HUMANS AND MICROBIOLOGY OF THE BUILT ENVIRONMENT

UO-CHC 441H/431H: Microbes + Social Equity

Lecture 10

Dr. Sue Ishaq Pellegrini

Learning objectives

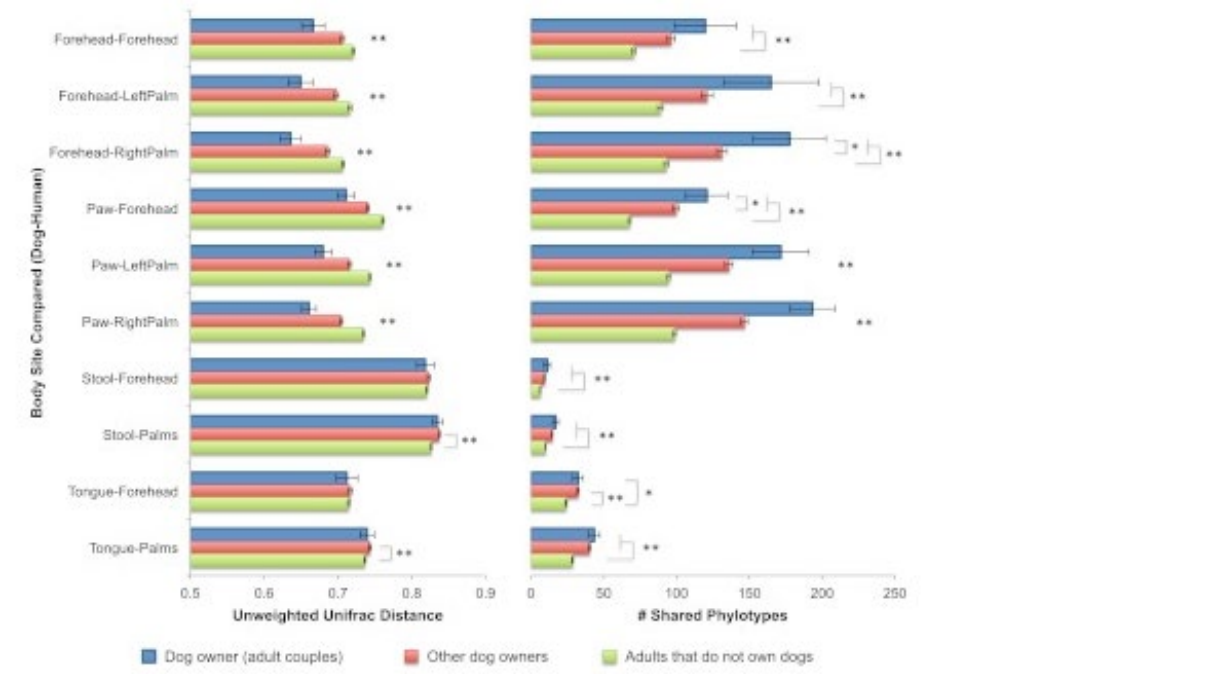
- General intro into the microbial sources for the built environment
- Ventilation, microbes in indoor air, sick building syndrome
- Water sources of microbial exposure
- Microbes in public spaces, enforced occupancy
- **Discussion:** public spaces and enforced occupancy

MICROBIAL COMMUNITIES IN THE BUILT ENVIRONMENT

A brief review of current knowledge

Major Driver: The Built Biome Reflects Us

- Microbial community specific to family, moved with the family
  - *(Dunn et al., 2013; Lax et al. 2014)*
- Family members share microbes with each other and with their dog
  - *(Song et al. 2013)*



Community similarity and phylotype sharing between dogs-owners and their dogs.

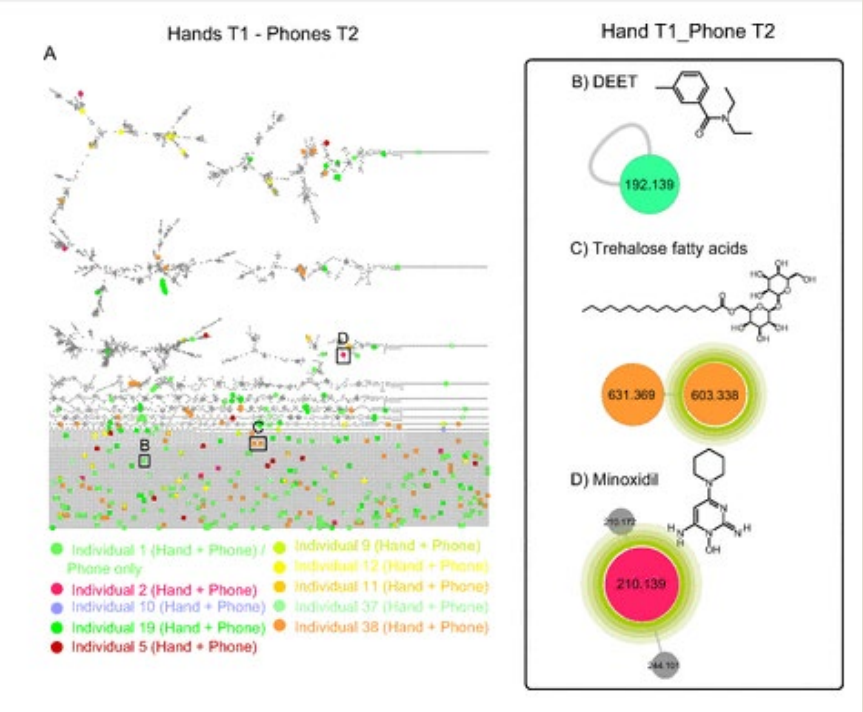
Your personal microbial cloud

- "Personal microbiome cloud"
  - *(Meadow et al. 2015), BioBE center*

Major Driver: The Built Biome Reflects Us

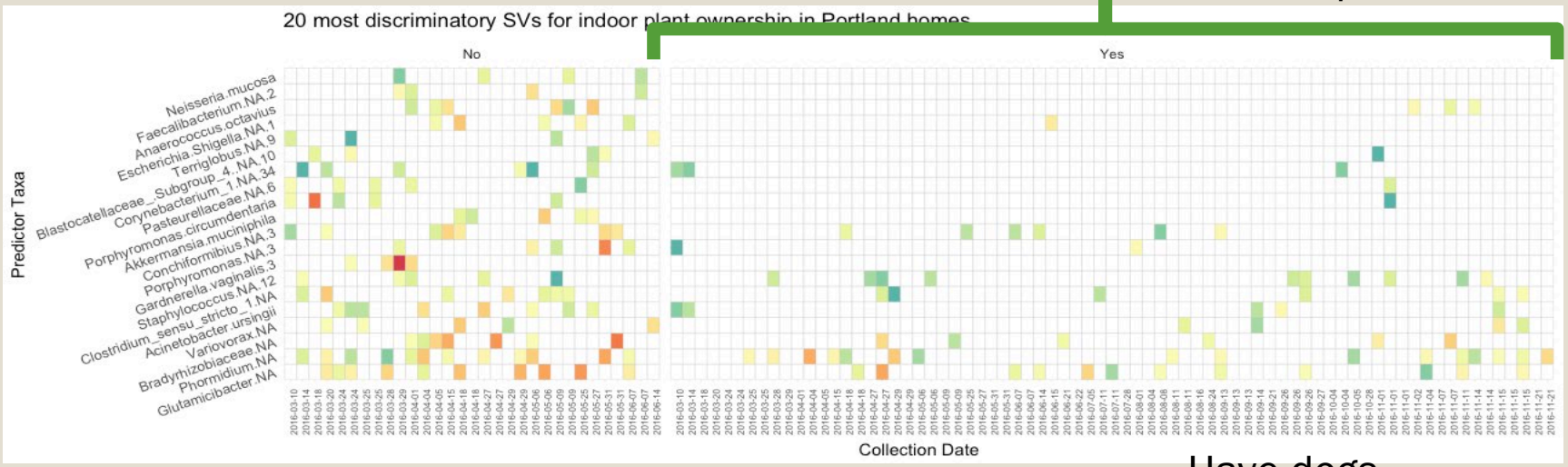
- Metabolome Fingerprint
  - *Could match phones to users 4 months later*
  - *(Bouslimani et al. 2016); similar work by Knight Lab and collaborators*

- We are feeding microbes with the chemical residues we leave behind

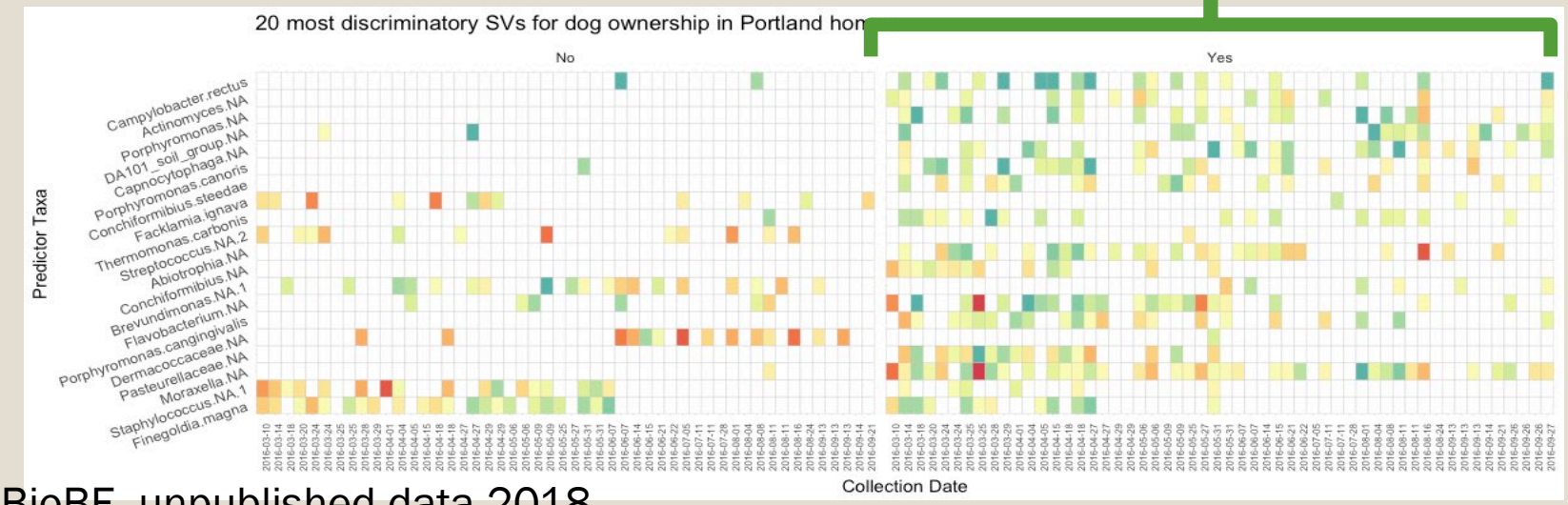


Other biotic sources indoors

Have indoor plants



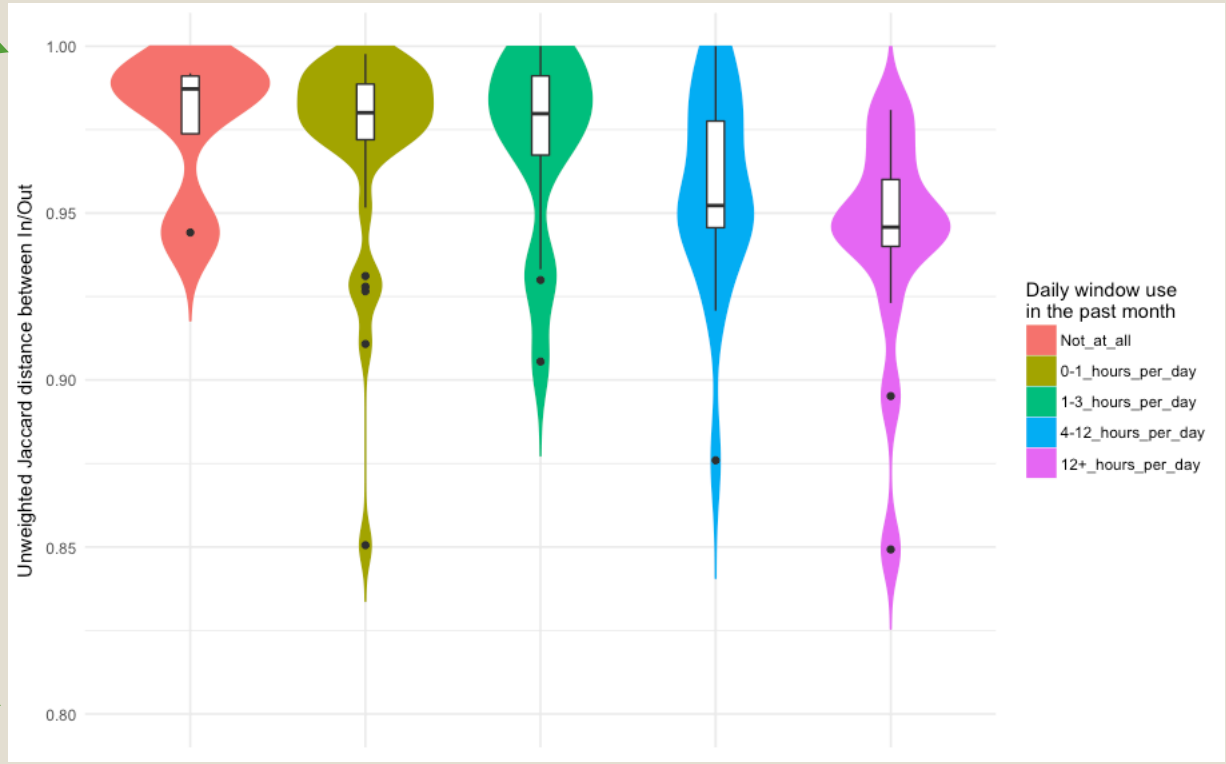
Have dogs



BioBE, unpublished data 2018

Windows vs. humans

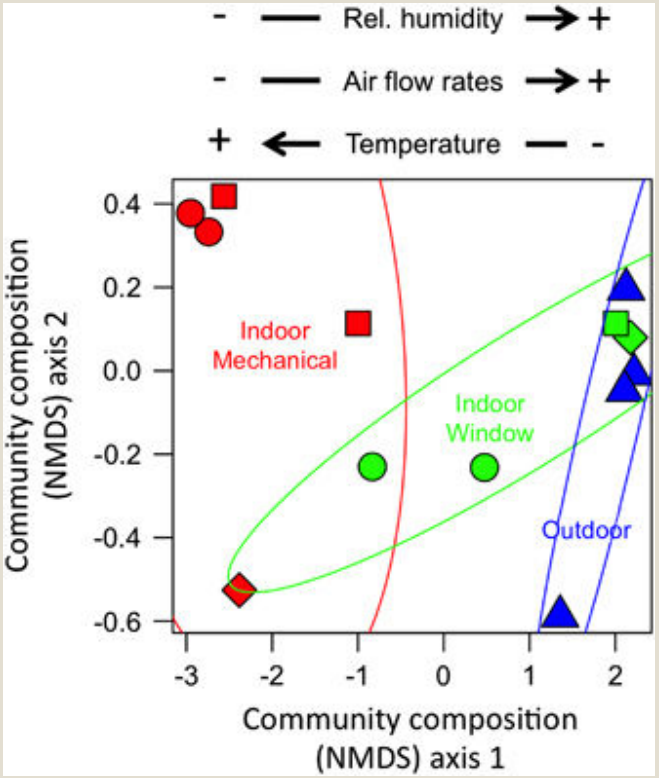
Indoor bacteria ≠ outdoor bacteria



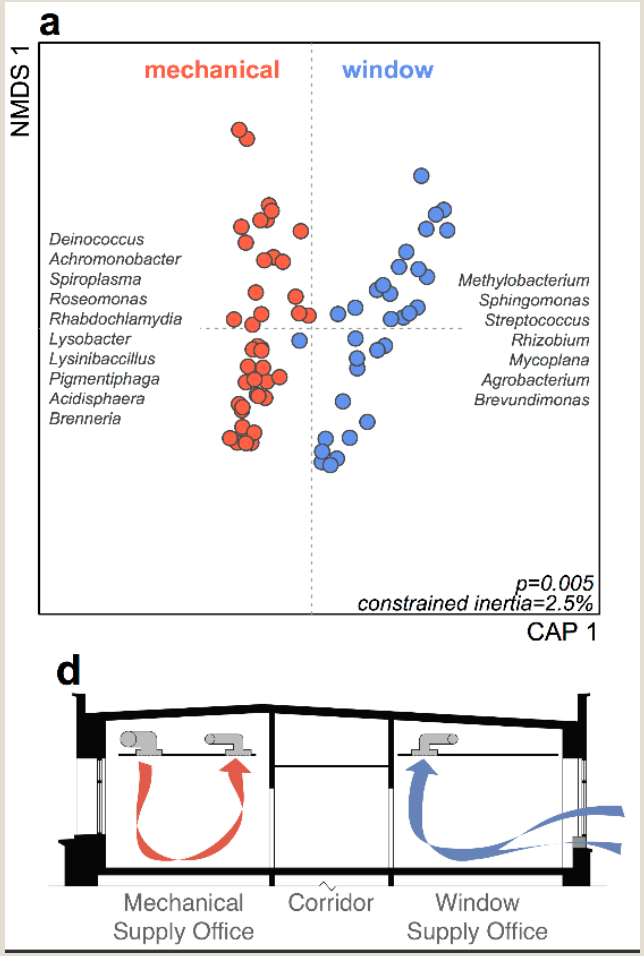
Indoor bacteria similar to outdoor bacteria

BioBE, unpublished data 2018

Major driver: Outdoor air and human occupants



Kembel et al. 2012

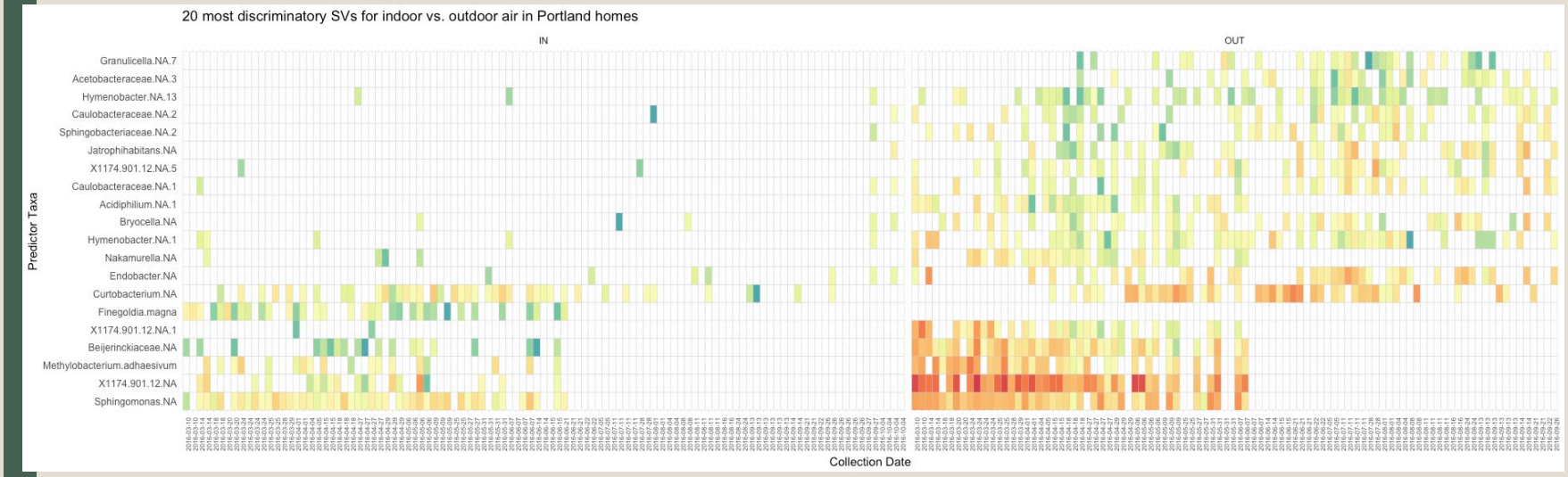


Kembel et al. 2014

Indoor air and outdoor air and host different microbial communities

Inside residential homes

Outside those residential homes



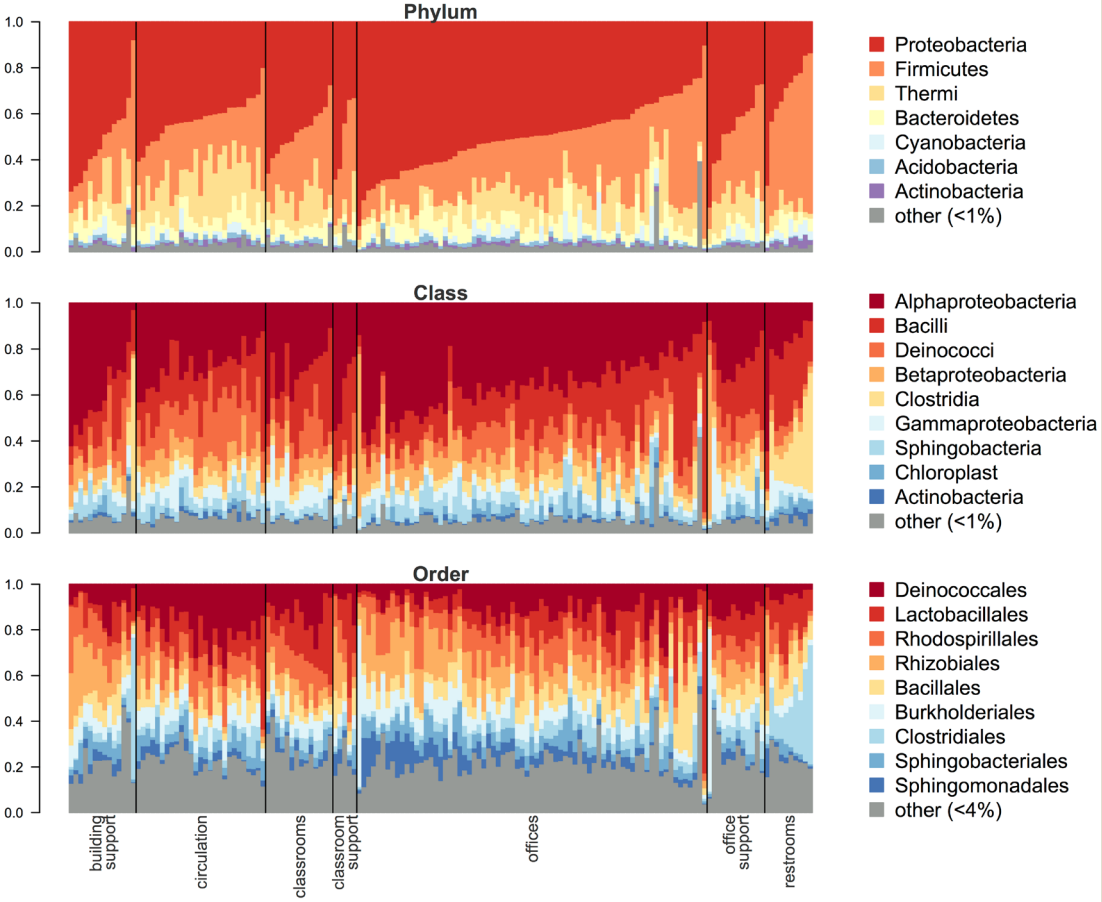
Colored block = bacteria was present. Green = low abundance and red = relatively more abundant

BioBE, unpublished data 2018

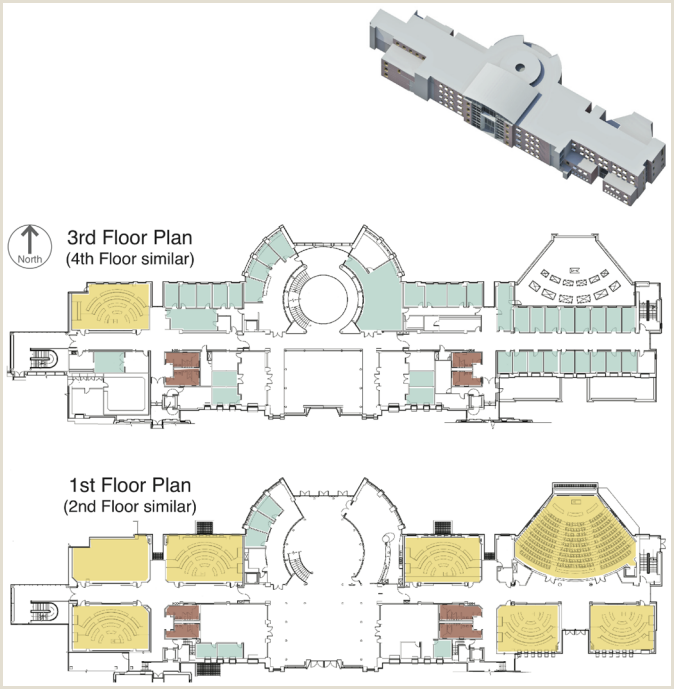
Different rooms host different microbial communities depending on use

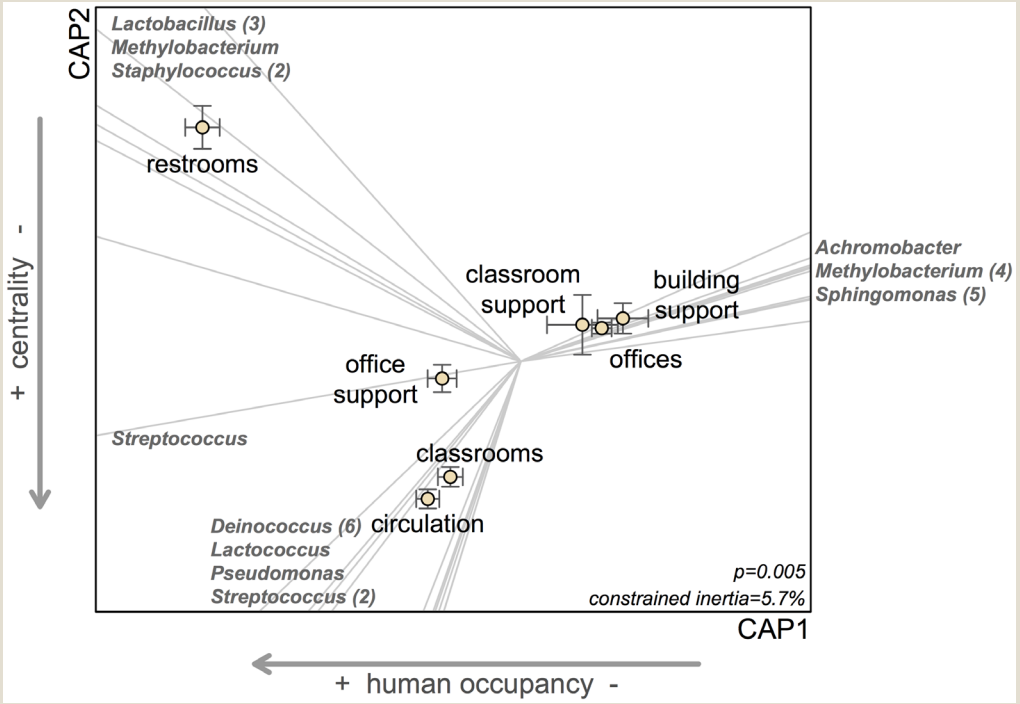
- Creates different ecosystems!
  - *Ventilation*
  - *Temperature*
  - *Humidity*
  - *Occupancy*
  - *Surface materials*

(Rintala et al. 2008; Kembel et al. 2012, 2014)



Lillis Hall, Eugene

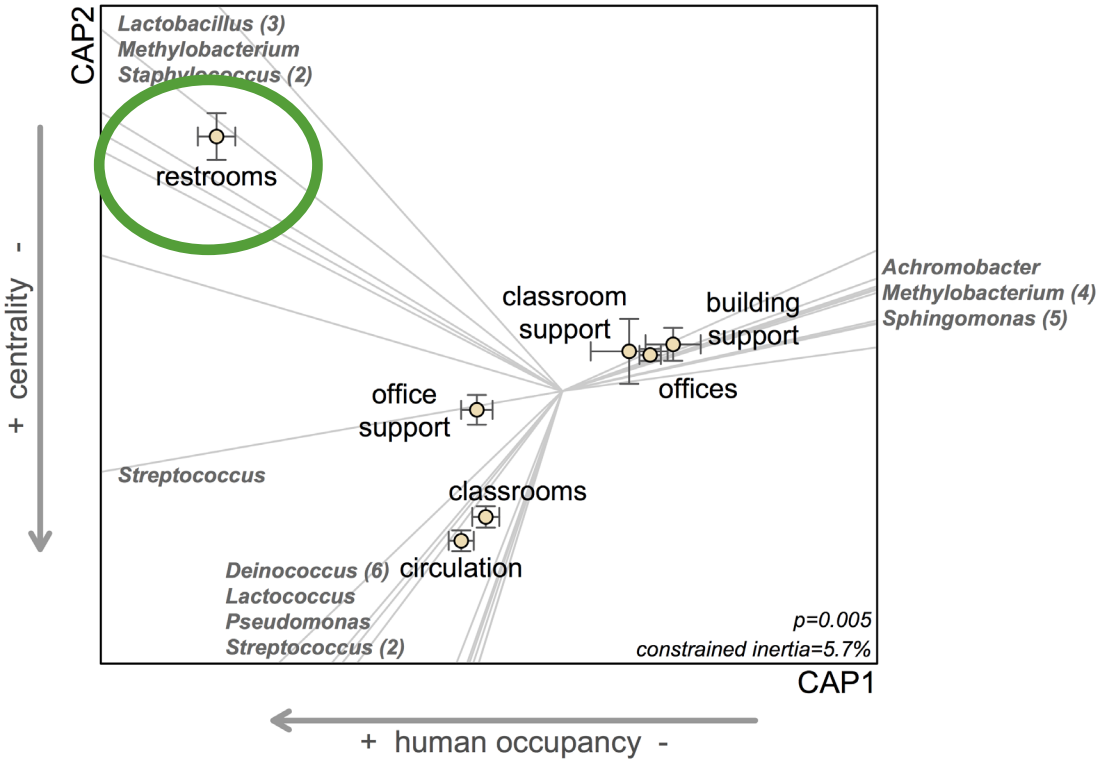




Kembel et al. 2014

Restrooms are consistently different from other spaces

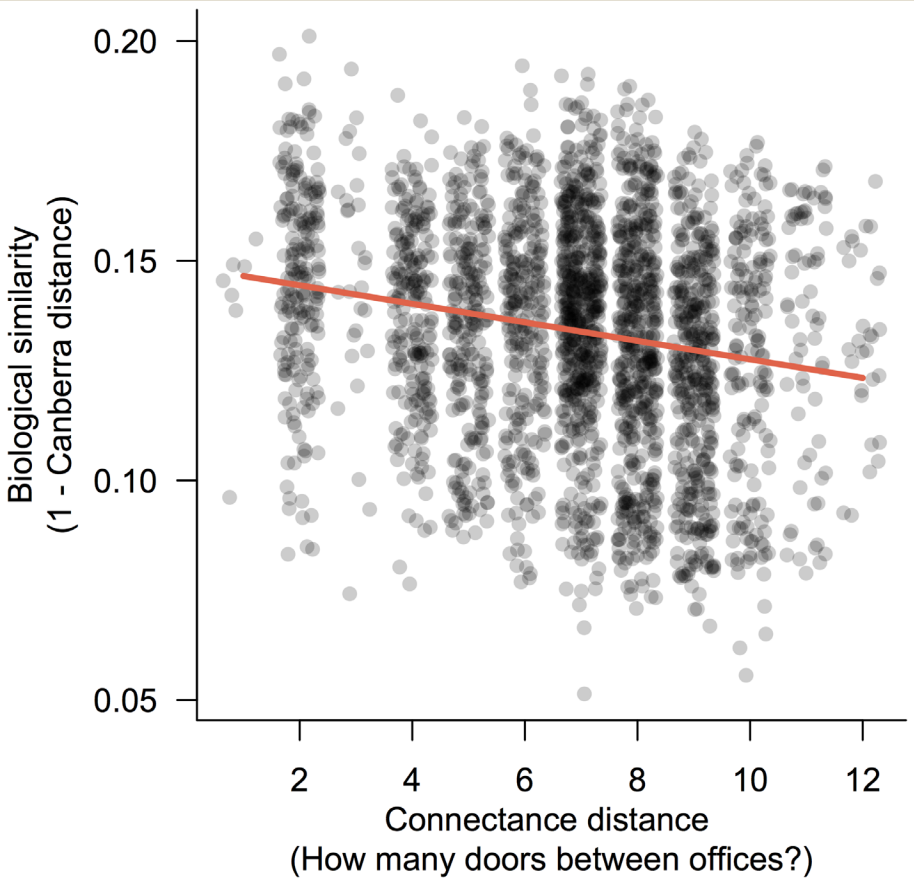
- Humidity
  - Standing water
  - High-velocity water/air dispersal
  - Potentially more nutritional resources than a hallway… think about it



Kembel et al. 2014

Can we just worry about bathrooms?

- Microbial dispersal
  - *Ventilation*
  - *Us*

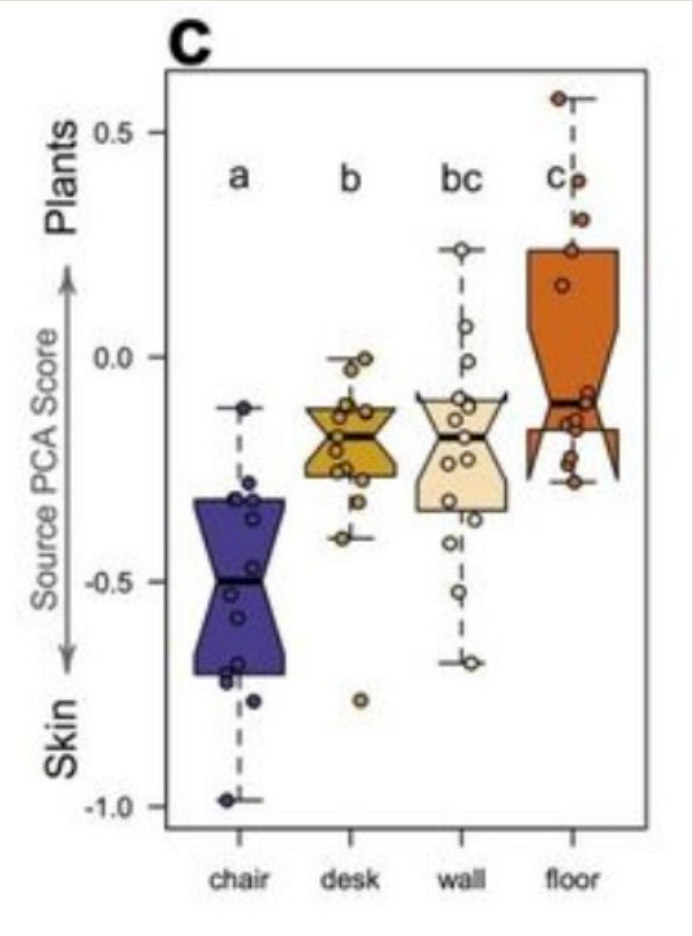


Kembel et al. 2014

Different surfaces host different communities depending on use

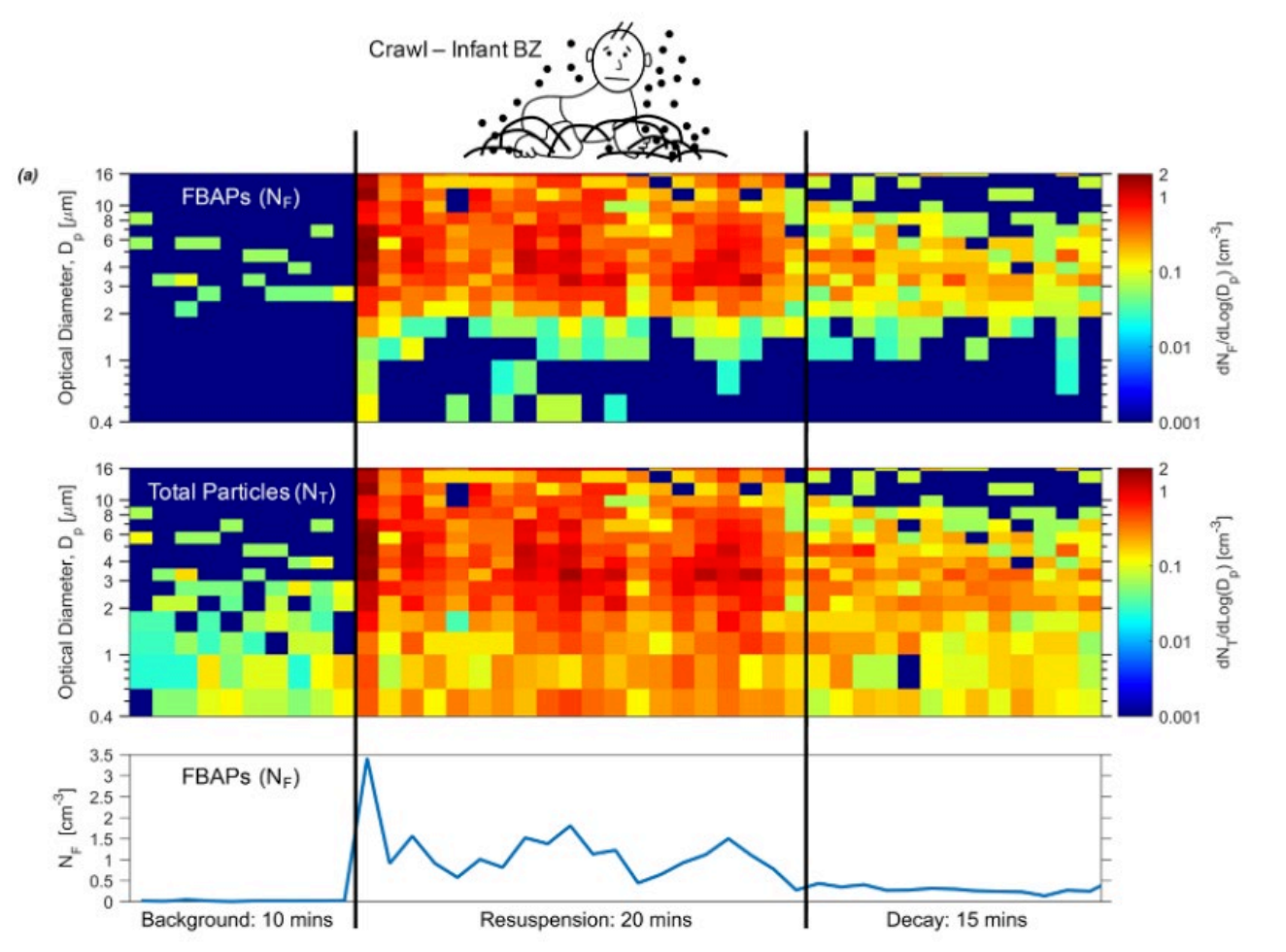
- Surface material type
  - *Carpets collect more than tile*
- Use patterns
- Points of contact

- Can assess whether surface microbial communities are human-associated or outdoor/plant-associated



Meadow et al. 2014

Resuspension from walking on carpet



Wu et al. 2018

“A simplified mechanical crawling infant…”

Wu et al. 2018, Hyytiäinen et al. 2018

Microbes in schools

- Chemicals, microbes, particulate matter (<10 µm)
  - *symptoms and physical damage*
    - EPA, Joshi 2008

- High concentrations of fungi and bacteria in indoor air
  - *40 – 50 year old primary schools*
    - (Borgo and Mostafavi, ACNAS 2007; Sturmer and Case, AEM 2016)
  - *University library in Ethiopia (Hayleeyesus and Manaye, 2014):*
    - *Bacteria: Micrococcus* sp., *Staphylococcus aureus*, *Streptococcus pyogenes*, *Bacillus* sp. and *Neisseria* sp.
    - Fungi: *Cladosporium* sp., *Alternaria* sp., *Penicillium* sp. and *Aspergillus* sp.

Indoor microbiome and health?

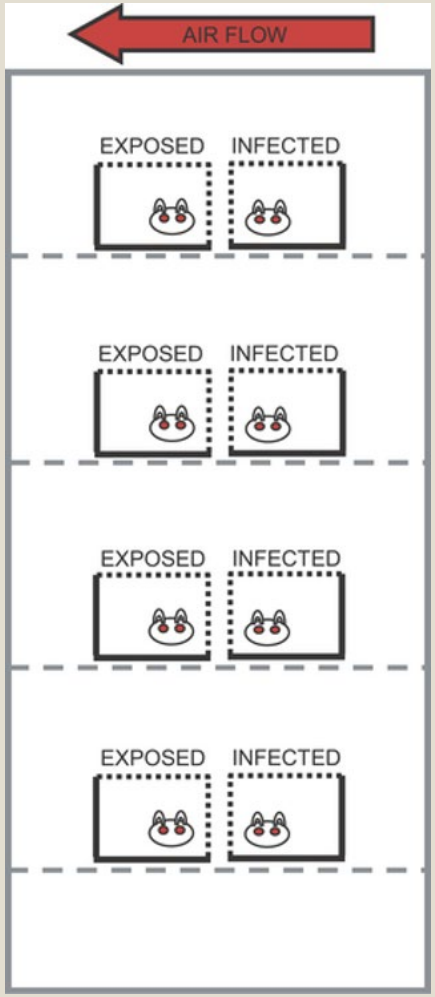
- There are demonstrated building-sourced infections based on certain pathogens

- As far as the whole community…we have no idea what is “good” or “bad”
  - *Total cell biomass*
  - *Species diversity*
  - *The presence or absence of “outdoor associated microbes”*
  - *Seasonal changes in the indoor microbiome or stability over time*

  - *Does ”good” or “bad” change if you are talking about immune-compromised or healthy individuals?*
  - *Age?*

THE INDOOR ENVIRONMENT CAN AFFECT MICROBIAL VIABILITY AND OCCUPANT SUSCEPTIBILITY

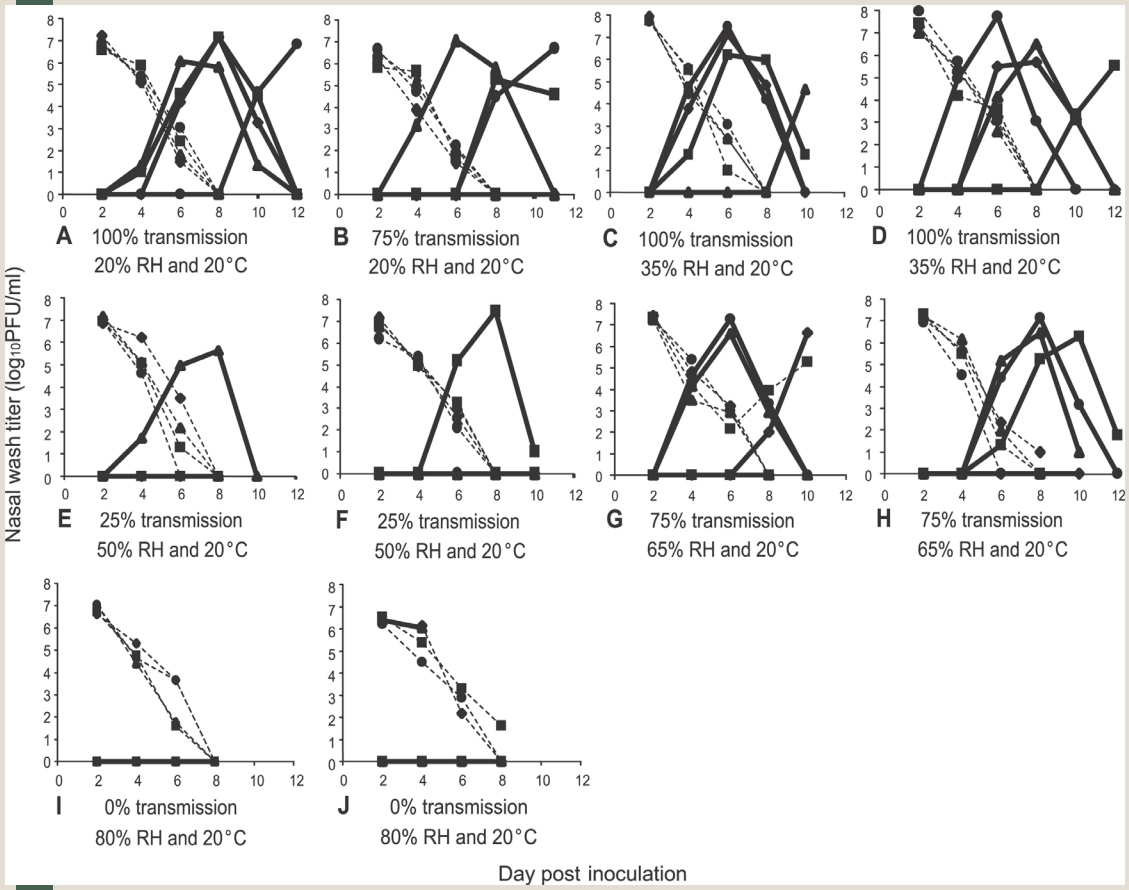
Humidity affects the ability of influenza virus to transmit



- Guinea pigs with influenza (infected) were housed upwind of healthy guinea pigs (exposed)
- Airflow moved from infected cage to the exposed cage
- Altered relative humidity in the cages: RHs (20%, 35%, 50%, 65%, and 80%)

Lowen et al. 2007

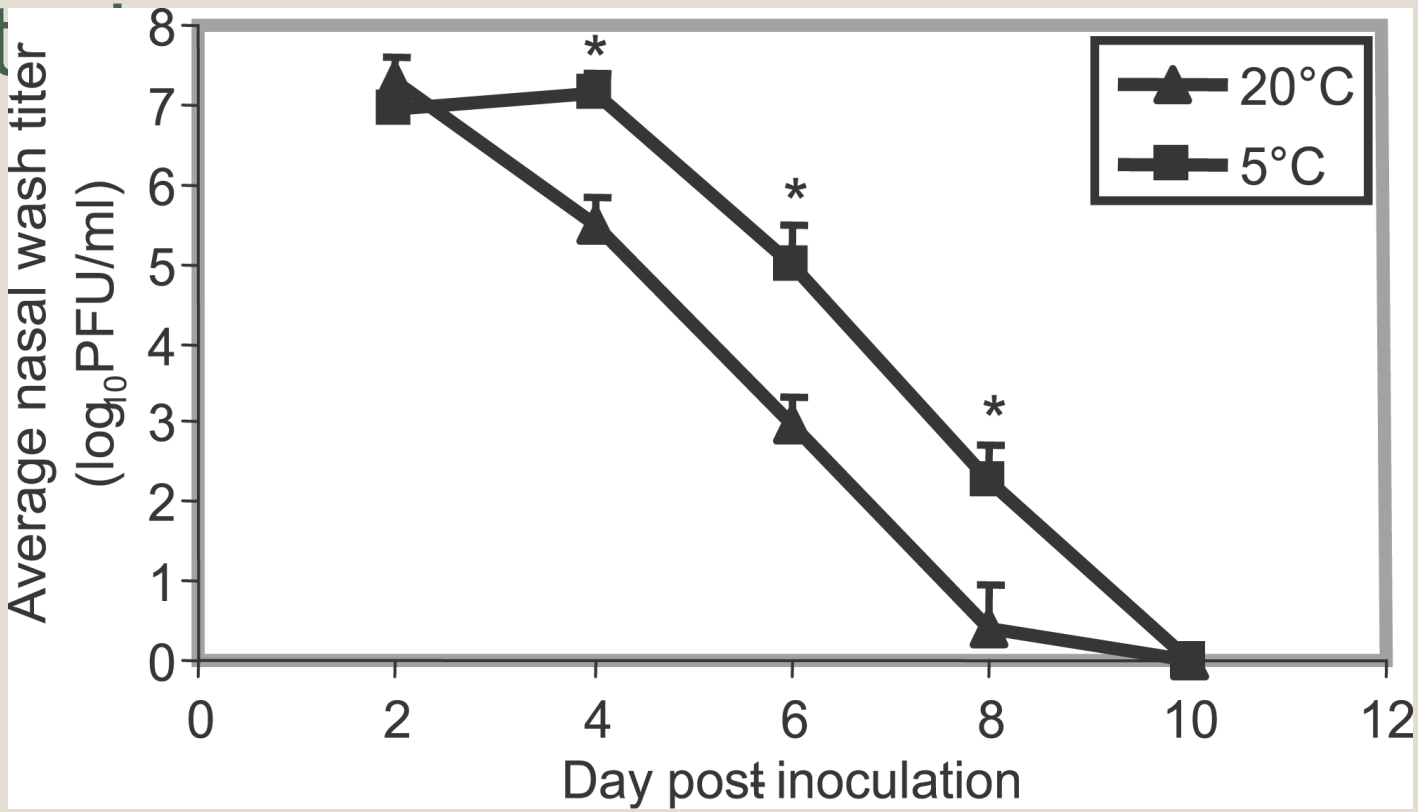
Humidity affects the ability of influenza virus to transmit



- Low humidity (20%, very dry) transmitted influenza to 100% of the exposed guinea pigs
- High humidity (80%) transmitted influenza to 0 guinea pigs
- Indoor RH is usually 40-60% but can get down to 20% in dry areas or in the winter!!!

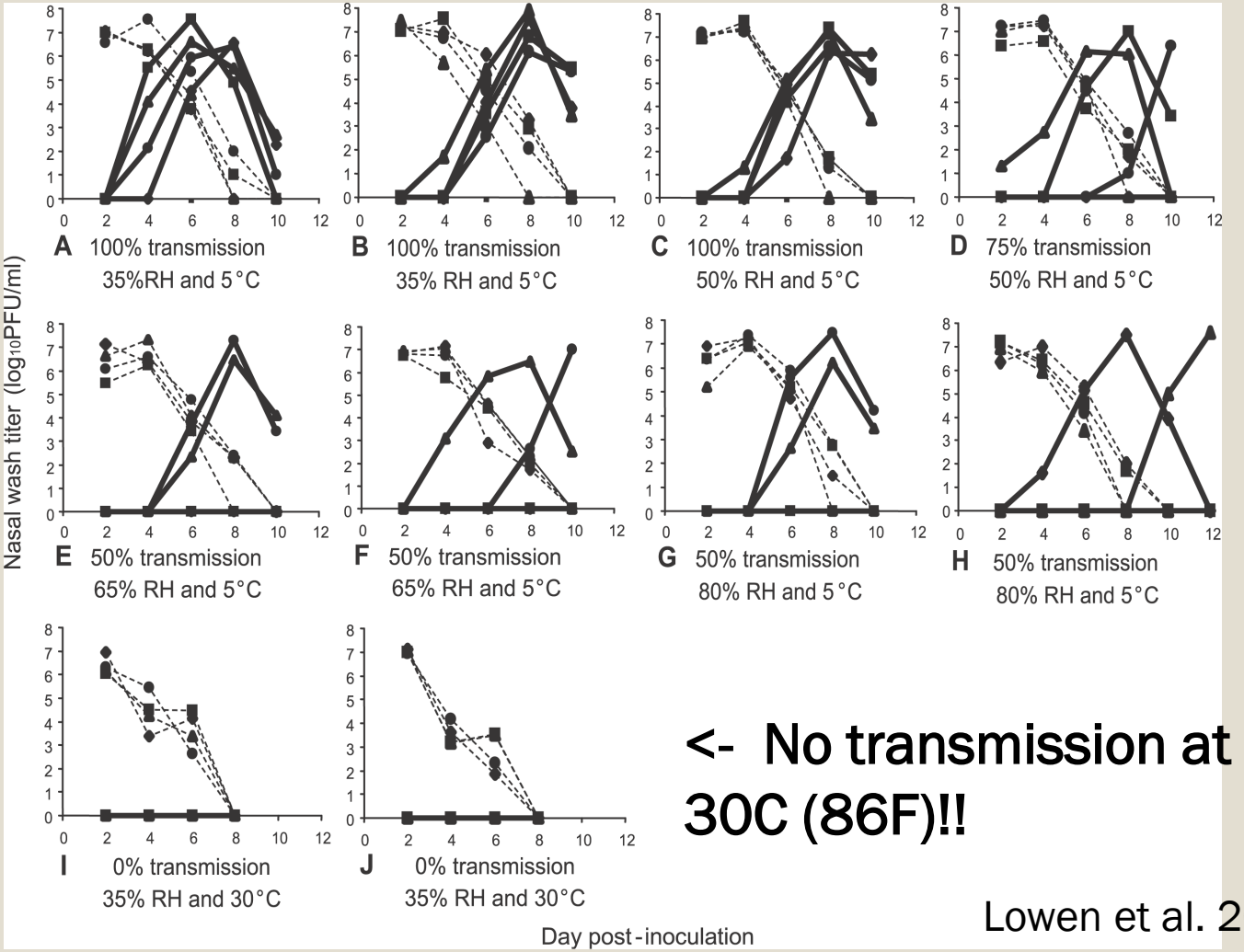
Lowen et al. 2007

Temperature had no effect of innate immune system, but did affect how many virions you emitt



Lowen et al. 2007

More virions emitted meant more transmission in cold air (5C)



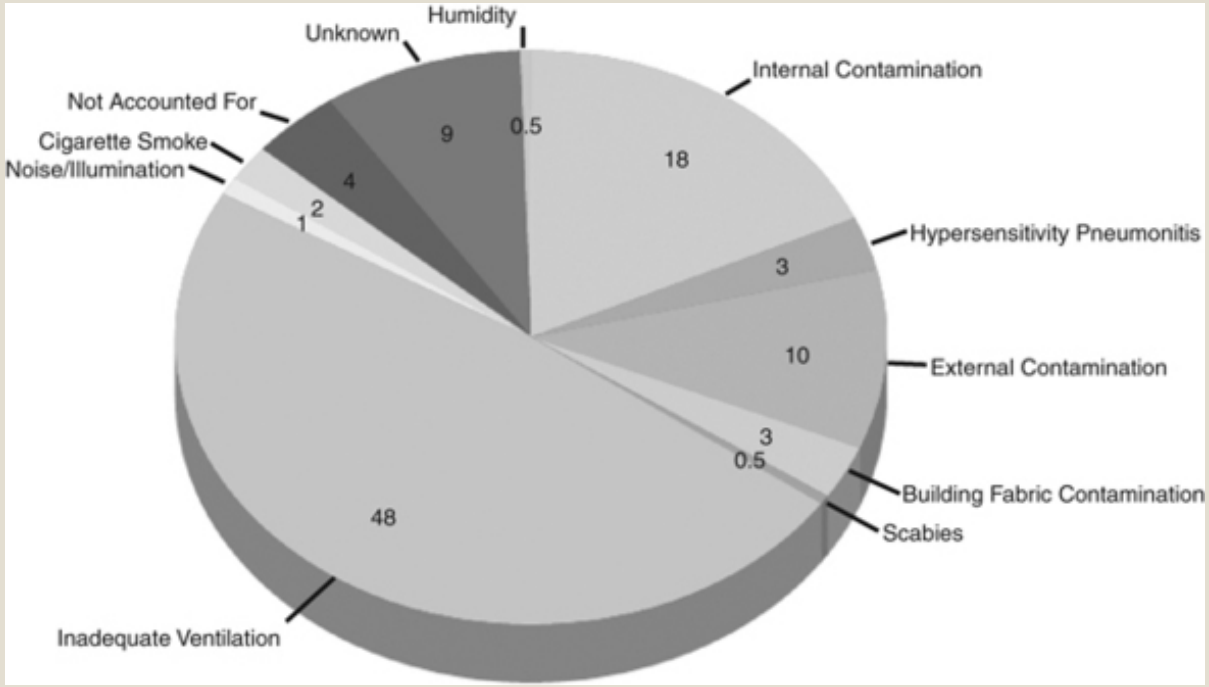
<- No transmission at 30C (86F)!!

Lowen et al. 2007

SICK BUILDING SYNDROME AND RESPIRATORY HEALTH

“Sick Building Syndrome”

- Volatile organic chemicals
- Microbes
  - *mVOCs*
  - *Antigens*
  - *Allergens*
- Heavy metals



Passarelli 2009

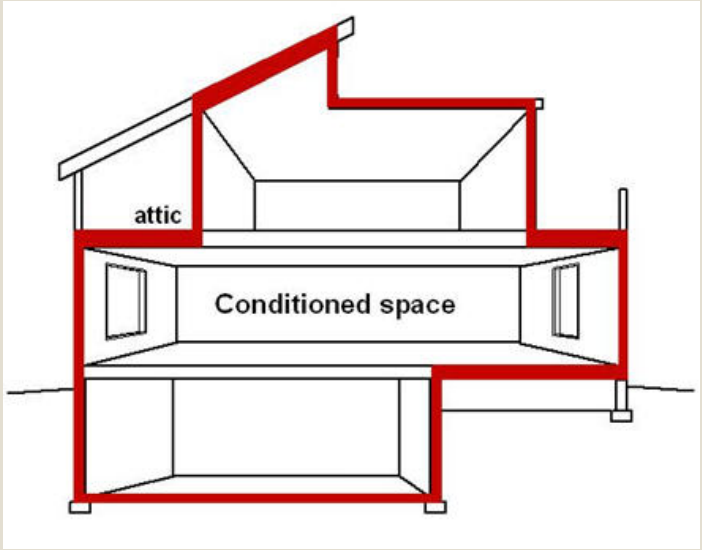
Sick Building Symptoms

(Rostron 1998):

- Mucus Membrane Irritation
  - *Congestion, sneezing, throat irritation, dry cough, thirst, dry eyes*
- Neuropsychiatric disturbances
  - *Fatigue, headache, confusion, dizziness*
- Skin disorders
  - *Itchiness, dryness, rash*
- Asthma-like symptoms
  - *Tight chest, difficulty breathing, wheeze*
- Unpleasant odor and taste
  - *nausea*

Building envelope dictates how connected the indoors is to the outdoors

- Important for energy efficiency
- Encourages entrapment of VOCs and other gases
  - *Improper ventilation*
  - *If ventilation requires energy, low-income occupants might not use it*



Silverman Construction Program Management

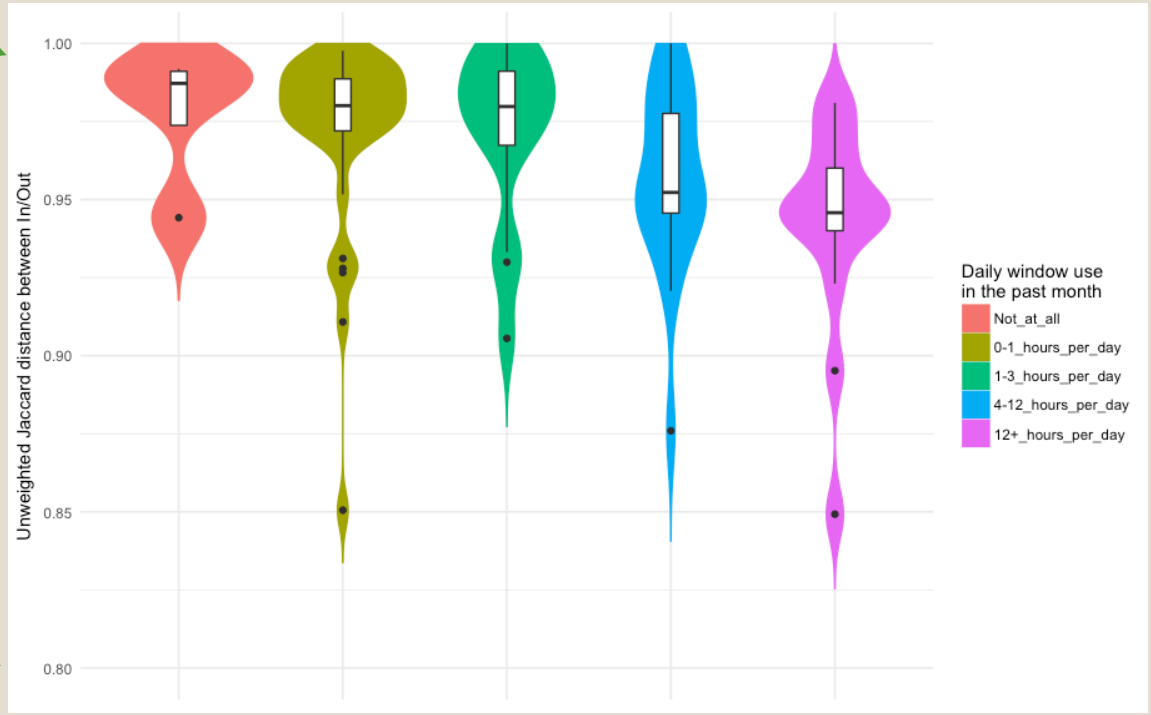
Housing quality has demonstrated effect on health

Krieger and Higgins, 2002:

- "Damp, cold, and moldy housing is associated with asthma and other chronic respiratory symptoms, even after potentially confounding factors such as income, social class, smoking, crowding, and unemployment are controlled for.21–31
- Water intrusion is a major contributor to problems with dampness. In 1999, eleven million occupied homes in America had interior leaks and 14 million had exterior leaks.6
- Overcrowding and inadequate ventilation also increase interior moisture.32
- Damp houses provide a nurturing environment for mites, roaches, respiratory viruses, and molds, all of which play a role in respiratory disease pathogenesis.33–39
- Cross-sectional epidemiological studies have also established associations between damp and moldy housing and recurrent headaches, fever, nausea and vomiting, and sore throats.37,40
- Old, dirty carpeting, often found in substandard housing, is an important reservoir for dust, allergens, and toxic chemicals.41,42 Exposure to these agents can result in allergic, respiratory, neurological, and hematologic illnesses."

Window ventilation can improve IAQ and wash out the human-associated microbial signal

Indoor bacteria ≠ outdoor bacteria



Indoor bacteria similar to outdoor bacteria

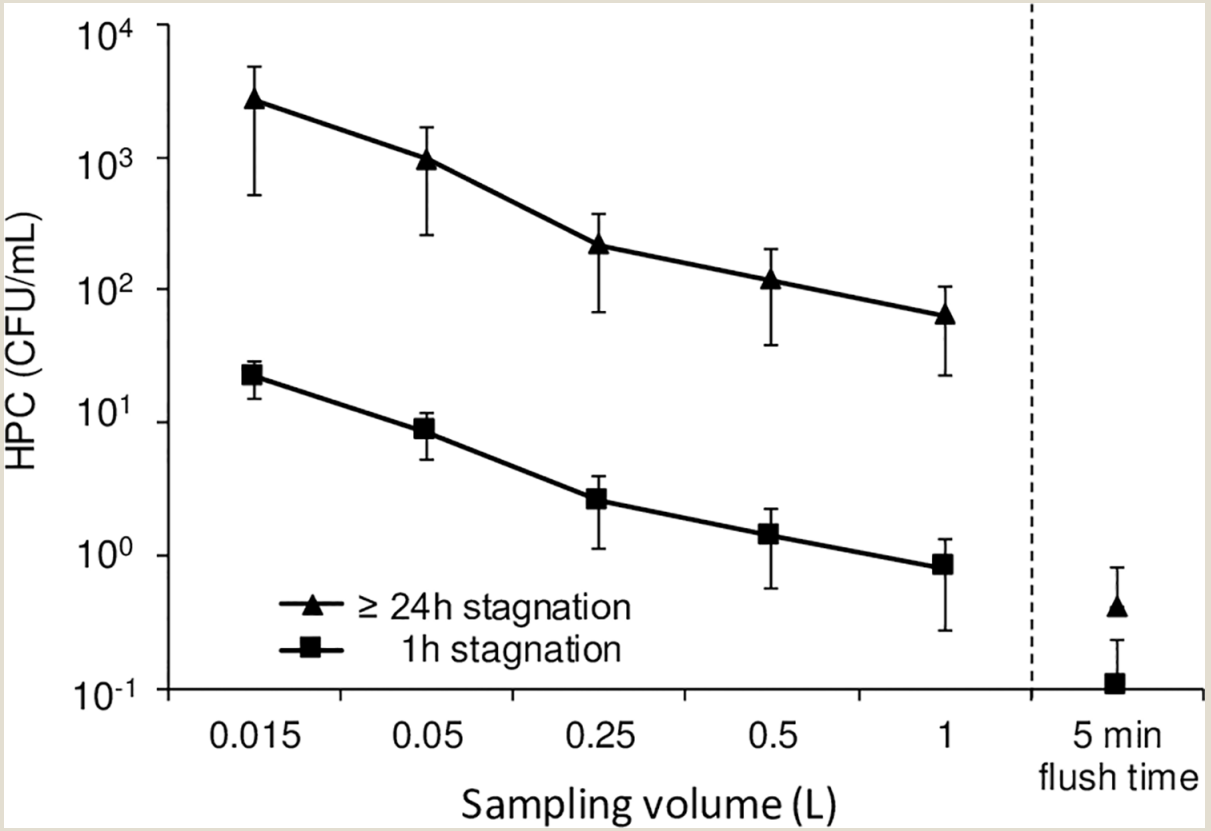
BioBE, unpublished data 2018

WATER SOURCES AND MICROBIAL EXPOSURE

Microorganisms (bacteria and fungi) survive in water systems, especially if there is stagnation

HPC = Heterotrophic plate counts

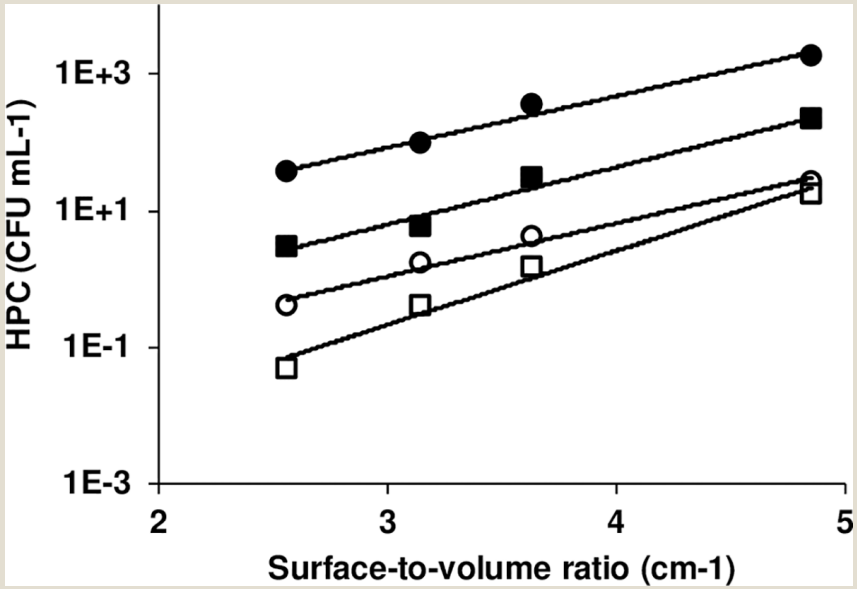
CFU = colony forming units (i.e. cells that went on to form a colony



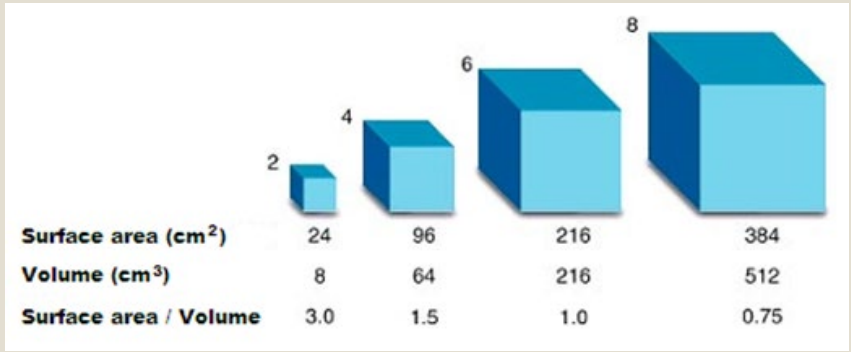
Bedard et al. 2018

More microorganisms in small pipes

HPC = Heterotrophic plate counts
CFU = colony forming units (i.e. cells that went on to form a colony



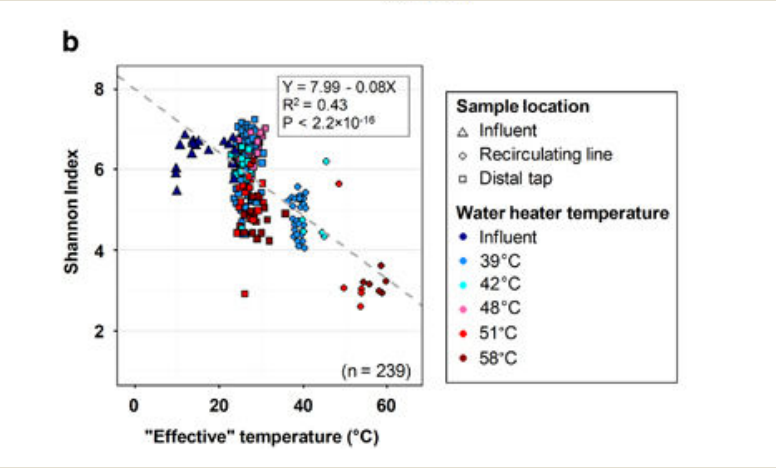
Bedard et al. 2018

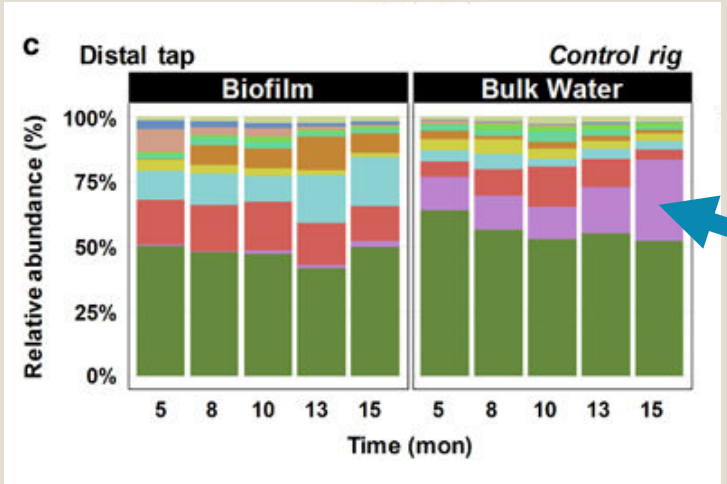


CELLS / SURFACE AREA TO VOLUME

Bacteria even in hot water tanks

- Bacteria indoors slightly negatively correlated with indoor temp
  - *i.e. don't like it too hot (Frankel et al. 2012)*
- Communities in water taps changed with water heater set temp (Ji et al. 2017)
  - *Hotter water = less diverse bacterial community*
  - *Prevents growth of Mycobacterium*



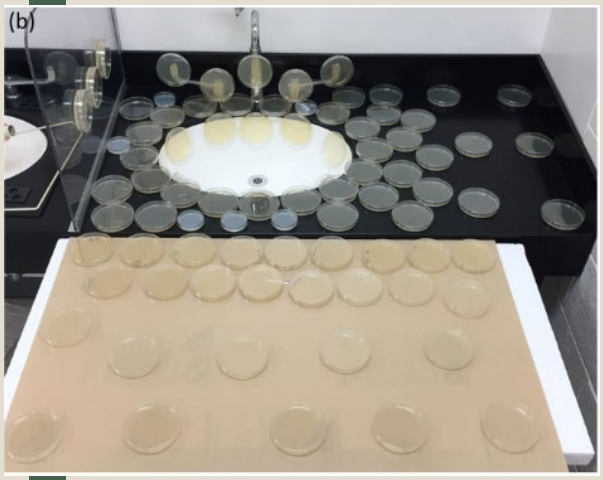


Thermo-philes

(Ji et al. 2017)

Water Quality

- More valves and parts to the pipe = more bacteria
  - *Problem with automatic sinks (Sydnor and Perl, 2011)*



- Bacteria from sink u-bends traveled 2.5 cm/day back up into sink (Kotay et al. 2017)
  - *Contaminated counter/other sinks during use*
  - *Used GM-fluorescent bacteria to track*

Potential for aerosolization

- Dental waterlines and air contained with:
  - *Pseudomonas, Micrococcus, Staphylococcus, Alternaria, Cladosporium, Penicillium, Aspergillus, and Paecilomyces (Kadaifciler and Cotuk, 2014)*
- Lots of documentation for spread of disease through water systems
  - *Legionnaires' from Legionella pneumoniae (Burge 2008)*
  - Nontuberculous **Mycobacterial** (NTM) pneumonia
    - (various Mycobacterium species but not M. tuberculosis or M. leprae) (Gebert et al. 2018)

Legionnaires' Disease Overviewpublichealth.lacounty.gov

Prisons are designed to contain people, not microbes

- Personal and environmental hygiene is difficult to maintain
- High transmission of microbial infections in prison
- Health problems related to incarceration and building conditions are well-documented
  - *Ex. Viggiani 2007, Bick 2007*

Precaution	Challenge(s)
Hand hygiene	Many areas in which clinical care is provided lack hand washing stations. Soap and soap dispensers are valuable commodities and may be stolen by inmates. Alcohol-based hand washes burn with a clear flame and may raise concerns with custody staff.
PPE	Custody employees routinely search inmates and conduct cell searches, increasing the risk for sharps injuries and contact with blood and other potentially infectious materials. Inmates may intentionally expose staff to blood and other potentially infectious materials by either spitting or throwing fluids. PPE is often stored in locked containers to prevent theft, limiting access.
Sharps	To limit syringe diversion, puncture-resistant leak-proof containers may not be available at the site where sharp instruments are used. Use of sharps in nonclinical areas, such as housing units (e.g., cells and dormitories), increases the risk for injury.
Patient care equipment	Patient care equipment (e.g., stethoscopes, blood pressure cuffs, and otoscopes) can be made into weapons or escape paraphernalia and, therefore, cannot be left in the rooms of inmates who are on contact precautions. These items can become contaminated and lead to transmission of pathogenic organisms.
Housing	Most jails and prisons are overcrowded and have an inadequate number of single cells that can be used for isolation, facilitating the transmission of contagious illnesses. Large dormitories make it difficult to cohort inmates.
Patient hygiene	Many inmates do not have ready access to soap and water. Shower access is often restricted. The number of toilets may be insufficient to serve the population.
Laundry	Clothing and linen is strictly rationed. Inmates who have conditions that predispose to soiling clothing with blood and/or body fluids may not be able to secure additional clothing. Inmates often wash their own clothes in buckets, sinks, or bags to ensure that they do not lose their clothes. This may remove dirt and odors, but it does not disinfect clothing. Bleach is contraband and is not available to inmates.
Housekeeping and sanitation	Most housecleaning is performed by inadequately trained inmates who do not have access to effective cleaning supplies. Housing areas and common areas (such as booking and bus screen areas, showers, toilets, day rooms, gymnasiums, weight equipment, and clinic waiting rooms) may be infrequently cleaned.
Patient transport	Inmates are often moved without informing clinical services. Transportation vehicles may be inappropriate for transmission-based precautions. Vehicles may not be routinely cleaned and can be a source of transmission of contagious illnesses. Custody restraints are often reused without disinfection.
Access to medical care	Many facilities have lengthy delays for inmates to see clinicians. Copayments discourage inmates from seeking care and may lead to further transmission of contagious conditions.

NOTE. Prisons are defined as detention centers operated by state and federal governments that serve as detention centers for persons who have been sentenced to >1 year of incarceration. Jails are defined as detention centers operated by city and county governments that serve as detention centers for persons who are either awaiting trial or who have been sentenced to <1 year of incarceration. Inmates are defined as residents of jails and prisons. Prisoners are defined as residents of prisons. PPE, personal protective equipment.

Bick 2007

Prisons are microbial hotspots

(Bick 2007):

- New inmates have an increased prevalence of
  - *human immunodeficiency virus*
  - *hepatitis B virus*
  - *hepatitis C virus*
  - *Syphilis, Treponema pallidum*
  - *Gonorrhea, Neisseria gonorrhoeae*
  - *Chlamydia, Chlamydia trachomatis*
  - *Mycobacterium tuberculosis*

- During incarceration, increased risk for
  - *blood-borne pathogens*
  - *sexually transmitted diseases*
  - *methicillin-resistant Staphylococcus aureus*
  - *M. tuberculosis*
  - *influenza virus*
  - *varicella-zoster virus.*

Living facilities in California State Prison (July 19, 2006), Wikipedia

Tuberculosis is a problem, even in the U.S.

Author, Year (Country)	Period	Cases, *n* (At Risk)	Incidence in Prisons, %	Incidence in General Population, %[a]	Incidence Rate Difference	IRR (95%CI)	Incarcerated Population, ×1,000 Inhabitants[b]	PAF%
Ferreira et al., 1996 (Brazil)	1992–1993	21 (68)	30.9	0.5	30.4	61.76 (40.27–94.73)	1.91	10.4
Hung et al., 2003 (USA)	2000–2001	49 (9,746)	0.53	0.1	0.43	5.03 (3.8–6.65)	7.38	2.9
Koo et al., 1997 (USA)	1989–1991	130 (2,201)	5.91	0.1	5.81	59.06 (49.74–70.14)	7.38	30.0
MacIntyre et al., 1997 (USA)	1993–1994	86 (1,027)	8.37	0.1	8.27	83.74 (67.79–103.45)	7.38	37.9
Mitchell et al., 2005 (USA)	1999–2000	3 (231)	1.30	0.1	1.20	12.99 (4.19–40.27)	7.38	8.1
Steenland et al., 1997 (USA) (high)	1991–1992	169 (10,104)	1.67	0.1	1.57	16.73 (14.39–19.45)	7.38	10.4
Steenland et al., 1997 (USA) (low)	1991–1992	212 (8,027)	2.64	0.1	2.54	26.41 (23.08–30.22)	7.38	15.8

Characteristics of the study, estimated annual incidence of LTBI in prisons, estimated annual incidence of LTBI in the general population, estimated annual incidence of LTBI difference, estimated annual incidence of LTBI ratio, fraction of the population in prison, fraction of LTBI in the population attributable to the exposure in prisons.

[a]As reported in Menzies et al., 2007 [49]; Steenland et al. reported LTBI cases among prisons personnel separately according to their "high" or "low" risk of being exposed to inmate cases of tuberculosis cases [30].

[b]As reported in the the Human Development Report (year 2007/08) [47].

doi:10.1371/journal.pmed.1000381.t001

Baussano et al. 2010

Food safety and quality is lacking, resulting in gastrointestinal disease

Marlow et al. 2017:

- *Discussed more broadly in Fassler and Brown, 2017, The Atlantic*

- From 1998 – 2014:
- 200 foodborne outbreaks in correctional institutions
- 20, 625 illnesses, 204 hospitalizations, and 5 deaths
  - *Higher frequency than general population*
- *Clostridium perfringens* was most frequent cause (28%)
- food remaining at room temperature responsible for 37% of outbreaks

DISCUSSION AND HOMEWORK

Discussion

- If we make people spend time in a space are we responsible for the health impacts for that space?
  - *Public school*
  - *Universities*
  - *Prisons*
  - *City buildings*

Homework

- **Reading (pick 2):**
  - *Bick_2007_infection control prisons*
  - *Hajat_2015_smog and socioeconomics*
  - *Huttenen_2016 IAQ and student immune rxn*
  - *Rossen_2012_zoning and health*
  - *Tessum_2019_air pollution and racial inequity*
  - *Wilson_2008_zoning and injustice*

Citations

Baussano et al. 2010 https://journals.plos.org/plosmedicine/article?id=10.1371/journal.pmed.1000381#s4

Bedard et al. 2018 https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0199429

Bick 2007 https://academic.oup.com/cid/article/45/8/1047/344842

Borgo and Mostafavi, ACNAS 2007

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