Microbial exposures indoors

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Full disclosure: Speaker is not a microbiologist

Indoor Bioarerosol Dynamics

William W Nazaroff

Keynote lecture at Indoor Air 2014, Hong Kong, July 2014

"In our daily lives, we humans move through a sea of microbial life that is seldom perceived except in the context of potential disease and decay. Indoor air typically has approximately 10^6 bacteria per m^3; municipal tap water usually contains at least 10^7 bacteria per L. Little is known about the nature of these microbial populations."

Source: Levin, 2016

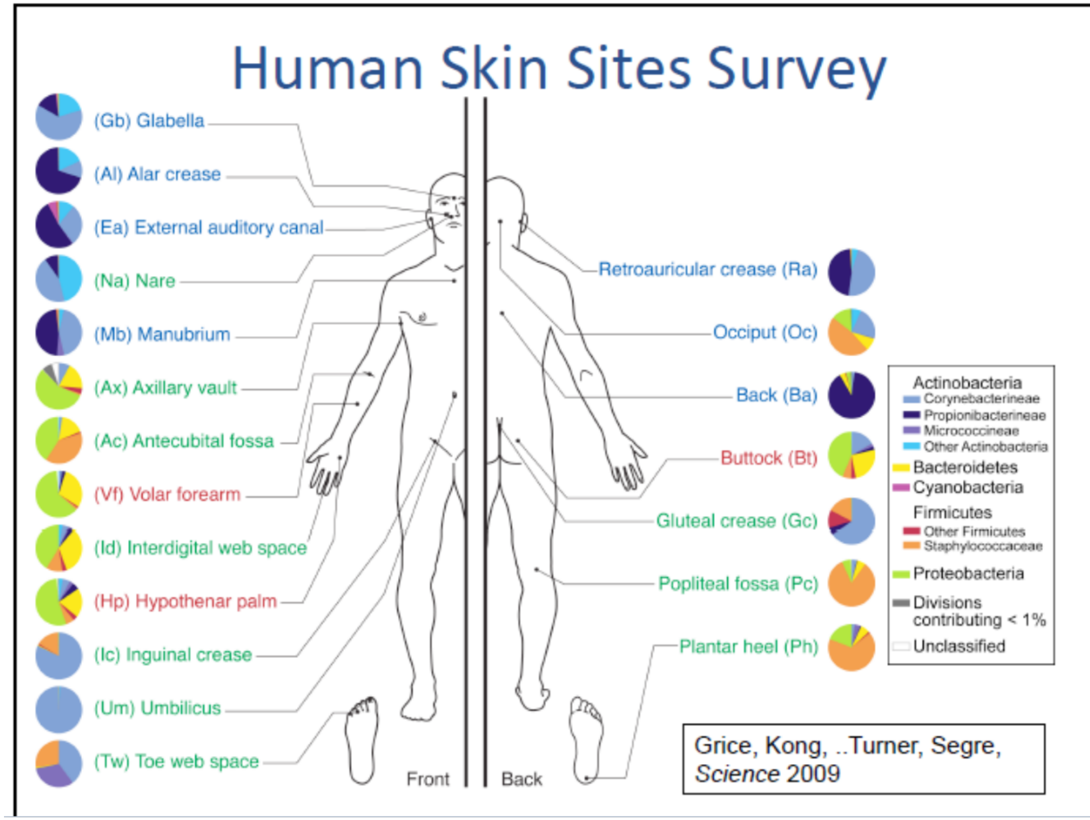
Soil – 10^6 organisms / gram of soil

Humans – about 2 kg of microbes, ~80% in the gut

Humans – about 2*10^6 organisms per cm^2 of skin surface

Human skin microbiome

(Grice and Segre, 2009. *Science*)



Approximately 10^6 microbes/cm^2 of human skin

Typically we each have ~ 2 kg microbes, 1.6 kg in gut

Apparent that ind envt'l conditions affect metabolic rate, skin moisture, sweating,

Sources

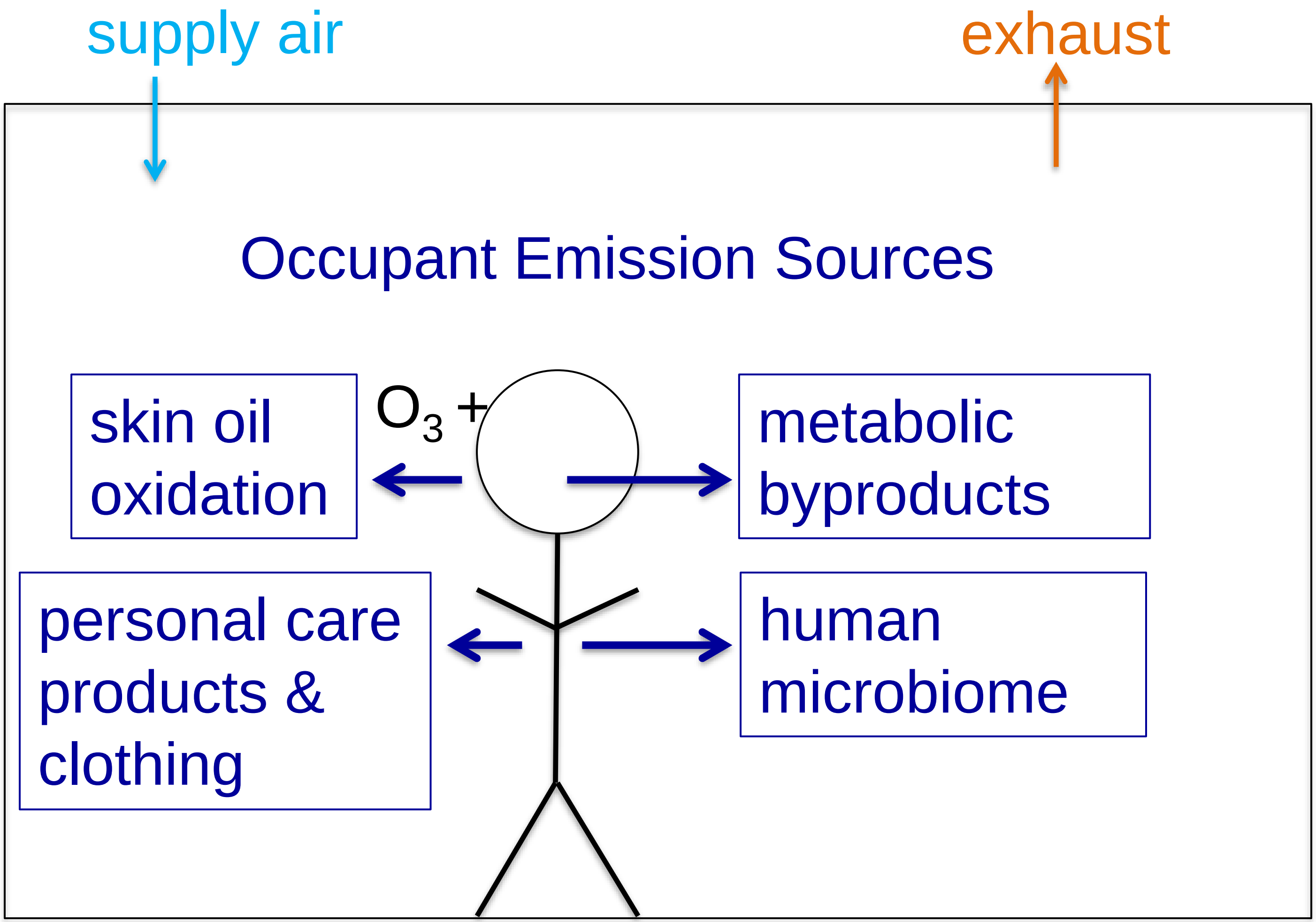
- Outdoor
  - Track in
  - Ventilation
- Humans
  - Shedding
    - Respiratory, Skin, Gut
  - Re-suspension
- Growth – needs nutrients and water
- Virulence – dependent on viability, H_2O

The indoor microbiome

- Humans shed skin each 2 – 4 weeks
- Weschler has shown that oil from the skin covers virtually all indoor surfaces in spaces humans occupy
- Moisture film on surfaces when RH > 55%
- Do the microbes on our skin also cover all surfaces? Some of them do, for sure.
- Are these microbes dangerous? Some of them are, for sure. But most are not.
- Communities of microbes exist in relationship to each other and as affected by relevant indoor microbial conditions and human occupants and their activities.
- Studies have found microbes on surfaces can be tracked to their individual human sources.
- Tom Bruns says most come from outdoors (he is a mycologist)

Human Emissions Indoors

Goldstein et al, 2015. Sloan symposium, Boulder



Determined VOC Source Rates

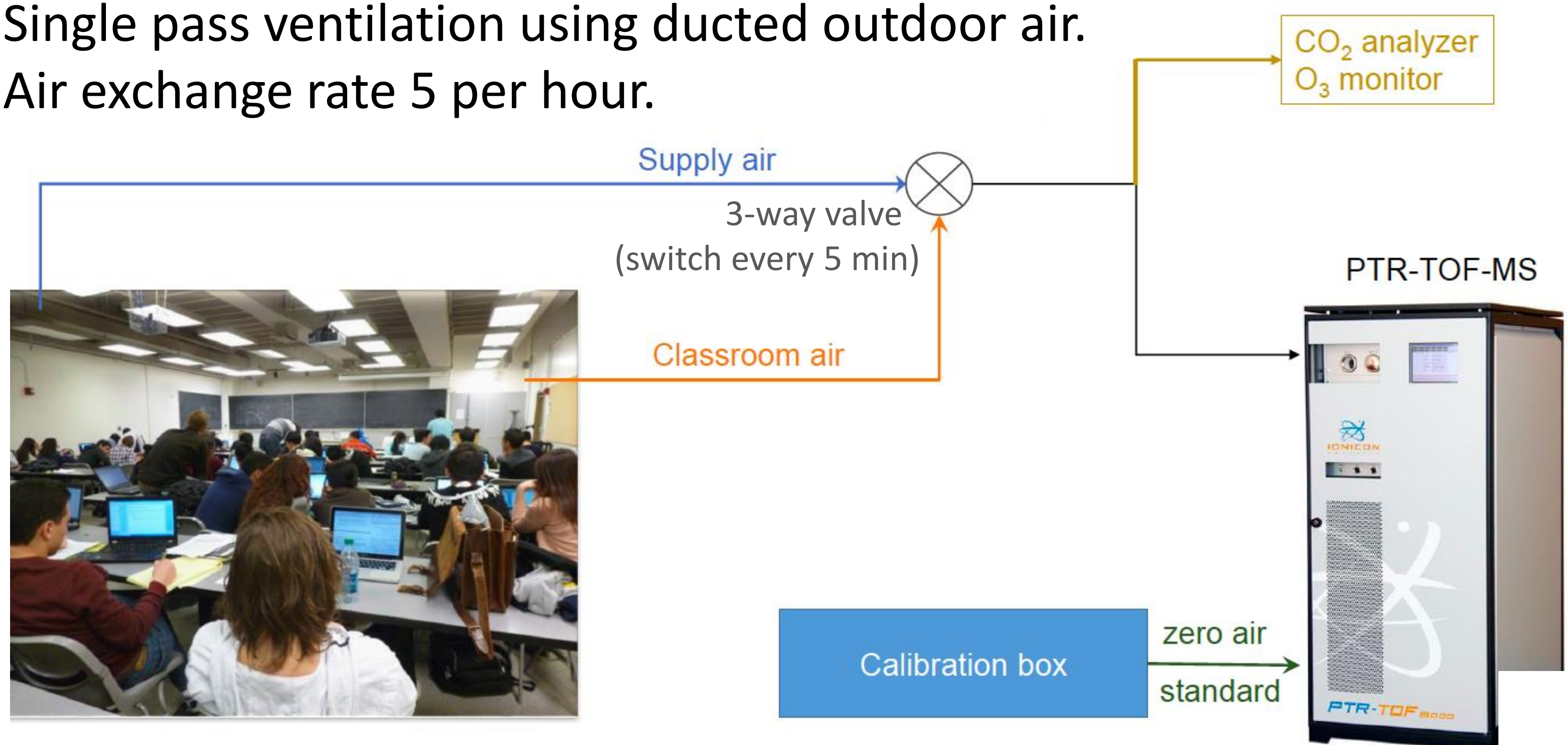
Total Source = Occupants + Supply Air + Classroom

Calculated by integral material-balance in stable occupancy periods.

18 Class sessions observed, with 20 to 70 students per session.

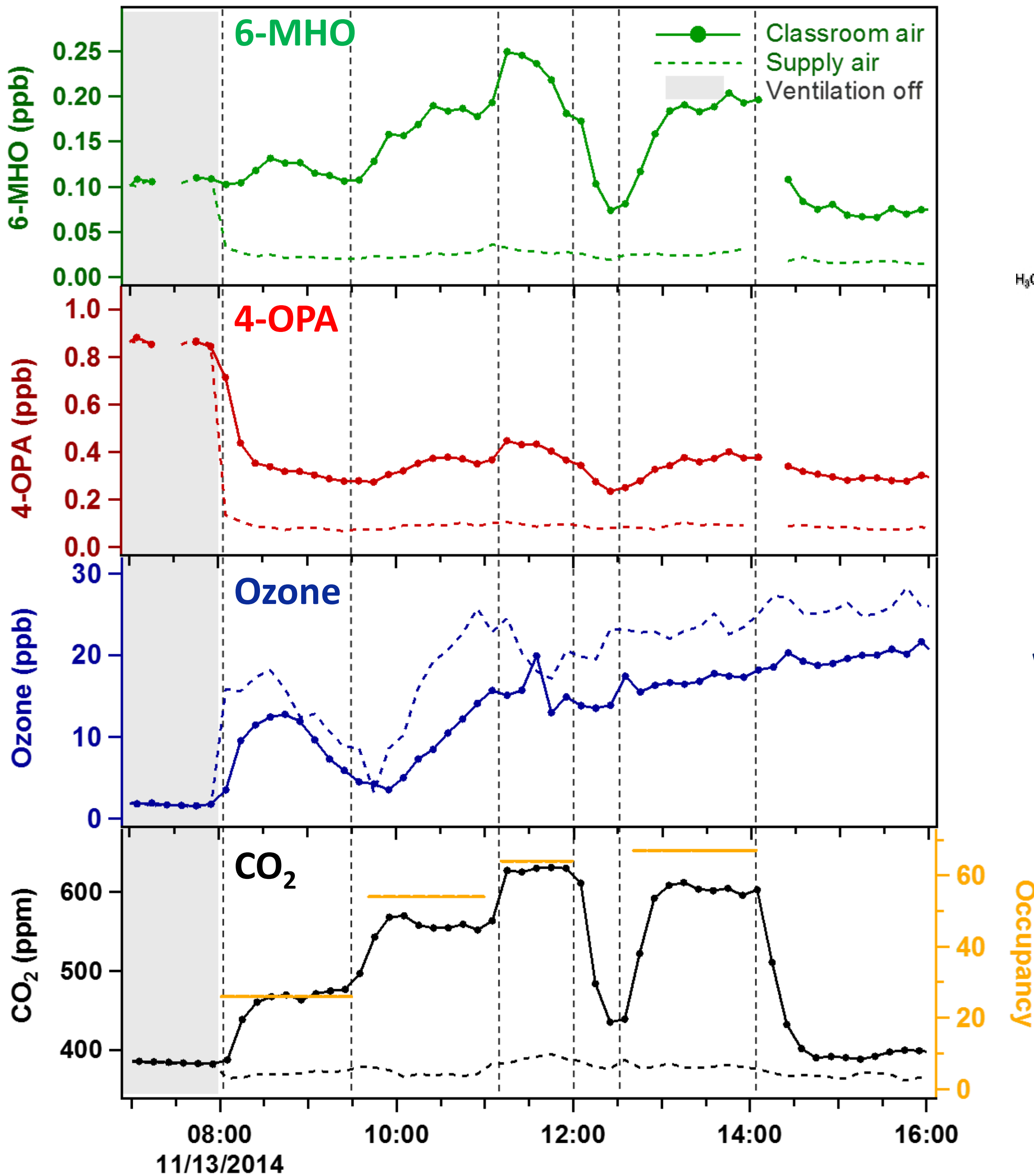
Single pass ventilation using ducted outdoor air.

Air exchange rate 5 per hour.

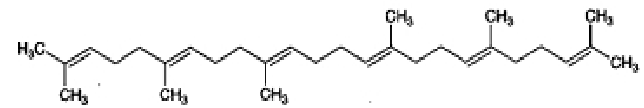


Proton Transfer Reaction Time-Of-Flight Mass Spectrometer (PTR-TOF-MS) offers exquisite sensitivity, specificity, and time resolution for measuring VOCs.

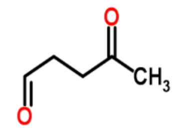
Human Skin Oil Oxidation



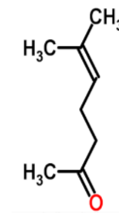
Squalene



+ O_3



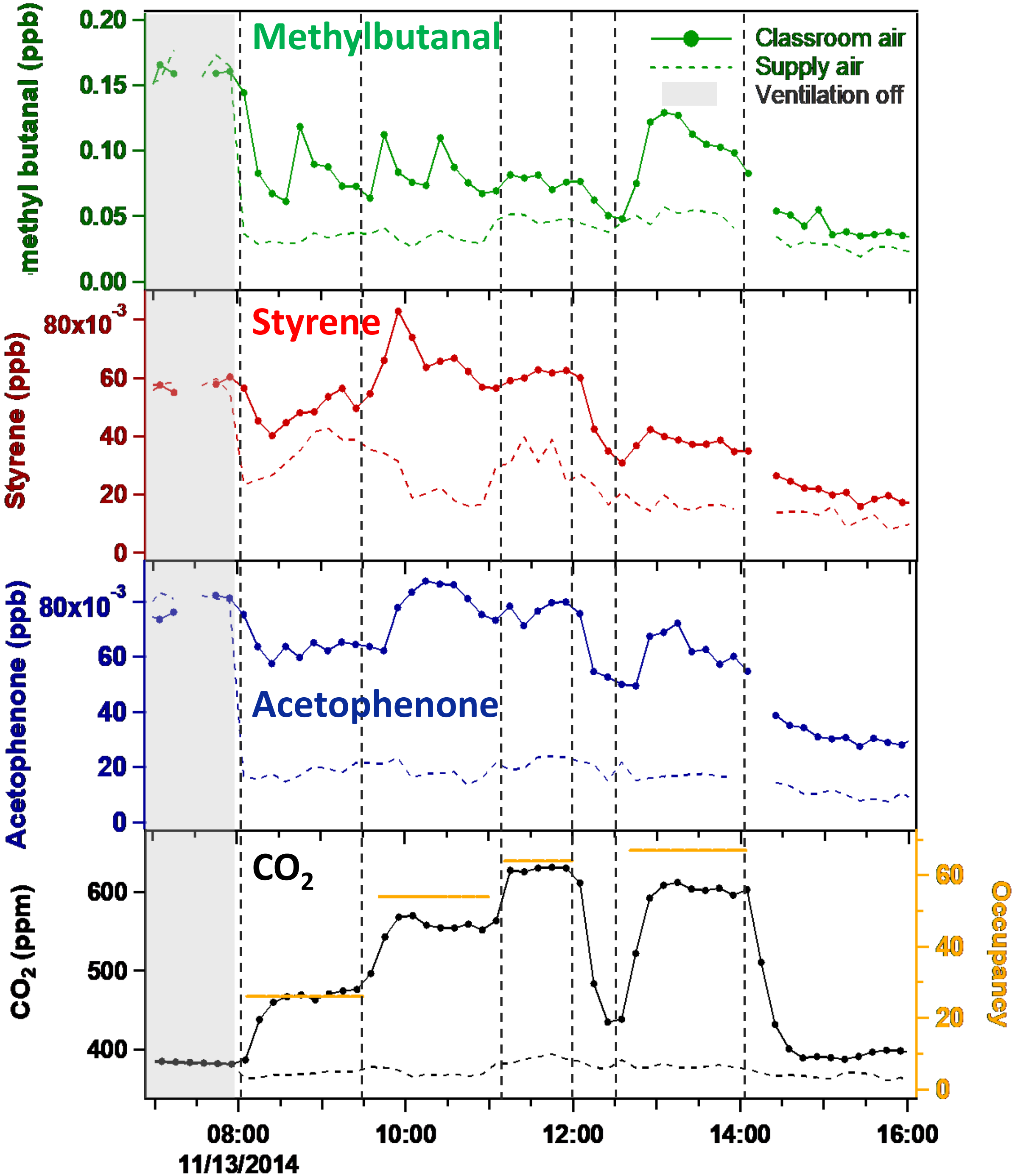
4-OPA



6-MHO

Wisthaler and Weschler (2010)

Concentrations vary with O_3 X Occupancy



Microbial VOC Emitted from Human Skin?

Emissions of these 3 chemicals not common in microbes, but observed specifically from *Staphylococcus hominis* in human skin derived cultures.

NOT observed in breath (5 people measured)

We create our own indoor microbial environment and it follows us when we move

Lax et al, 2014, *Science*

- Microbial communities associated with 7 families and their homes over 6 weeks were assessed, including three families that moved their home.
- Microbial communities differed substantially among homes, and the home microbiome was largely sourced from humans.
- The microbiota in each home were identifiable by family. Network analysis identified humans as the primary bacterial vector, and a Bayesian method significantly matched individuals to their dwellings.
- Draft genomes of potential human pathogens observed on a kitchen counter could be matched to the hands of occupants.
- After a house move, the microbial community in the new house rapidly converged on the microbial community of the occupants' former house, suggesting rapid colonization by the family's microbiota.

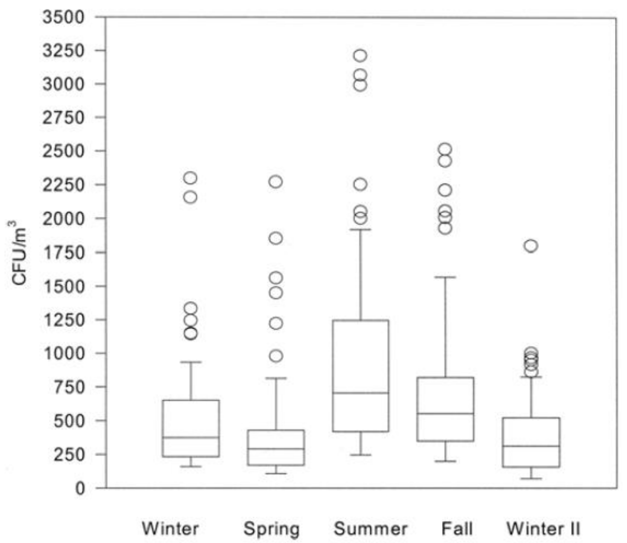
Does season affect indoor microbiome

Aerosol Science and Technology, 2003. "Time and Space Uniformity of Indoor Bacteria Concentrations in Chicago Area Residences"

Average and standard deviation of indoor airborne bacteria levels

	Bathroom		Kitchen		Outdoor		Bedroom		Basement	
CFU/m^3	x_{avg}	SD	x_{avg}	SD	x_{avg}	SD	x_{avg}	SD	x_{avg}	SD
Winter	640	503	455	443	332	211	506	365	422	297
Spring	568	478	498	511	245	169	791	1009	299	247
Summer	1003	753	1026	814	444	371	818	660	1207	1966
Fall	1061	1089	758	621	302	169	672	323	457	453
Winter II	491	417	350	203	101	107	394	262	403	461
Average	753	719	620	600	286	249	636	604	558	975

Seasonal Variation of Viable Bacteria



Does Size matter?

Moschandreas et al, 2003

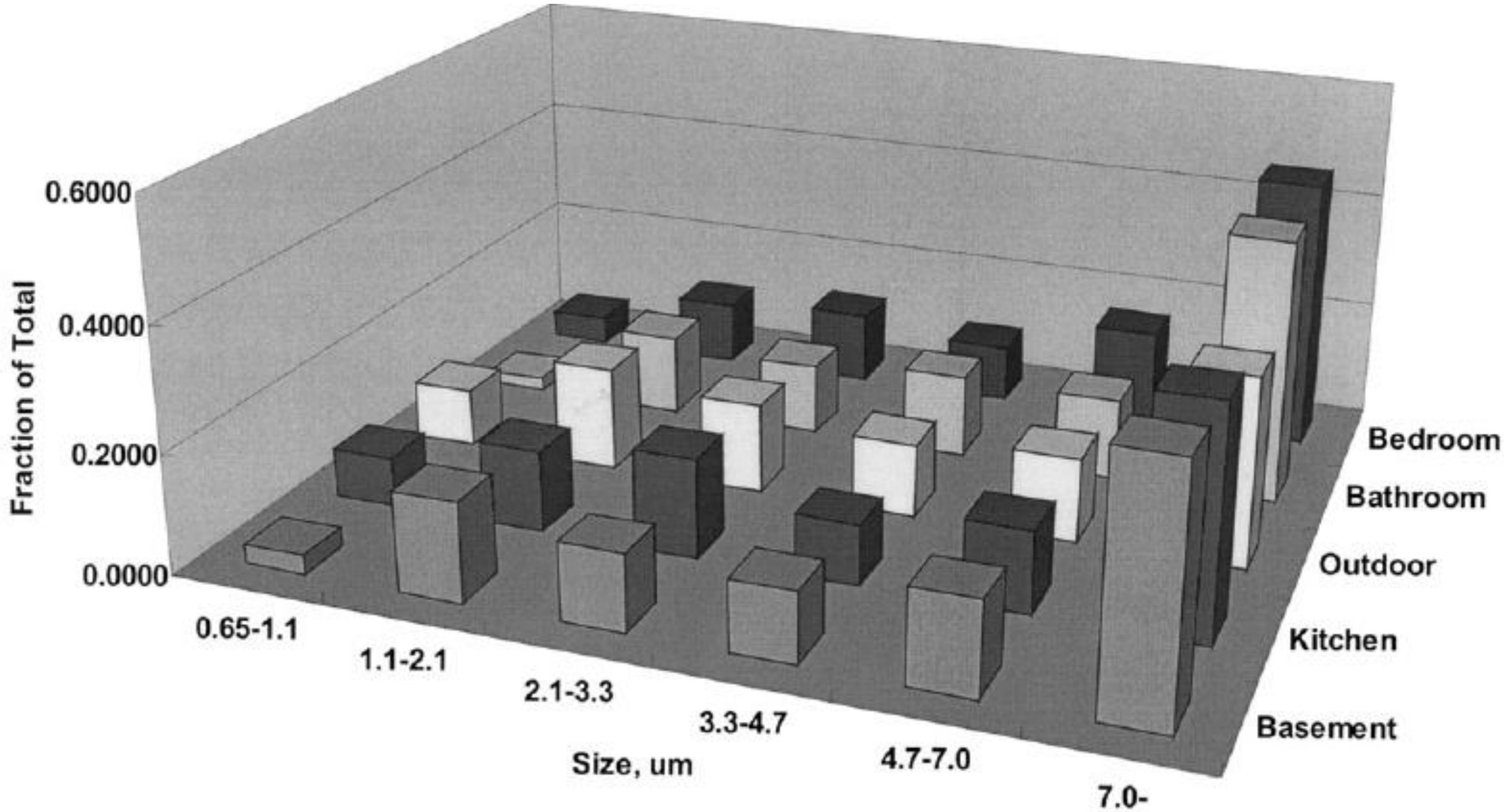
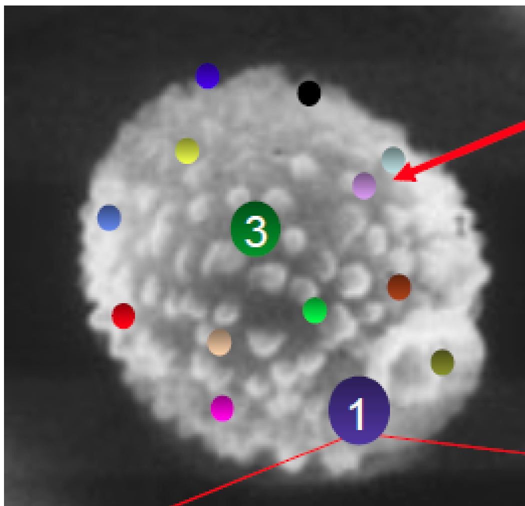


Figure 4. Size distribution of *Staphylococcus* sp. over all seasons in different rooms.

Fungal exposures

- Ubiquitous
- The good, bad, and ugly
- Allergens
- Asthmagens – age of exposure dependent
- Infectious agents
  - Superficial Fungal Infections
  - Dermatophyte Infections
  - Subcutaneous Mycoses
  - Systemic Mycoses

Example: common fungus *Aspergillus fumigatus*



Aspergillus fumigatus **has 23 allergenic proteins. (proteins have diversity of functions e.g. ribotoxin, heat shock protein)**

IgE can bind to multiple sites within a specific protein

TTGGSSSTPHGKDDHYLLEFFWTCINGIVAHQR

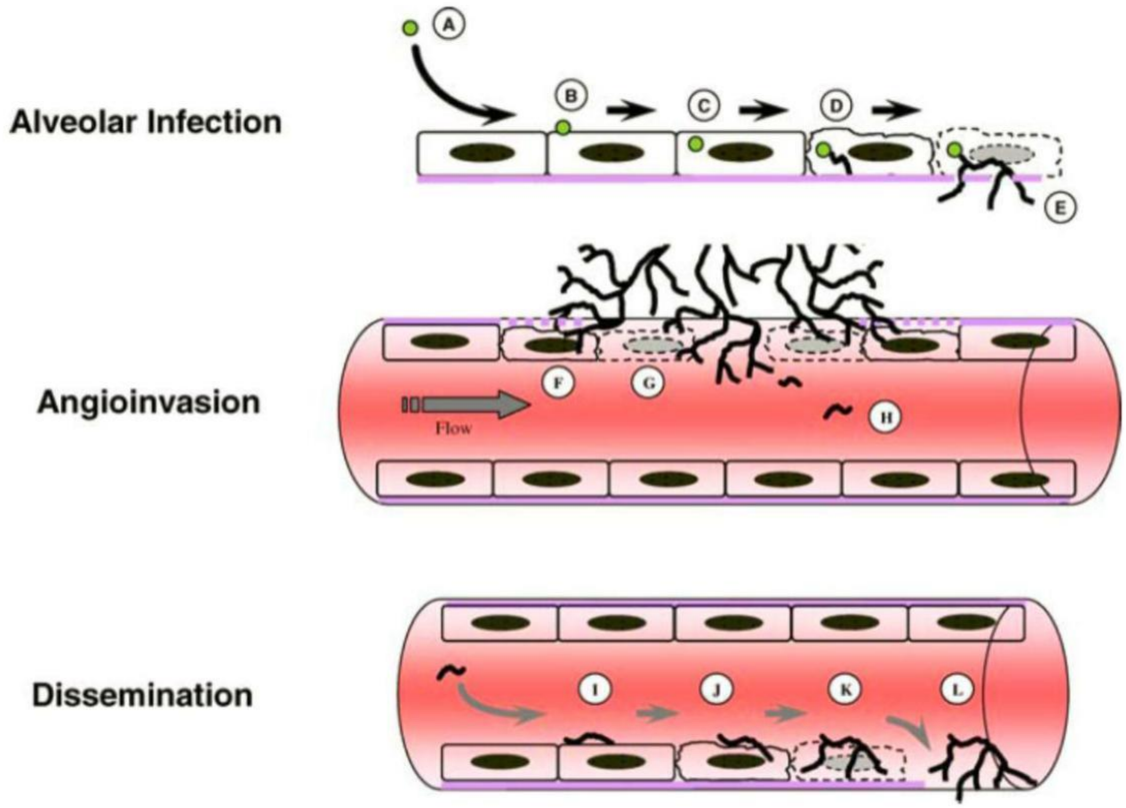
Yang-low et al, 2011. Proceedings: Indoor Air 2011. "Growth temperature strongly influence the allergenicity of *Aspergillus fumagatus"* spores

Survivability of airborne fungi

- The aim of the present study was to investigate the effect of some air pollutants and meteorological parameters on the survivability of airborne fungi.
- T°C was positively and negatively correlated with Aspergillus (P=0.000) and Penicillium (P=0.007), respectively.
- RH% was positively correlated with total fungi (P=0.001), *Aspergillus* (P =0.002) and *Cladosporium* (P =0.047).
- Multiple regression analysis showed that T°C and RH% were the most predicted variants.
- **Non-significant correlations were found between fungal concentrations and air pollutants. !!!!! Fungi not AP????**
- **Meteorological parameters were the critical factors affecting fungal survivability.**
- **Implications for importance of indoor envt for microbial effects**

Hameed et al, 2011. Study on some factors affecting survivability of airborne fungi. *Science of the Total Environment* 414 (2012) 696–700.

Fungal invasion of normally non-phagocytic host cell



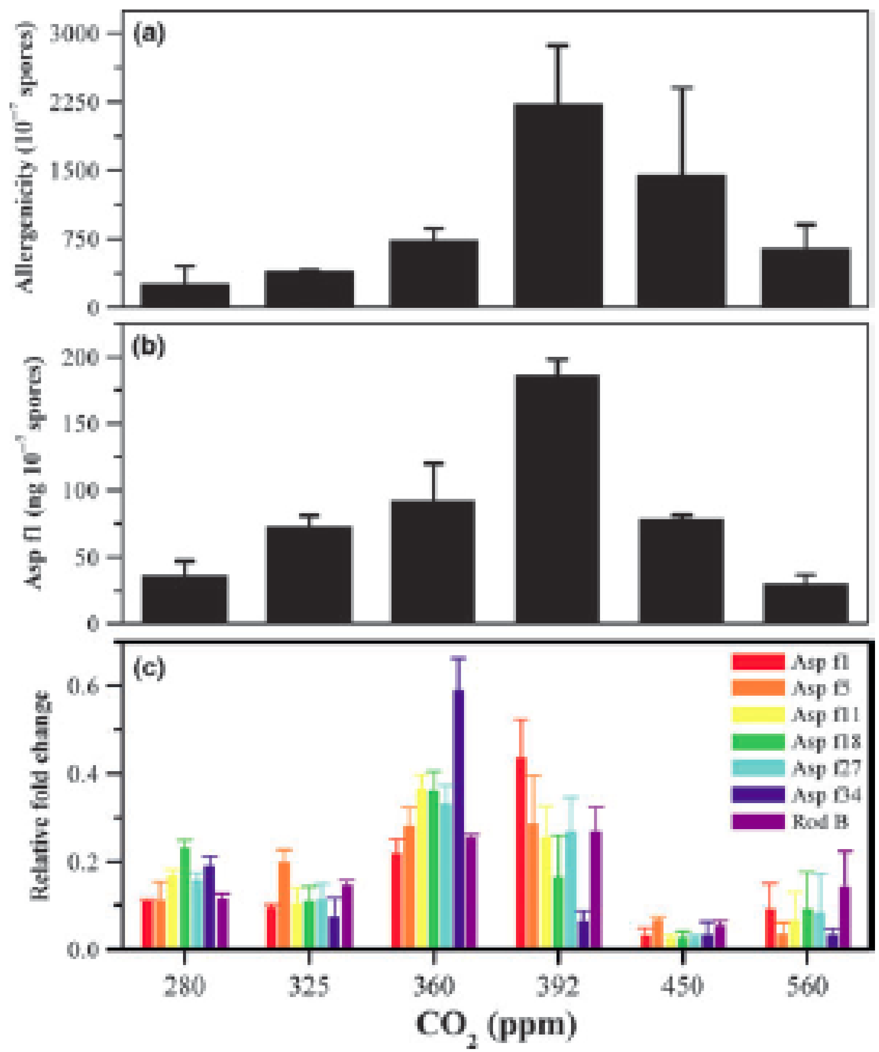
By Scott G. Filler, Donald C. Sheppard - Filler SG, Sheppard DC. Fungal invasion of normally non-phagocytic host cells. PLoS Pathog. 2006;2;(12)e129. PMID: 17196036,
https://commons.wikimedia.org/w/index.php?curid=14882847

Changes in Atmospheric CO_2 Influence the Allergenicity of *Aspergillus fumigatus*

Lang-Yona et al, 2013. *Global Change Biology*, 19, 2381–2388

Table 1 The different CO_2 concentrations for each treatment in the CO_2 chamber experiment

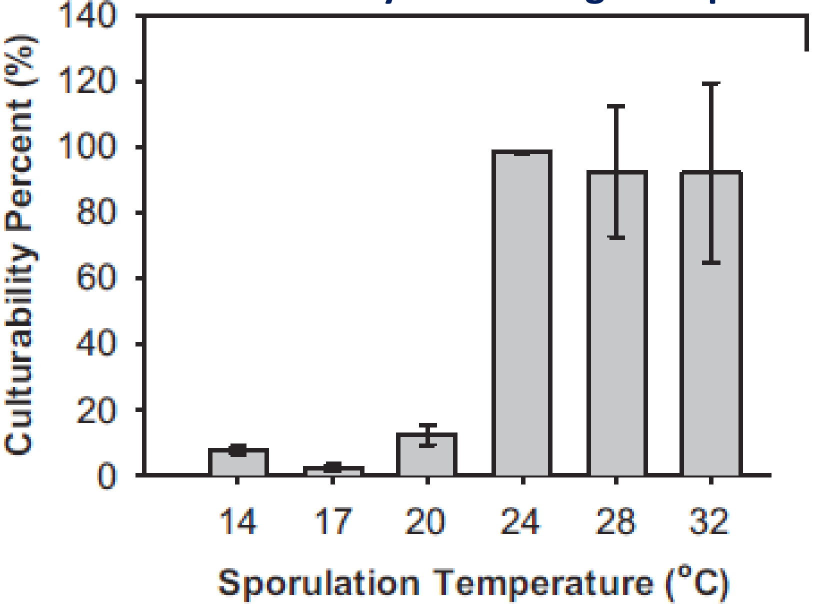
Treatment	CO_2 concentration (ppm)	Remarks
1	280	Preindustrial equivalent concentration
2	325	Atmospheric CO_2 levels during the year of 1968 (Tans, 2008)
3	360	Atmospheric CO_2 levels during the year of 1993 (Keeling, 1999; Tans, 2008)
4	392	Atmospheric CO_2 levels during the year of 2010 (Keeling, 1999; Tans, 2008)
5	450	Future prediction for the year of 2030 according to the A1F1 model (Johns *et al.*, 2003)
6	560	Future prediction for the year of 2050 according to the A1F1 model (Johns *et al.*, 2003)



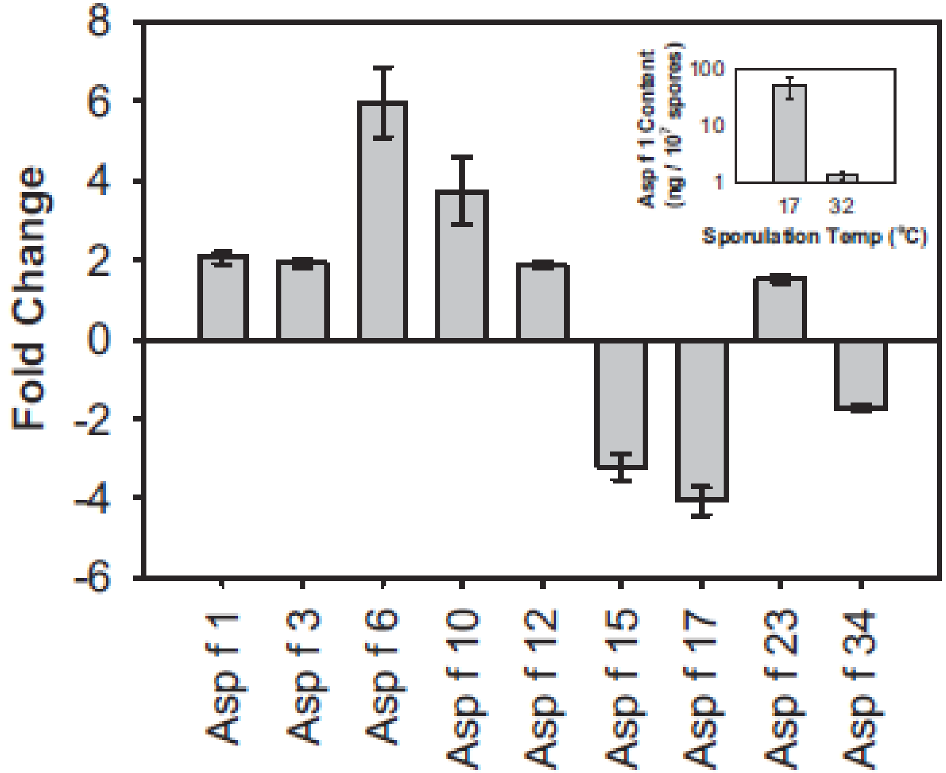
The allergenicity of *Aspergillus fumigatus* conidia is influenced by growth temperature

(*Fungal Biology* 115 (2011) 625-632)

Culturability of A. fumigatus spores

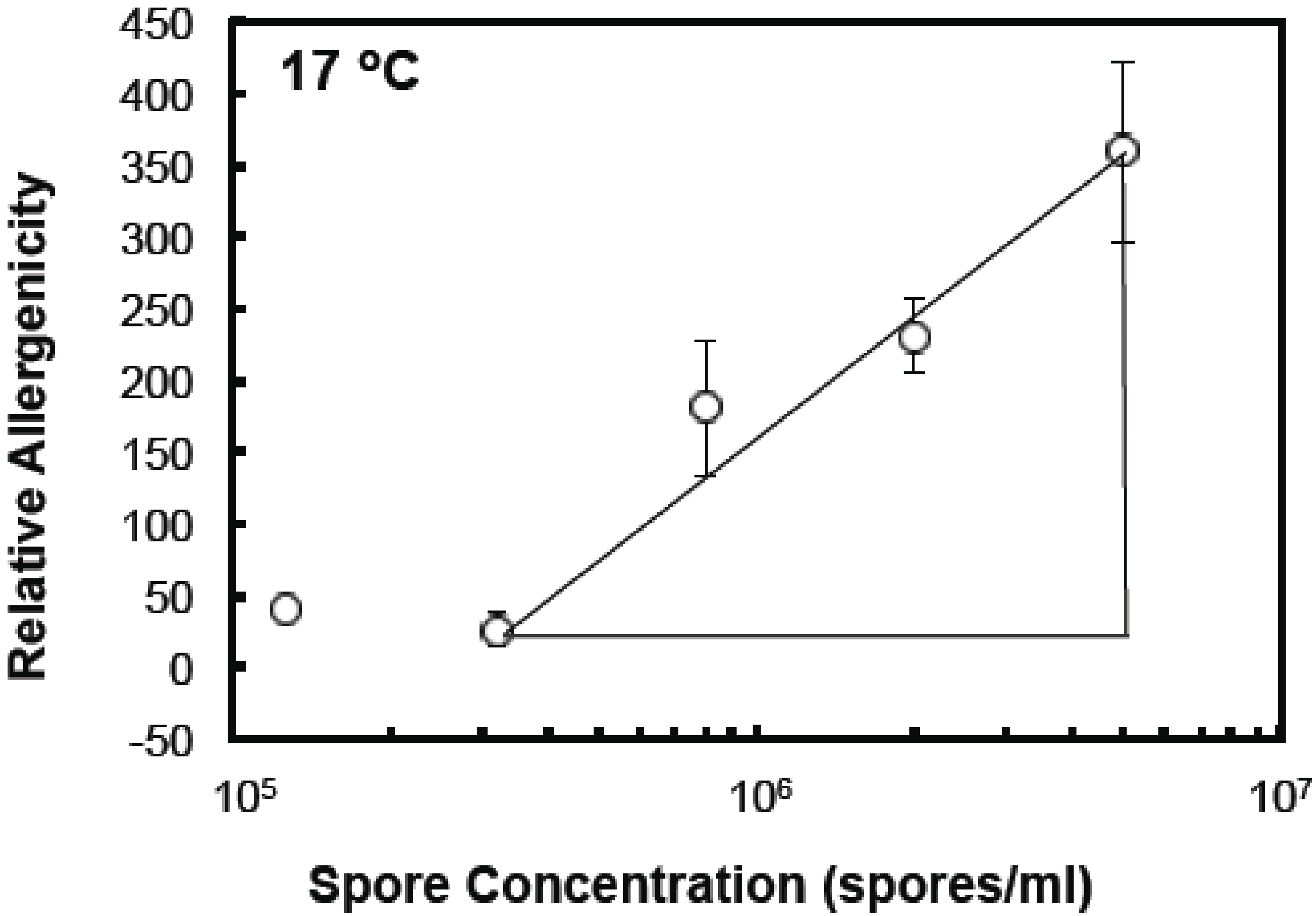


Allergenic gene expression and Asp f 1 protein production in 17 C and 32 C spores.



Could this explain increase in asthma during past 2 or 3 decades in advanced economies and in past decade in developing economy (China?)

Allergenicty as f(spores/ml)



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CONCLUSIONS

- Environmental conditions during sporulation influence the allergenicity "IgE binding capacity" and allergen production in *A. fumigatus* spores.

Human IgE binding → Total and allergenic protein → Microarray and qPCR gene expression

- Culturability and qPCR can underestimate (5 to 50 times) the allergenicity of *A. fumigatus* spores that were produced at lower temperature.

Questions

- What's the point? (Eric Lebret at ISES 2014)
- Does the building affect the indoor microbiome? If so, how?
- Does the indoor microbiome affect human health? If so, how?
- What about the hygiene hypothesis
- Can NGS methods help inform us w.r.t. these Qs?

Conclusionh

Buildings are ecosystems

(Logue, ISEA, 2011)