



# MoBE research and architectural engineering

Brent Stephens, PhD

Assistant Professor (Associate Professor effective Fall '16)

Civil, Architectural and Environmental Engineering



## The Built Environment Research Group

advancing energy, environmental, and sustainability  
research within the built environment  
at Illinois Institute of Technology



**web** [www.built-envi.com](http://www.built-envi.com) **email** [brent@iit.edu](mailto:brent@iit.edu) **twitter** @built\_envi

# Architectural Engineering is \_\_\_\_\_.

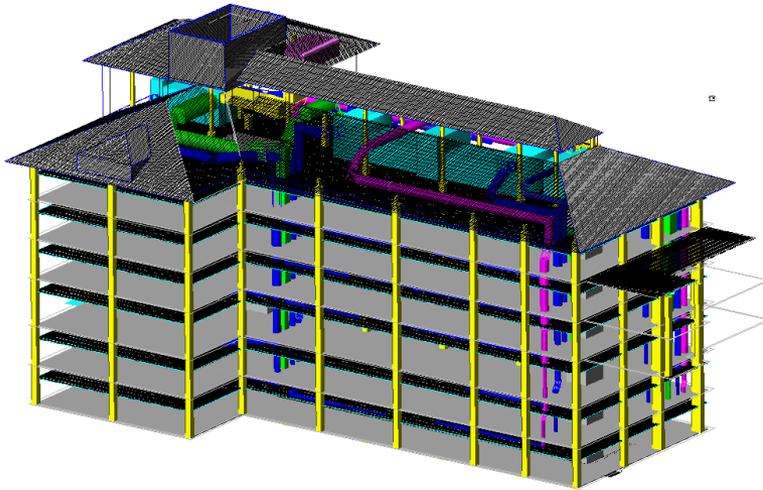
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- Structural engineering
- Mechanical engineering
- Electrical engineering
- Environmental engineering
- Construction engineering and management
- Plumbing design

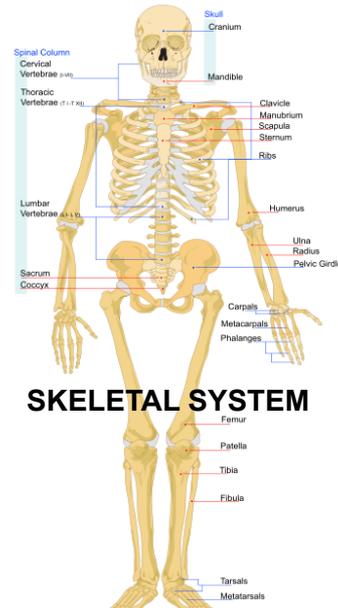
All of these disciplines must all work together to design, build, and operate a building successfully and efficiently

- **Architectural engineering** has become a catch-all for many of these disciplines

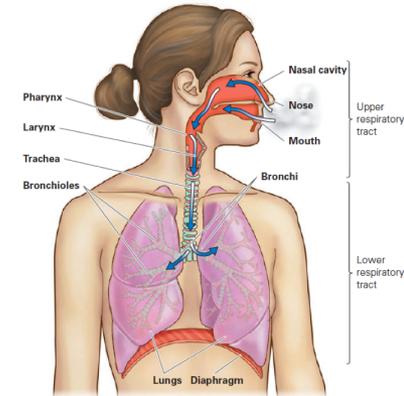
# When architectural engineers look inside a building...



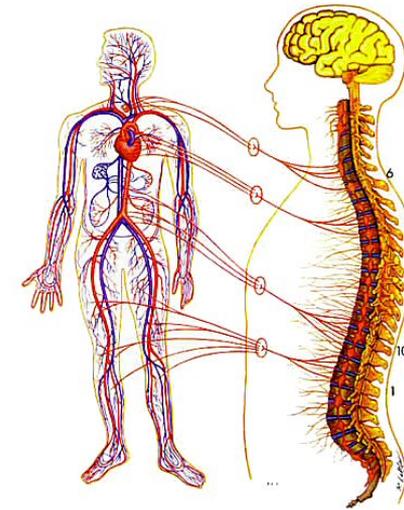
**Structural**



**RESPIRATORY SYSTEM**

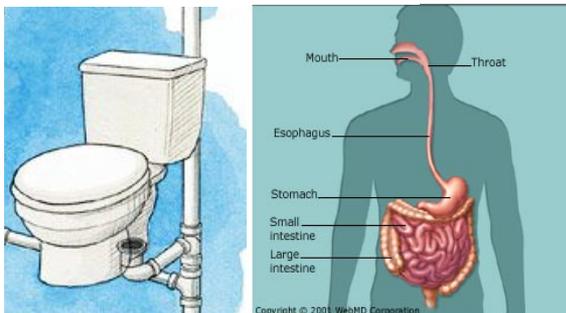


**CIRCULATORY SYSTEM**

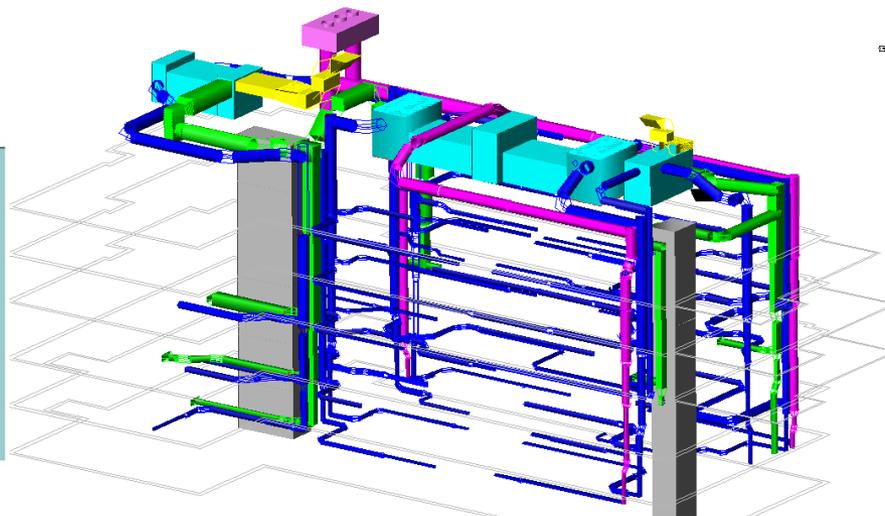


**CENTRAL NERVOUS SYSTEM**

**Plumbing**

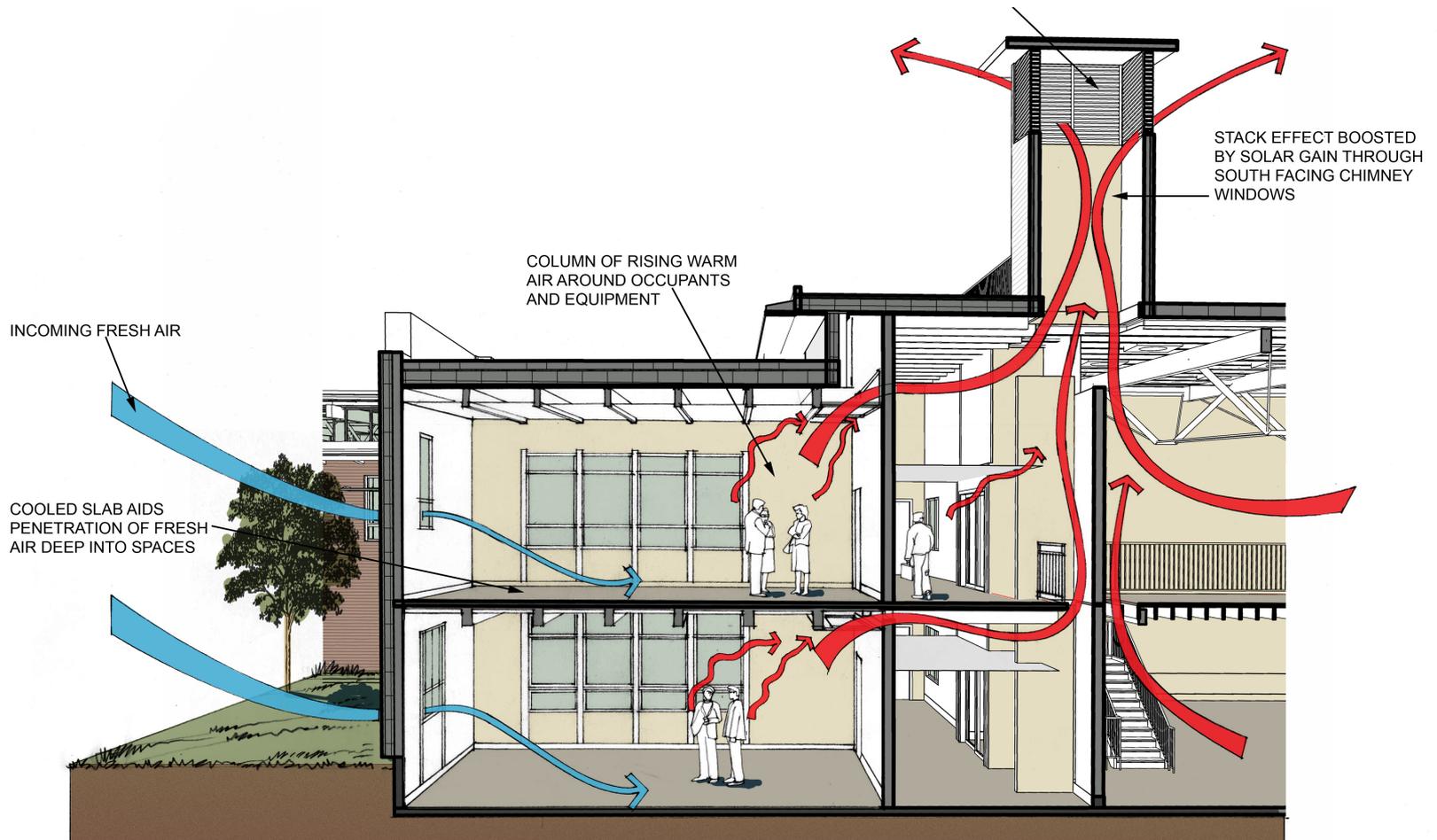


**Digestive system??**



**Mechanical and Electrical**

# Why do we need architectural engineering?



Architect's rendering

# Why do we need architectural engineering?

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We need to understand the fundamental physics of energy, heat transfer, fluid flow, and mass transport – collectively termed *building science* – to understand how buildings work and how design and operational decisions influence their performance



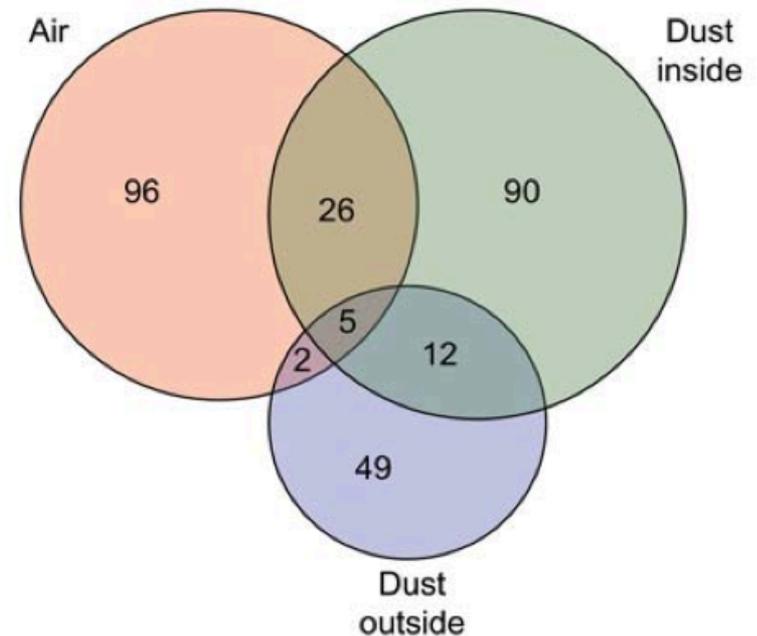
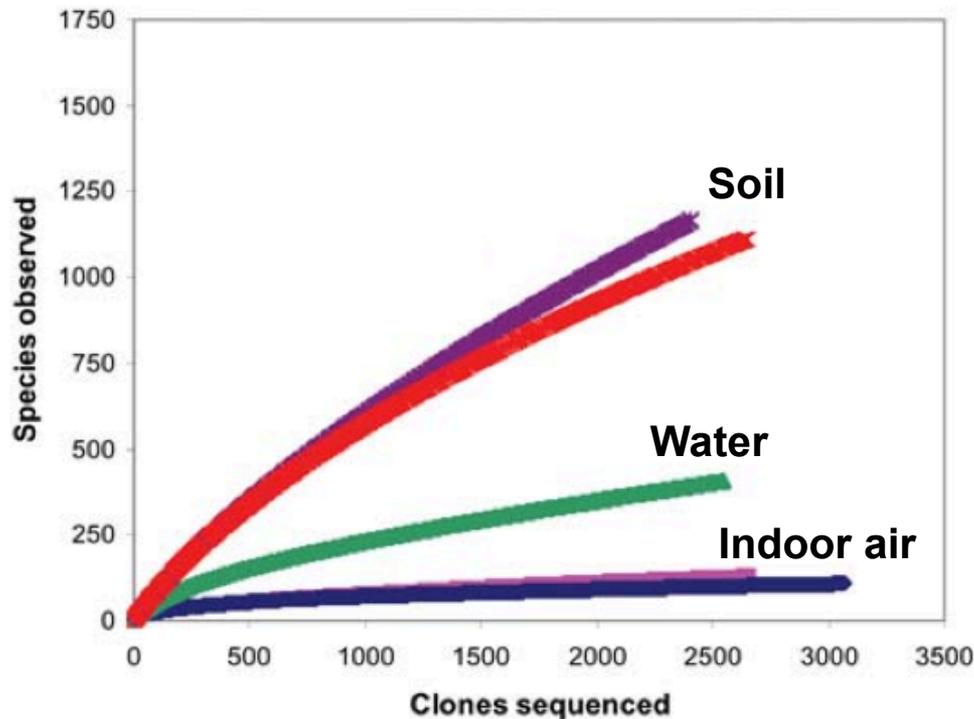
## **Summary of MoBE research (2004 – present)**

Through the lens of an architectural engineer

# 2004-2008: Initial MoBE studies

## Early findings

“Comparison of air samples with each other and nearby environments suggested that the **indoor air microbes** are not random transients from surrounding outdoor environments, but rather **originate from indoor niches.**”

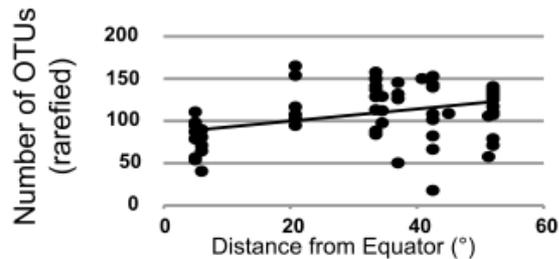


# 2009-present: Indoor **funga** communities are largely driven by outdoor fungal communities

Indoor fungal composition is geographically patterned and more diverse in temperate zones than in the tropics

Anthony S. Amend<sup>a,1</sup>, Keith A. Seifert<sup>b</sup>, Robert Samson<sup>c</sup>, and Thomas D. Bruns<sup>a</sup>

“Contrary to common ecological patterns, we show that fungal diversity is significantly higher in temperate zones than in the tropics, with distance from the equator being the best predictor of phylogenetic community similarity”



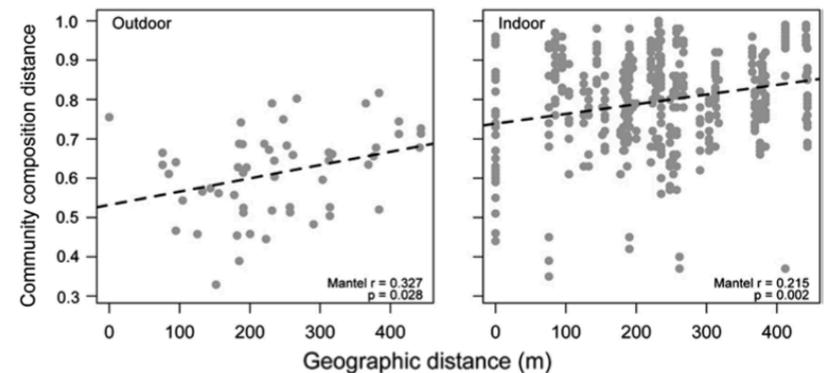
“Remarkably, building function has **no significant effect** on indoor fungal composition, despite stark contrasts between architecture and materials of some buildings in close proximity”

Amend et al. **2010** *PNAS* 107(31):13748

Dispersal in microbes: fungi in indoor air are dominated by outdoor air and show dispersal limitation at short distances

Rachel I Adams, Marzia Miletto, John W Taylor and Thomas D Bruns  
*Department of Plant and Microbial Biology, University of California, Berkeley, CA, USA*

“Fungal assemblages indoors were diverse and strongly determined by dispersal from outdoors, and no fungal taxa were found as indicators of indoor air”



“More fungal biomass was detected **outdoors** than indoors”

“Room and occupant behavior had **no detectable effect** on the fungi found in indoor air”

Adams et al. **2013** *ISME J* 1:1-12

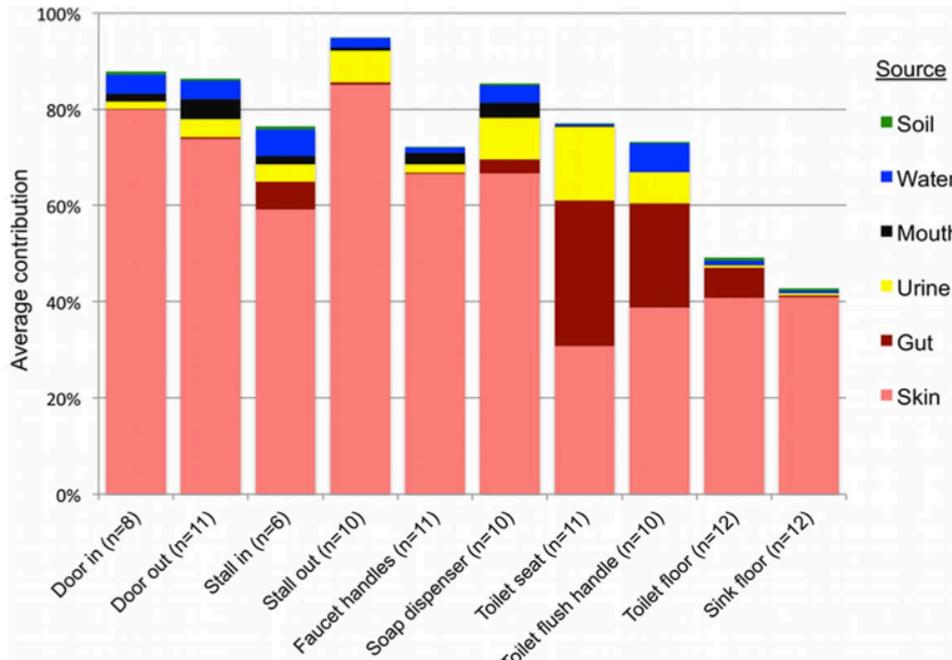
# 2009-present: Humans often dominate indoor bacterial communities in public spaces

## Microbial Biogeography of Public Restroom Surfaces

Gilberto E. Flores<sup>1</sup>, Scott T. Bates<sup>1</sup>, Dan Knights<sup>2</sup>, Christian L. Lauber<sup>1</sup>, Jesse Stombaugh<sup>3</sup>, Rob Knight<sup>3,4</sup>, Noah Fierer<sup>1,5\*</sup>

“Human-associated microbes are commonly found on restroom surfaces”

“Bacterial pathogens could readily be transmitted between individuals by the touching of surfaces”



Flores et al. 2011 *PLoS ONE* 6(11):e28132

## Human Occupancy as a Source of Indoor Airborne Bacteria

Denina Hospodsky<sup>1</sup>, Jing Qian<sup>1,2a</sup>, William W. Nazaroff<sup>2</sup>, Naomichi Yamamoto<sup>1,3</sup>, Kyle Bibby<sup>1</sup>, Hamid Rismani-Yazdi<sup>1,2b</sup>, Jordan Peccia<sup>1\*</sup>

“Occupancy increased the total aerosol mass and bacterial genome concentration in indoor air... with an increase of nearly two orders of magnitude in airborne bacterial genome concentration in PM<sub>10</sub>”

“Floors are an important reservoir of human-associated bacteria”

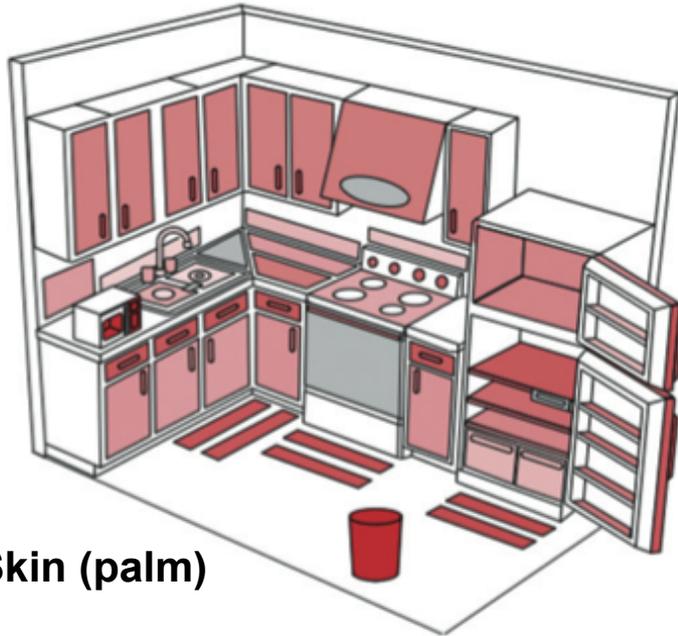
“**Direct particle shedding** of desquamated skin cells and their subsequent resuspension strongly influenced the airborne bacteria population structure in this human-occupied environment”

Hospodsky et al. 2012 *PLoS ONE* 7(40):e34867

# 2009-present: **Humans** often dominate indoor **bacterial** communities in **homes** (w/ modifications by other factors)

## Diversity, distribution and sources of bacteria in residential kitchens

“**Human skin** was the primary source of bacteria across all kitchen surfaces, with contributions from food and faucet water dominating in a few specific locations”



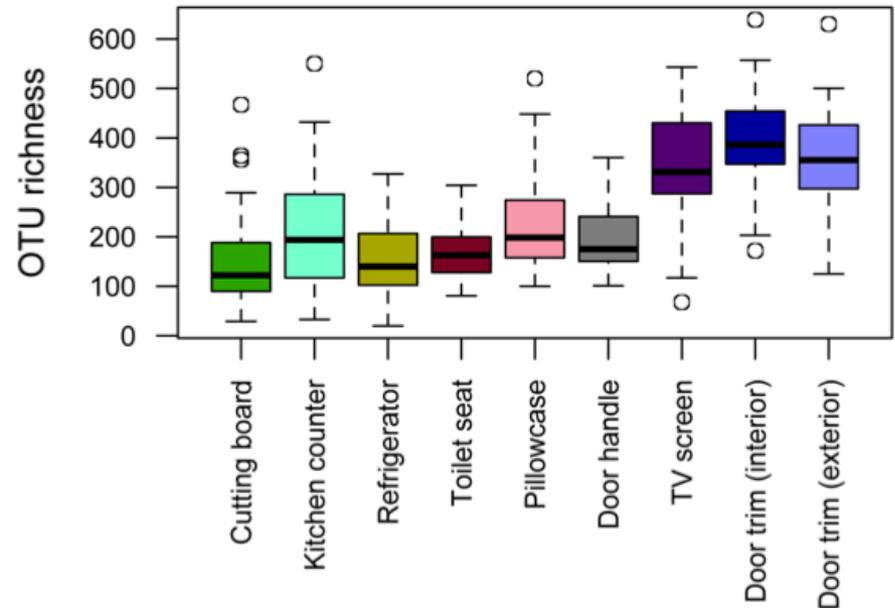
**Skin (palm)**

## Home Life: Factors Structuring the Bacterial Diversity Found within and between Homes

Robert R. Dunn<sup>1,3\*</sup>, Noah Fierer<sup>2,3,3</sup>, Jessica B. Henley<sup>2,3</sup>, Jonathan W. Leff<sup>2,3</sup>, Holly L. Menninger<sup>1,3</sup>

- Specific locations were distinct
- Presence of **dogs** → more diversity
- Correlations between I and O communities

## Bacterial diversity across 40 homes in NC

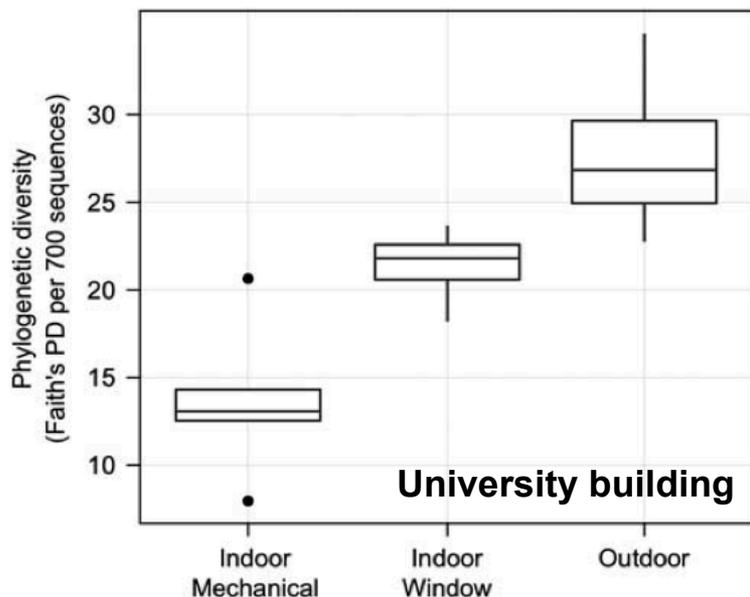


# 2009-present: Building **design** can influence indoor microbial communities

## Architectural design influences the diversity and structure of the built environment microbiome

Steven W Kembel<sup>1</sup>, Evan Jones<sup>1</sup>, Jeff Kline<sup>1,2</sup>, Dale Northcutt<sup>1,2</sup>, Jason Stenson<sup>1,2</sup>, Ann M Womack<sup>1</sup>, Brendan JM Bohannon<sup>1</sup>, G Z Brown<sup>1,2</sup> and Jessica L Green<sup>1,3</sup>

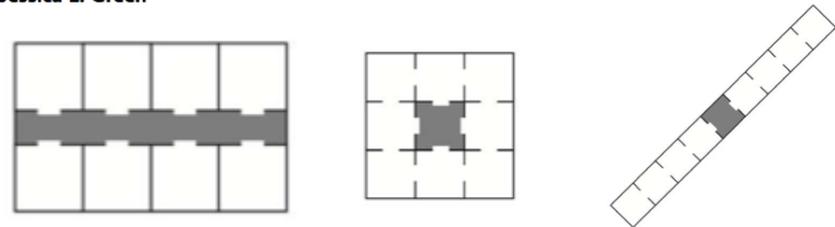
- Bacterial diversity: IA < OA
- Rooms w/ HVAC were less diverse than open window rooms
- **Source of ventilation air** and **T/RH** correlated w/ composition of IA bacteria



Kembel et al. 2012 *ISME J* 6:1469-1479

## Architectural Design Drives the Biogeography of Indoor Bacterial Communities

Steven W. Kembel<sup>1,2,3\*</sup>, James F. Meadow<sup>2,3\*</sup>, Timothy K. O'Connor<sup>2,3,4</sup>, Gwynne Mhuireach<sup>2,5</sup>, Dale Northcutt<sup>2,5</sup>, Jeff Kline<sup>2,5</sup>, Maxwell Moriyama<sup>2,5</sup>, G. Z. Brown<sup>2,5,6</sup>, Brendan J. M. Bohannon<sup>2,3</sup>, Jessica L. Green<sup>2,3,7</sup>



“Spaces with high human occupant diversity and a high degree of **connectedness** to other spaces via ventilation or human movement contained a distinct set of bacterial taxa when compared to spaces with low occupant diversity and low connectedness”

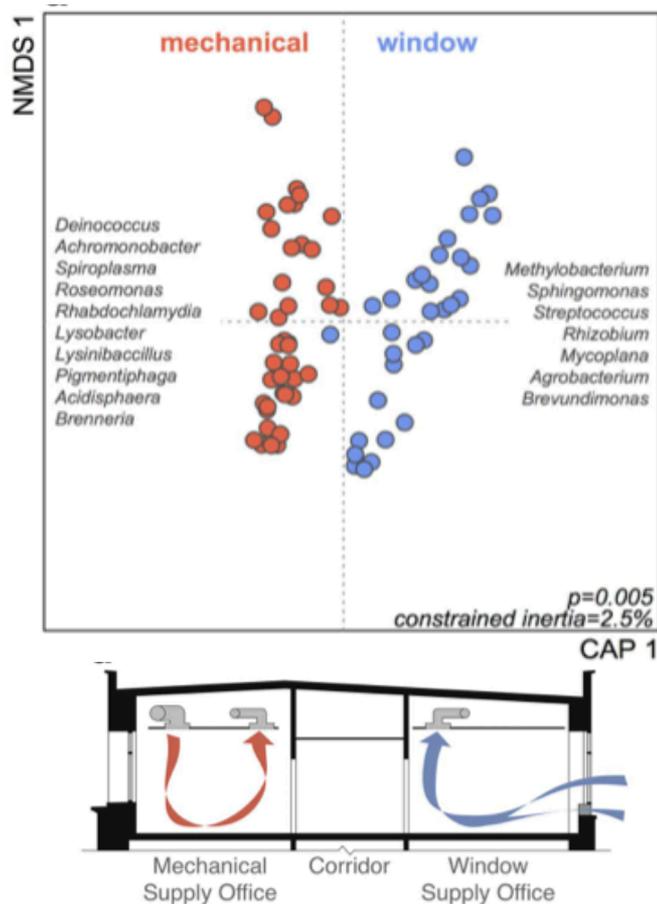
“Within offices, the **source of ventilation air** had the greatest effect on bacterial community structure”

Kembel et al. 2014 *PLoS ONE* 9(1):e87093

# 2009-present: Building **operation** can influence indoor microbial communities

## Architectural Design Drives the Biogeography of Indoor Bacterial Communities

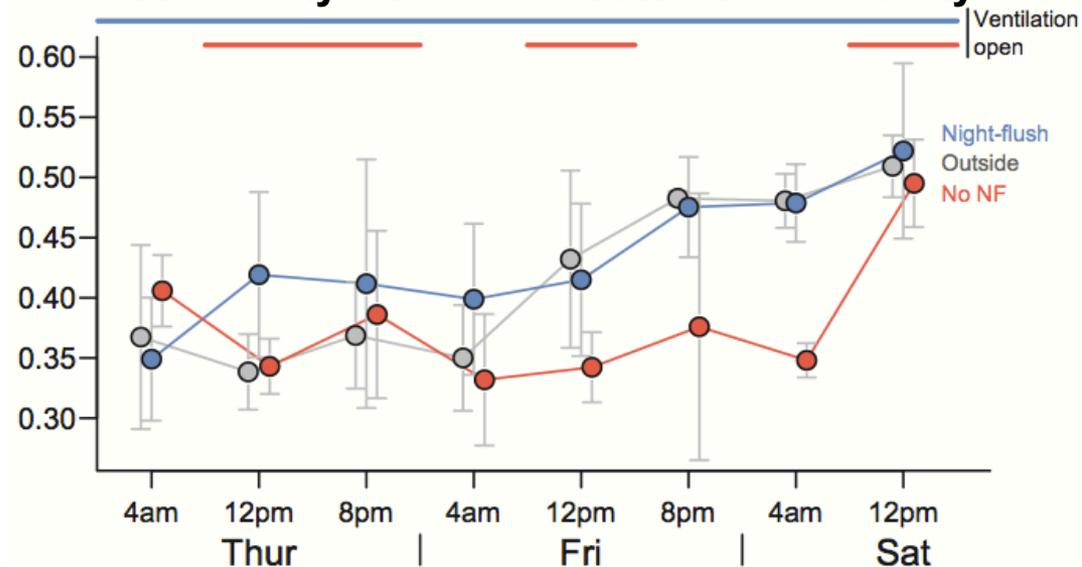
Steven W. Kembel<sup>1,2,3\*</sup>, James F. Meadow<sup>2,3\*</sup>, Timothy K. O'Connor<sup>2,3,4</sup>, Gwynne Mhuireach<sup>2,5</sup>, Dale Northcutt<sup>2,5</sup>, Jeff Kline<sup>2,5</sup>, Maxwell Moriyama<sup>2,5</sup>, G. Z. Brown<sup>2,5,6</sup>, Brendan J. M. Bohannon<sup>2,3</sup>, Jessica L. Green<sup>2,3,7</sup>



Indoor airborne bacterial communities are influenced by ventilation, occupancy, and outdoor air source

- Indoor air communities closely tracked OA
- Human-associated bacterial genera were more than 2x as abundant in IA vs. OA
- **Ventilation** had a demonstrated effect on indoor airborne bacterial community composition (following a time lag)

## Dissimilarity from initial outside community



## 2004-present (through the lens of an architectural engineer)

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- These, and many other, recent studies have greatly increased our knowledge of microbial ecology of the indoor environment
- **But**, the number of studies collecting robust, long-term data using standardized methods to characterize important **building operational characteristics**, **indoor environmental conditions**, and **human occupancy** (i.e., built environment metadata) remains limited
- Insufficiently described **built environment metadata** can limit our ability to compare microbial ecology results from one indoor environment to another or to use the results to assess how best to control indoor microbial communities

# Three main categories of investigations w/r/t buildings

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We identified three general categories based on level of detail in documenting built environment data/metadata:

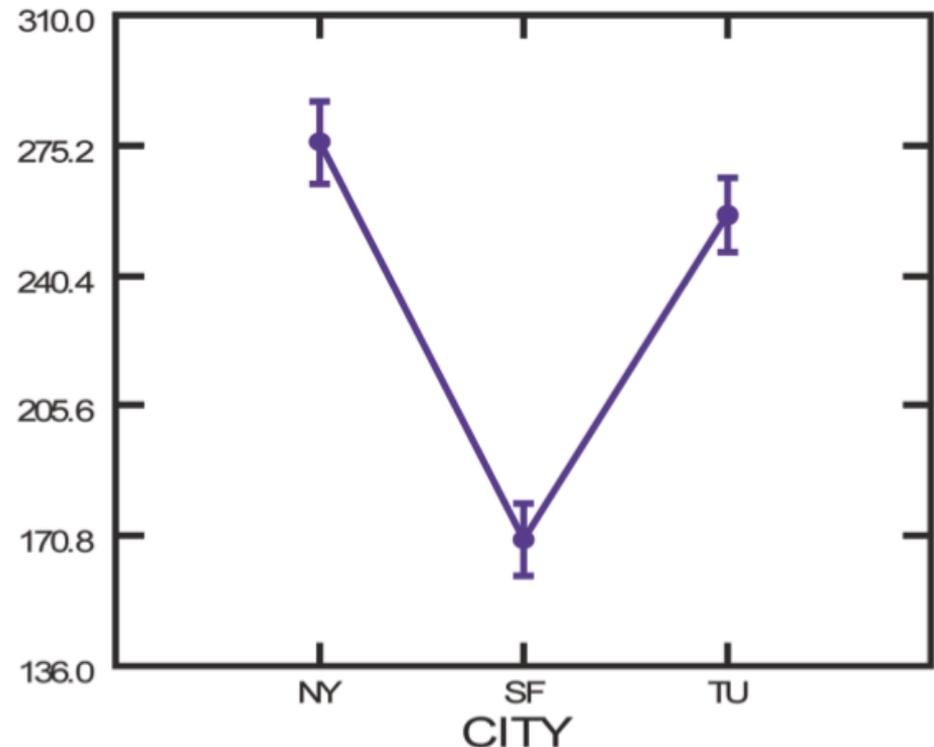
1. Microbial diversity **in the absence of** building characteristics
2. Microbial diversity and **basic** building, HVAC, and/or environmental metadata
3. Microbial diversity and **detailed** characterizations of built environment metadata and/or human occupancy/activities

# 1. Microbial diversity **in the absence** of building characteristics

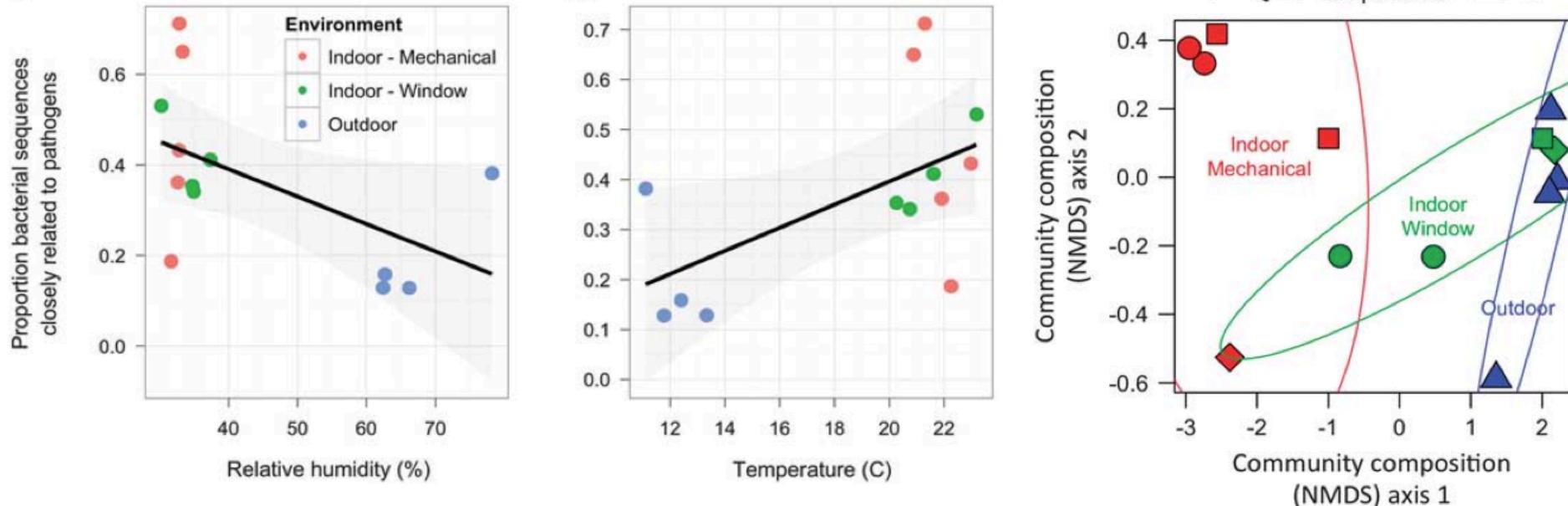
“Bacterial community diversity of the Tucson samples was clearly distinguishable from that of New York and San Francisco, which were indistinguishable”

Interesting, but **why?**

**Bacterial abundance in offices in 3 US cities**



## 2. Microbial diversity and *basic* building, HVAC, and/or environmental metadata



Kembel et al. **2012** *ISME J* 6:1469-1479

Interesting, but factors are correlated

“Bacterial richness tended to be higher in those four (of 11) units that reported at least occasional humidifier use”

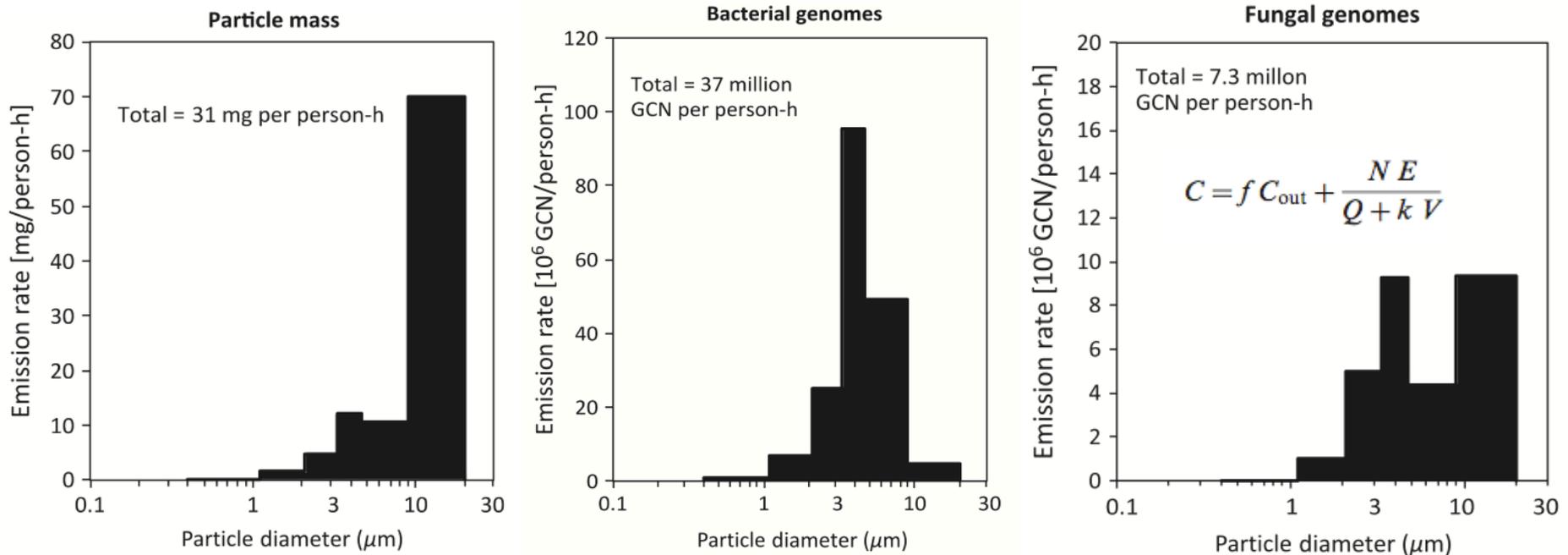
Adams et al. **2014** *PLoS ONE* 9(3):e91283

### 3. Microbial diversity and *detailed* building metadata and/or human activities

Size-resolved emission rates of airborne bacteria and fungi in an occupied classroom

J. Qian<sup>1,2</sup>, D. Hospodsky<sup>1</sup>,  
N. Yamamoto<sup>1,3</sup>, W. W. Nazaroff<sup>4</sup>,  
J. Peccia<sup>1</sup>

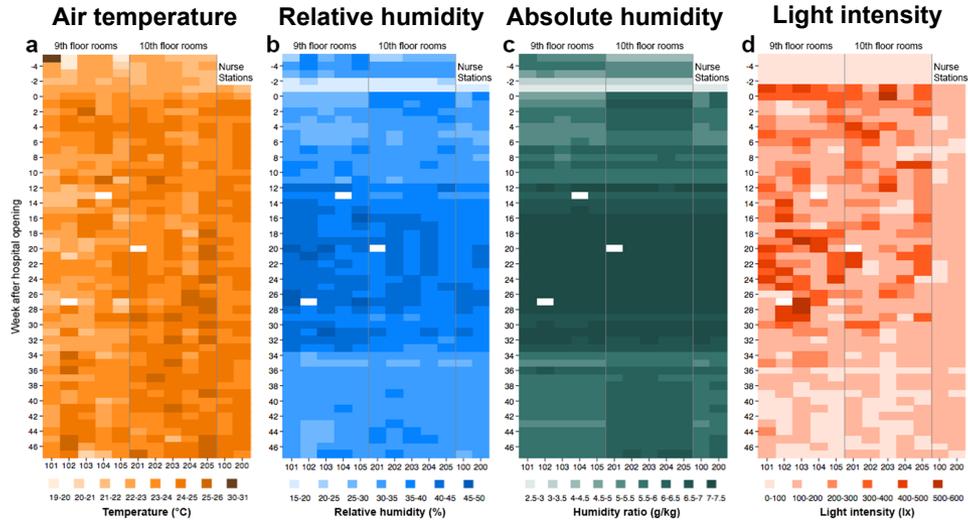
- Detailed characterization of building operation and occupancy allowed for estimating per-occupant emission rates using a mass-balance model... the **power of building characterization**



# **MoBE RESEARCH OPPORTUNITIES AS AN ARCHITECTURAL ENGINEER**

# MoBE research opportunities as an architectural engineer

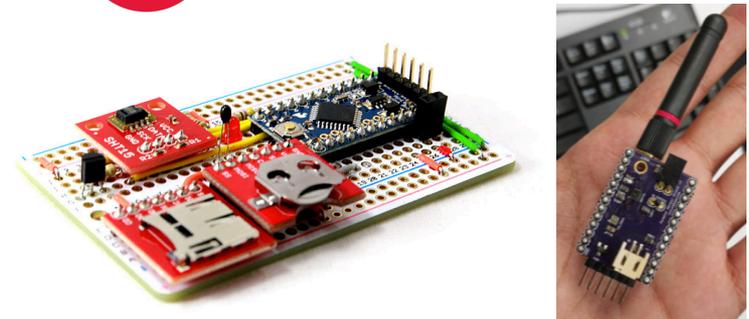
- Lower-cost, high accuracy building data collection



Ramos et al. 2015 *PLoS ONE* 10(3):e0118207  
 Ali et al. 2016 *Build Environ* 100:114-126



**OPEN SOURCE  
BUILDING SCIENCE SENSORS**



## RESEARCH ARTICLE

### Fungal and Bacterial Communities in Indoor Dust Follow Different Environmental Determinants

Fabian Weigl<sup>1\*</sup>, Christina Tischer<sup>2,3</sup>, Alexander J. Probst<sup>4</sup>, Joachim Heinrich<sup>2,5</sup>, Iana Markevych<sup>2,6</sup>, Susanne Jochner<sup>7</sup>, Karin Pritsch<sup>1</sup>

### Indoor fungal communities impacted by:

- Surrounding greenness
- Outdoor PM concentrations
- Age of building
- Window opening behavior

Weigl et al. 2016 *PLoS ONE* DOI:10.1371/journal.pone.0154131

# MoBE research opportunities as an architectural engineer

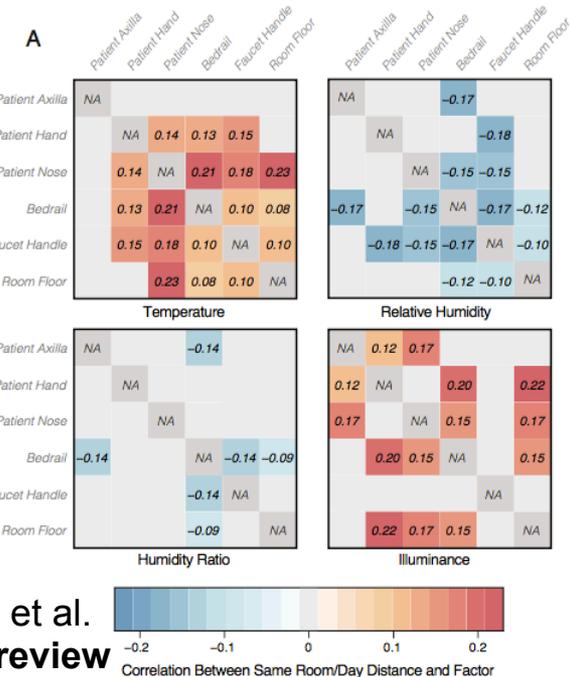
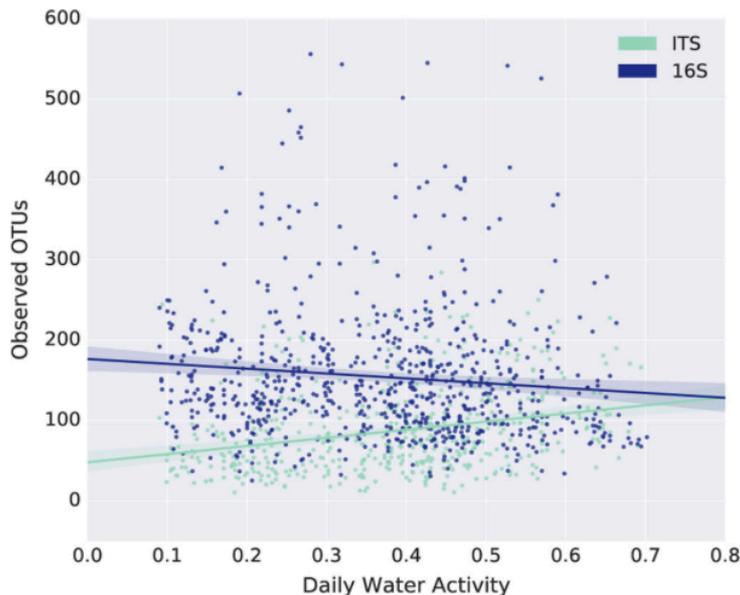
## The Built Environment Is a Microbial Wasteland

Gibbons 2016 *mSystems*



### Geography and Location Are the Primary Drivers of Office Microbiome Composition

Chase et al. 2016 *mSystems*



# MoBE research opportunities as an architectural engineer

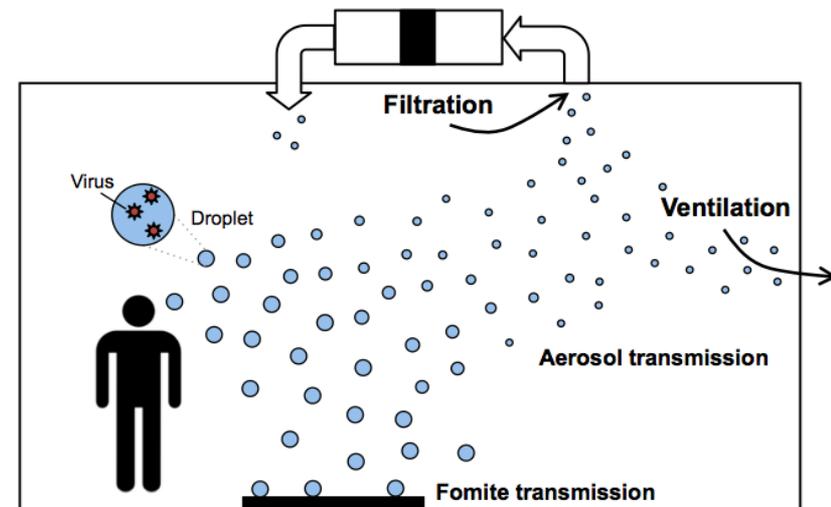
- Improving understanding of physical bioaerosol transport and control mechanisms
  - Increase use and development of quantitative methods and metrics
  - Conduct longitudinal intervention and controlled environment studies that focus on fundamental processes (e.g. emission, survival, alive/dead, activity, fate, transport)
  - Continue to communicate and transfer knowledge between disciplines
  - Broaden the funding base

## Editorial

From commensalism to mutualism: integrating the microbial ecology, building science, and indoor air communities to advance research on the indoor microbiome

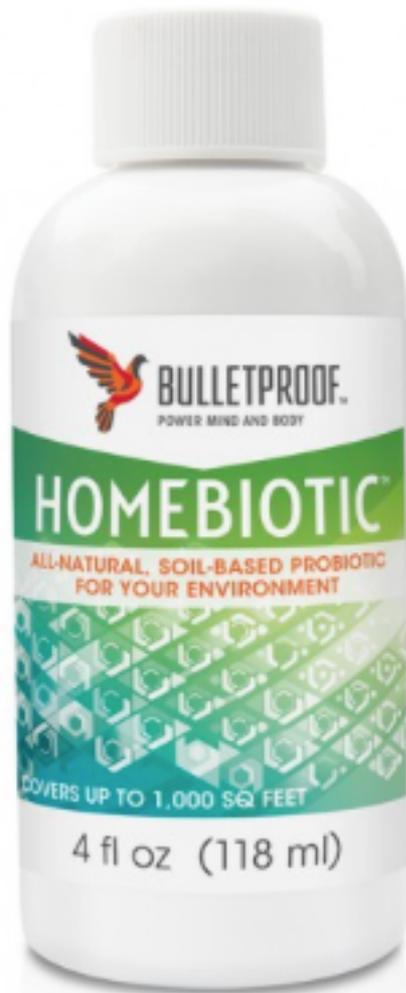
*Brent Stephens, Rachel I Adams, Seema Bhangar,  
Kyle Bibby, Michael S Waring*

Stephens et al. 2015 *Indoor Air* 25(1):1-3



# MoBE research opportunities as an architectural engineer

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# **SOME POINTERS ON GRANT WRITING AND EARLY CAREER FACULTY SUCCESS**

# 1. Have confidence in yourself!

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**Jeff Terry** @nuclear94 · 21 Jul 2013

Best advice to all junior faculty is to realize that you are very good at what you do and remember that always. @mutualism @built\_envi



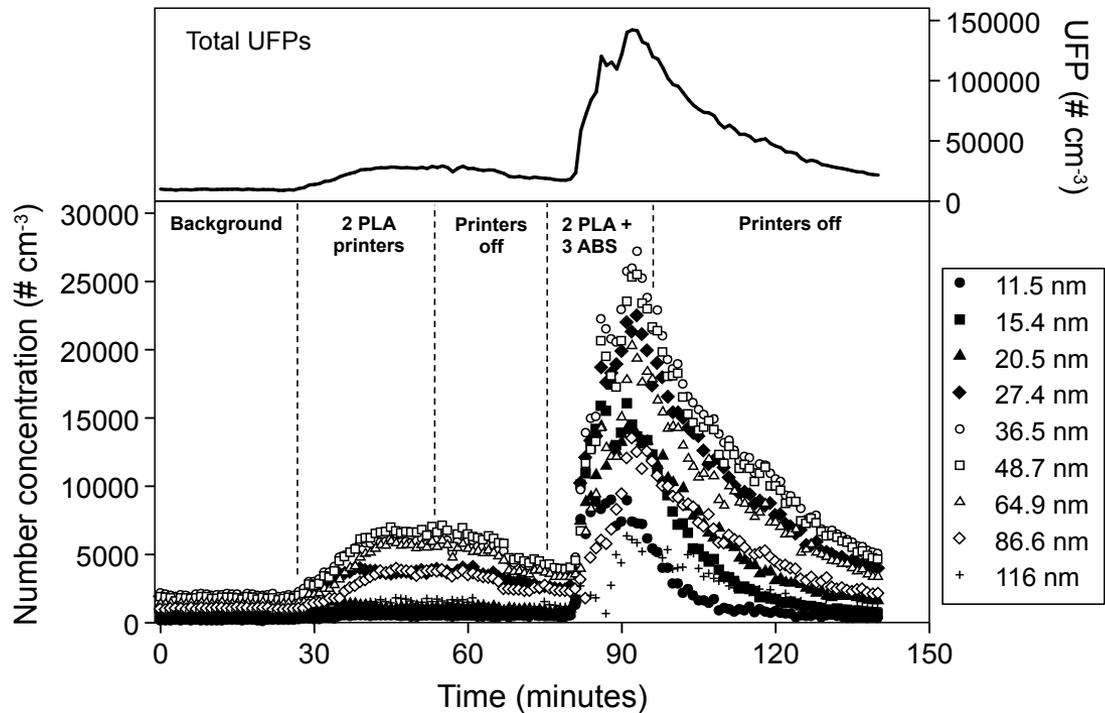
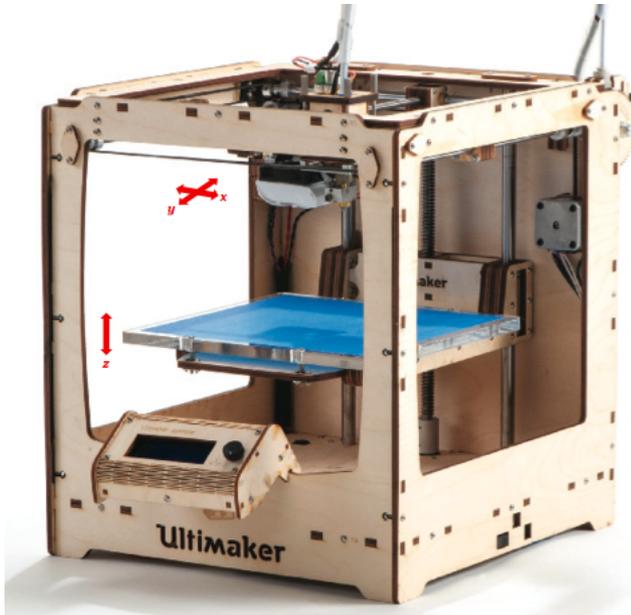
**BuiltEnvironment IIT** @built\_envi · 21 Jul 2013

@nuclear94 thanks Jeff -- I don't think we've met but perhaps we should!



# 2. Have confidence in your work!

Stephens et al. 2013 *Atmos Environ* 79:334-339



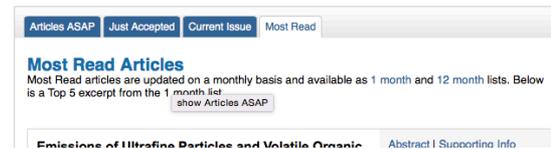
## Most Downloaded Articles

The most downloaded articles from Atmospheric Environment in the last 90 days.

[Ultrafine particle emissions from desktop 3D](#)

## Actual NIOSH proposal review:

- The PI could also use a mentor to improve the grantmanship of the proposal. The impact of the preliminary data (i.e., that the publication broke the record for most downloads for that journal) was buried in the biosketch.



[View All Articles](#)

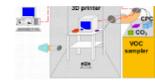


Figure 1 of 7

### 3. Get used to failure (well, sort of)

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Also realize that sometimes there are simply lost causes

Don't waste your time!

Status

Pending

Declined

Declined

Declined

Declined

Declined

Declined

Declined

Declined

Make reasonable assumptions for proposal success rates

Example: ~30% of proposals won and ~18% of total \$ sought won

## 4. Be selfish with your time

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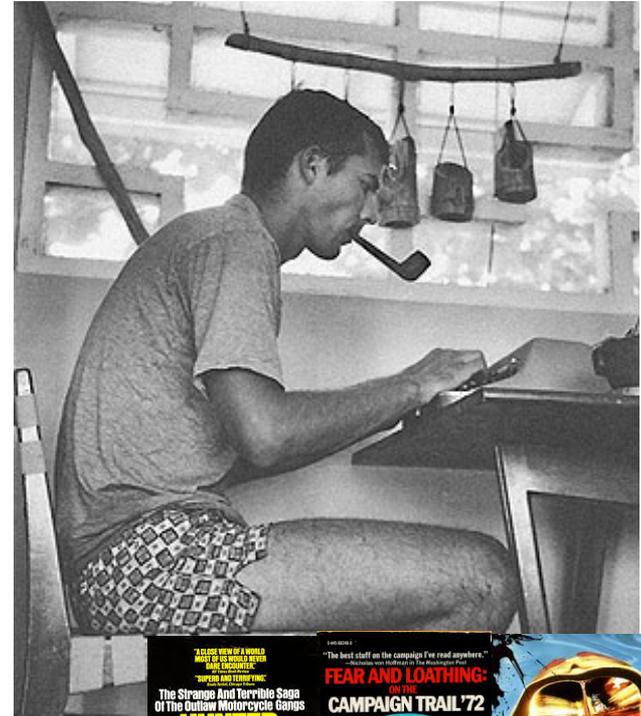
- Minimize (or optimize) excess teaching duties, advising commitments, and committee service
  - Make sure your department will protect you
- Teaching is like a gas – it expands to fill the volume you give it!
- Limit your courses – try to teach repeated courses as much as possible, particularly early on
- Minimize meetings for the sake of meeting

## 5. Learn to write well (and fast)

- Writing starts with reading

When Hunter S. Thompson was 21 years old, he “used a typewriter to copy F. Scott Fitzgerald's *The Great Gatsby* and Ernest Hemingway's *A Farewell to Arms* in order to learn about the writing styles of the authors”

- Find your most effective writing time (of day) and preserve it!



## 6. Develop short-term plans and stick to them

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Annual and 5-year plans:

- Publication plans
- Funding plans

**Publication plan**  
Brent Stephens  
Aug 2015 Update

**Goals**

Near-term goal: 12 total submitted by Fall 2014 (completed)

- **Update: 18 published, 2 under review, and 5 in preparation for current year**

Long-term goal: 20 articles published by Fall 2016

And periodically check in on them

- Hold “annual reviews” with yourself
  - *Can you fire yourself?*

# A few last thoughts

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- Collaborate!
- Be open to new ideas and relationships
- Celebrate wins and don't dwell on losses
- Contextualize your worry and fears
- Have fun

## **The Awesomest 7-Year Postdoc or: How I Learned to Stop Worrying and Love the Tenure- Track Faculty Life**

- I decided that this is a 7-year postdoc.
- I stopped taking advice.
- I created a "feelgood" email folder.
- I work fixed hours and in fixed amounts.
- I try to be the best "whole" person I can.
- I found real friends.
- I have fun "now".



email: [brent@iit.edu](mailto:brent@iit.edu)  
web: [www.built-envi.com](http://www.built-envi.com)