits or consequences of increasing relative humidity by 10%, for example
- Confounding variables included ventilation rates and exposure time
- For building occupants, what are the appropriate weightings of the comfort, health, and IEQ categories?

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QUESTIONS?

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