

The Microscopic World of Building Science

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SEPTEMBER 30, 2022

OCCUPATIONAL AND
ENVIRONMENTAL HEALTH
SEMINAR

det HFW HV curr WD mag PW
ETD 207 μm 10.00 kV 50 pA 14.2580 mm 1 000 x 33.7 nm

100 μm
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Civil & Mineral Engineering
UNIVERSITY OF TORONTO

BUILT ENVIRONMENT

- Coined in 1970s in Anthropology and Social Science realms
- “Complex systems and diverse structures, made up of many components responsible for functions such as transportation, organization, resource distribution, and protection, among many others”



INDOOR BUILT ENVIRONMENT

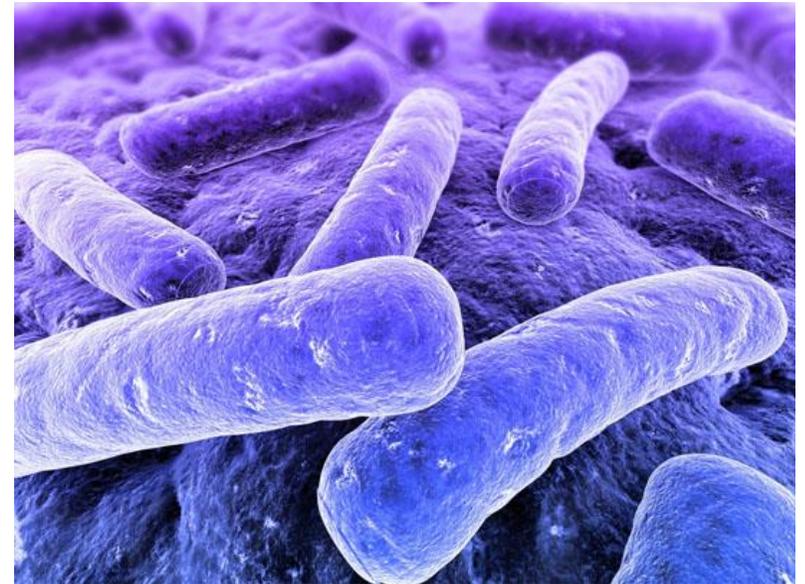


ALTERNATIVE INDOOR ENVIRONMENTS

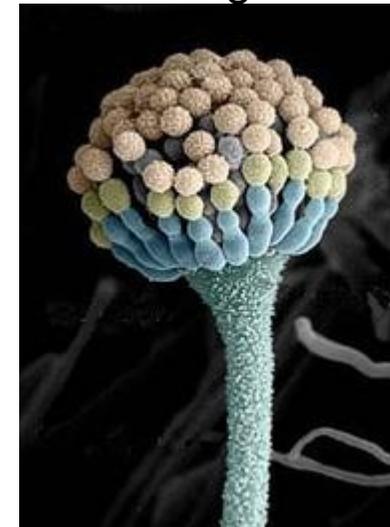




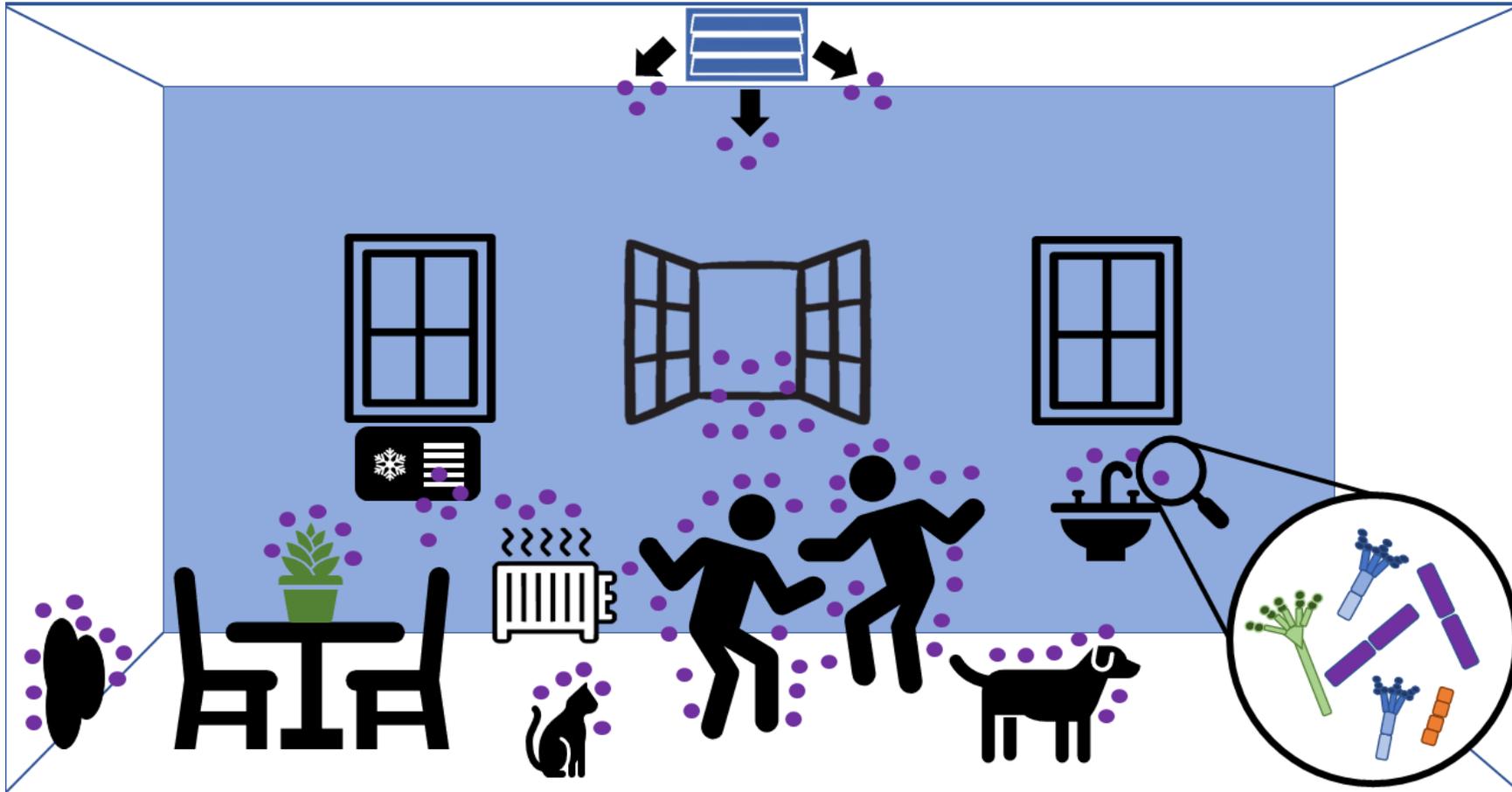
Bacteria



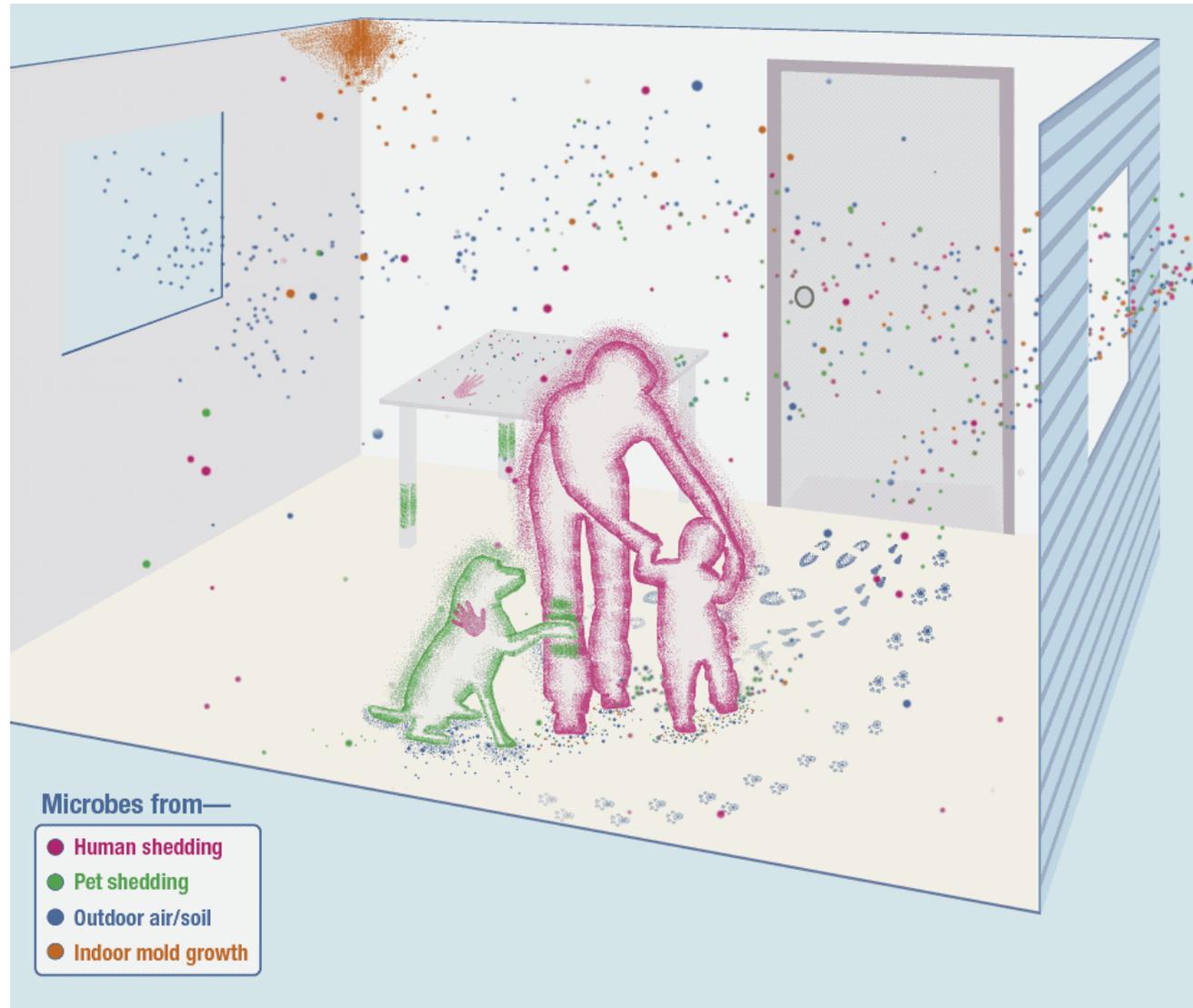
Fungi



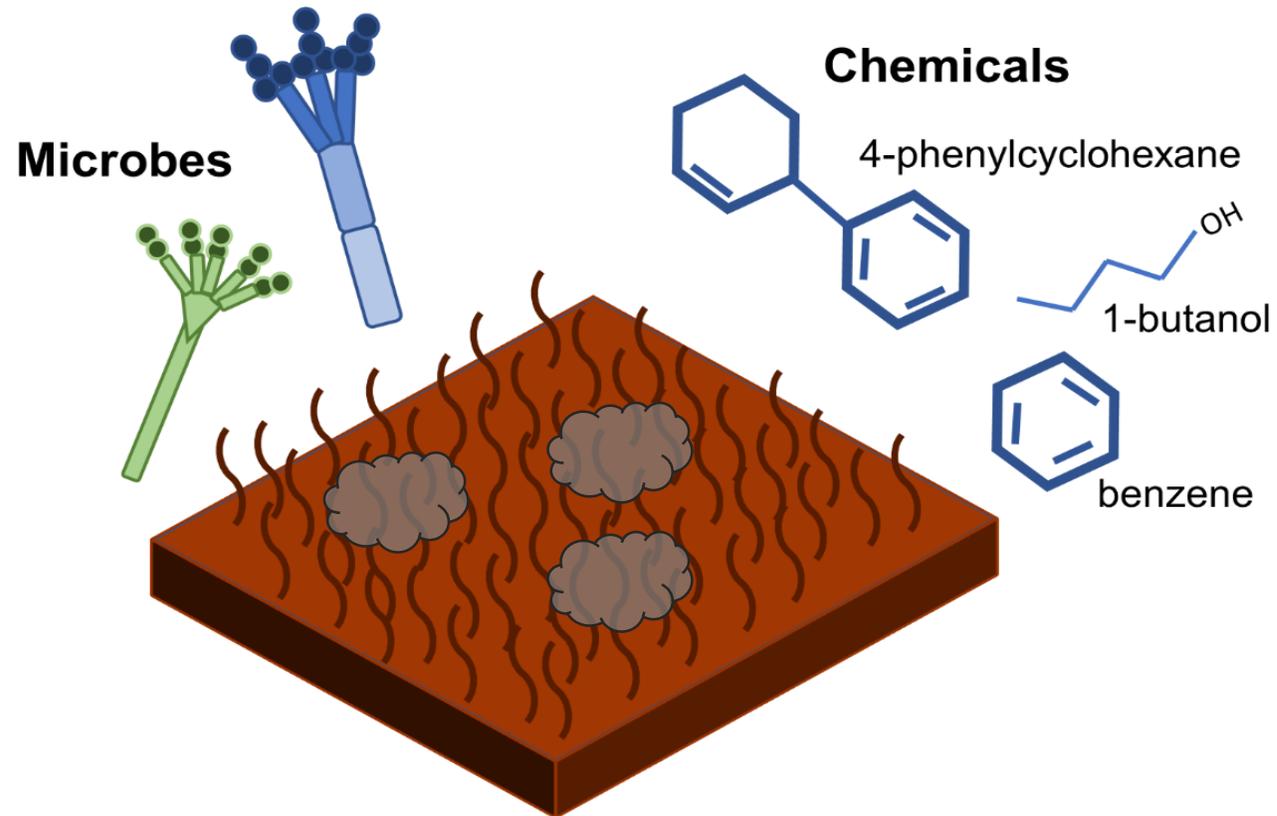
THE INDOOR MICROBIOME



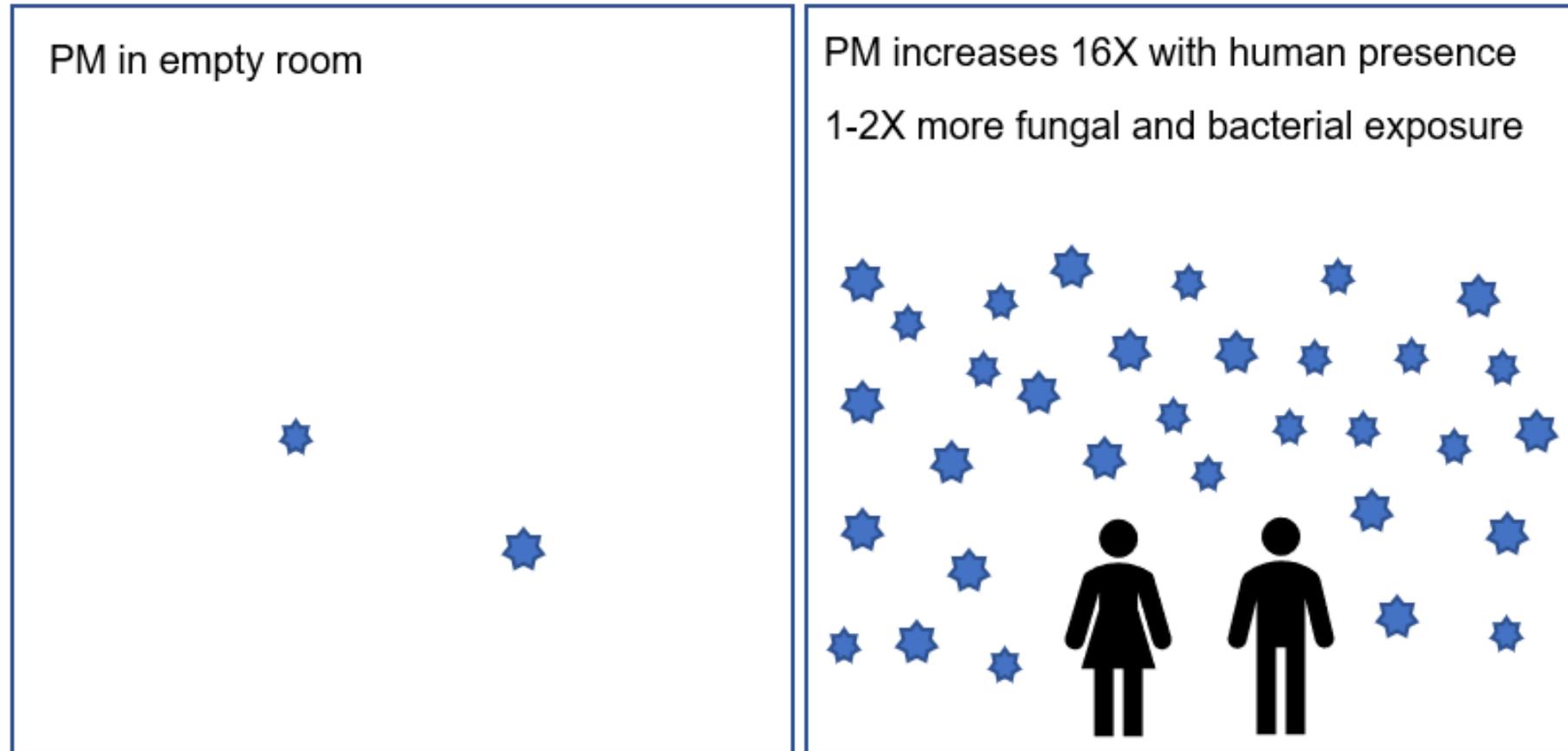
INDOOR BIOLOGICAL (BACTERIA, FUNGI, MOLD, VIRUSES, ETC.) EXPOSURES



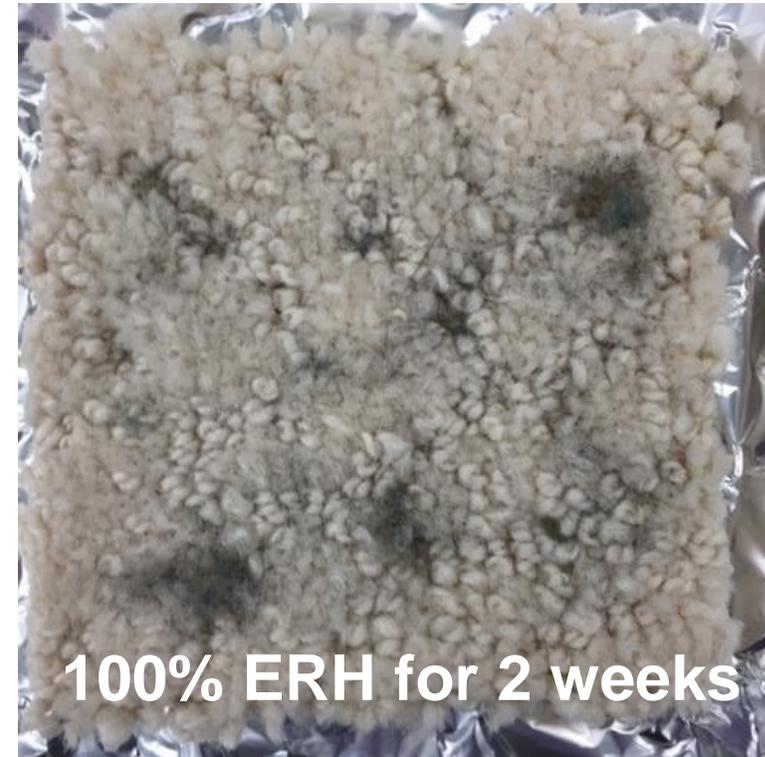
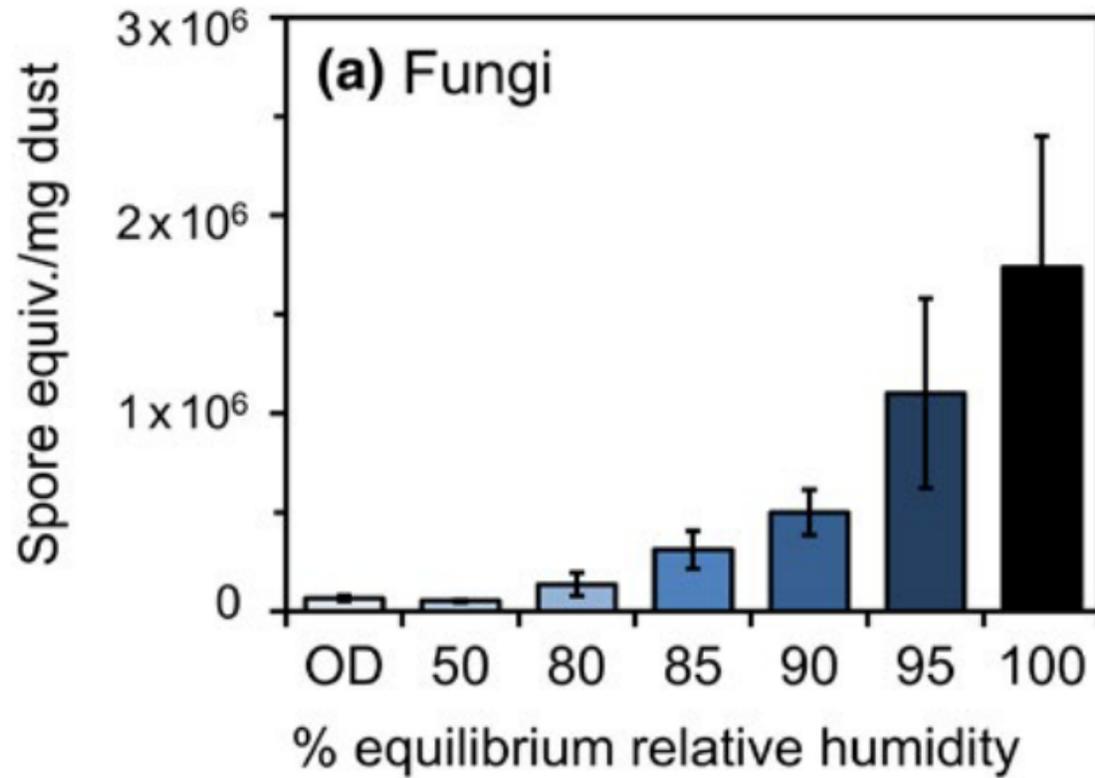
Carpet and dust are a source of microbial and chemical exposure indoors



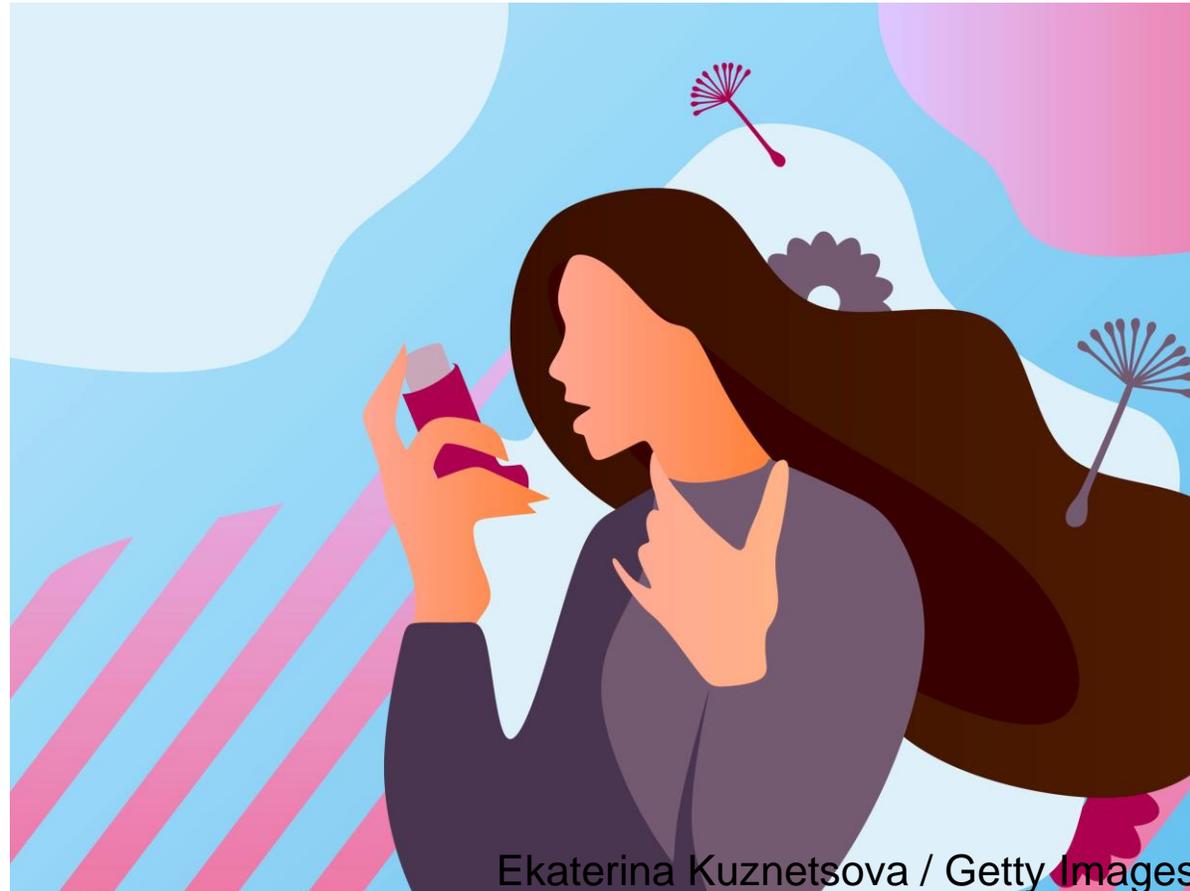
Most of our exposure to microbes indoors comes from resuspension of floor dust



Increased levels of relative humidity (RH) can increase microbial growth in building materials



Exposure to mold and dampness in housing is commonly associated with asthma and upper respiratory disease



Ekaterina Kuznetsova / Getty Images

Mold and dampness disproportionately impacts our most vulnerable communities



A home on the Wasagamack First Nation, about 600 kilometres north of Winnipeg in northern Manitoba. (Karen Pauls/CBC)

> [J Environ Health](#). Jan-Feb 2012;74(6):14-21.

Mold growth in on-reserve homes in Canada: the need for research, education, policy, and funding

[Michael Optis](#), [Karena Shaw](#), [Peter Stephenson](#), [Peter Wild](#)

In Public Housing, a Battle Against Mold and Rising Seas

Neglected infrastructure, already a source of mold, is also making public housing more vulnerable to climate change.

Visual: [Spencer Platt / Getty Images](#)



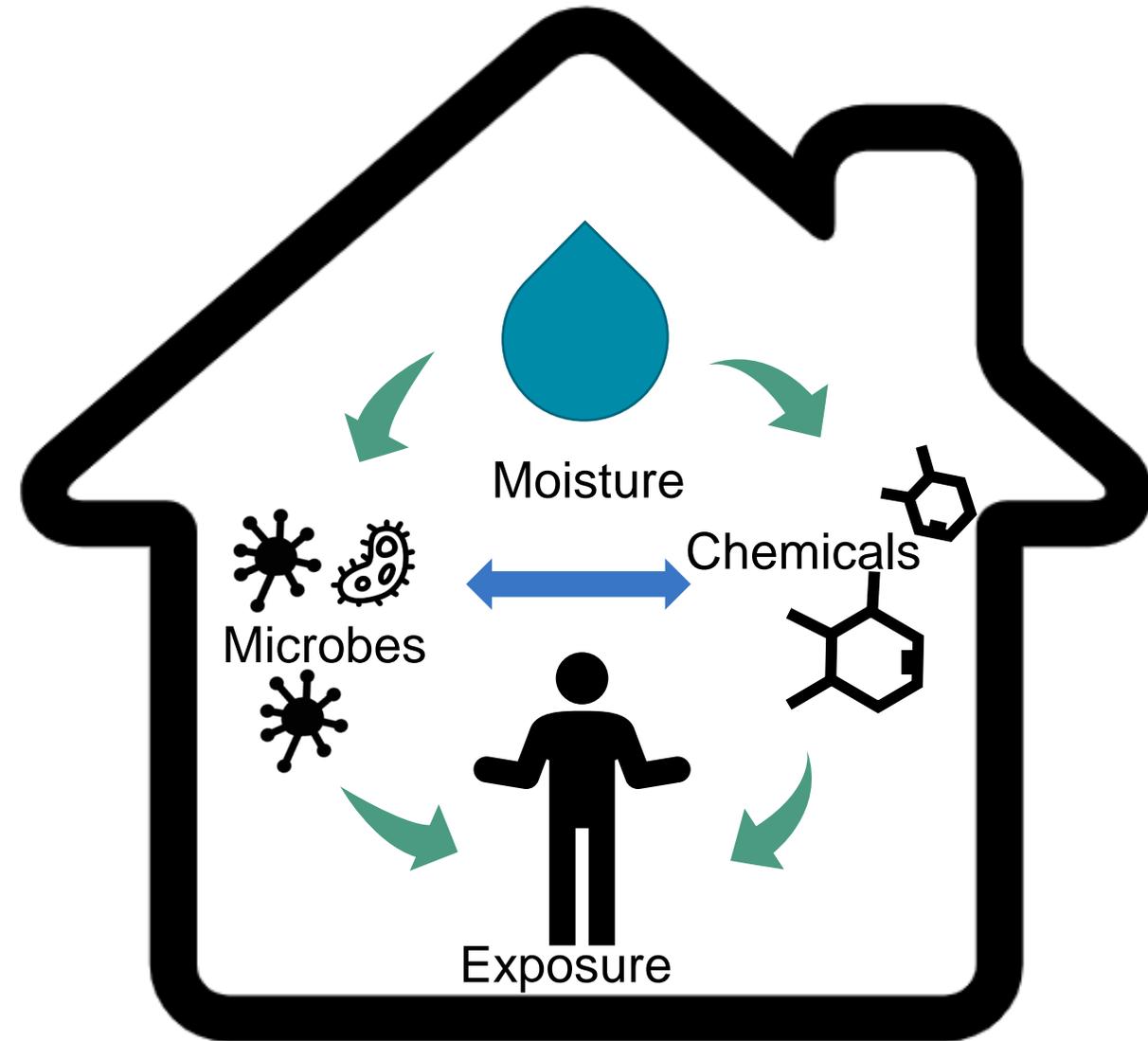
Mold grows on the walls of Brandy Cabrera's bathroom. Cabrera is one of hundreds of tenants in Brooklyn's Red Hook Houses that have sued the New York City Housing Authority due to leaks and mold. *Visual: Lili Pike*

Characterizing the indoor microbiome is critical to creating equitable, sustainable and **healthy** indoor spaces



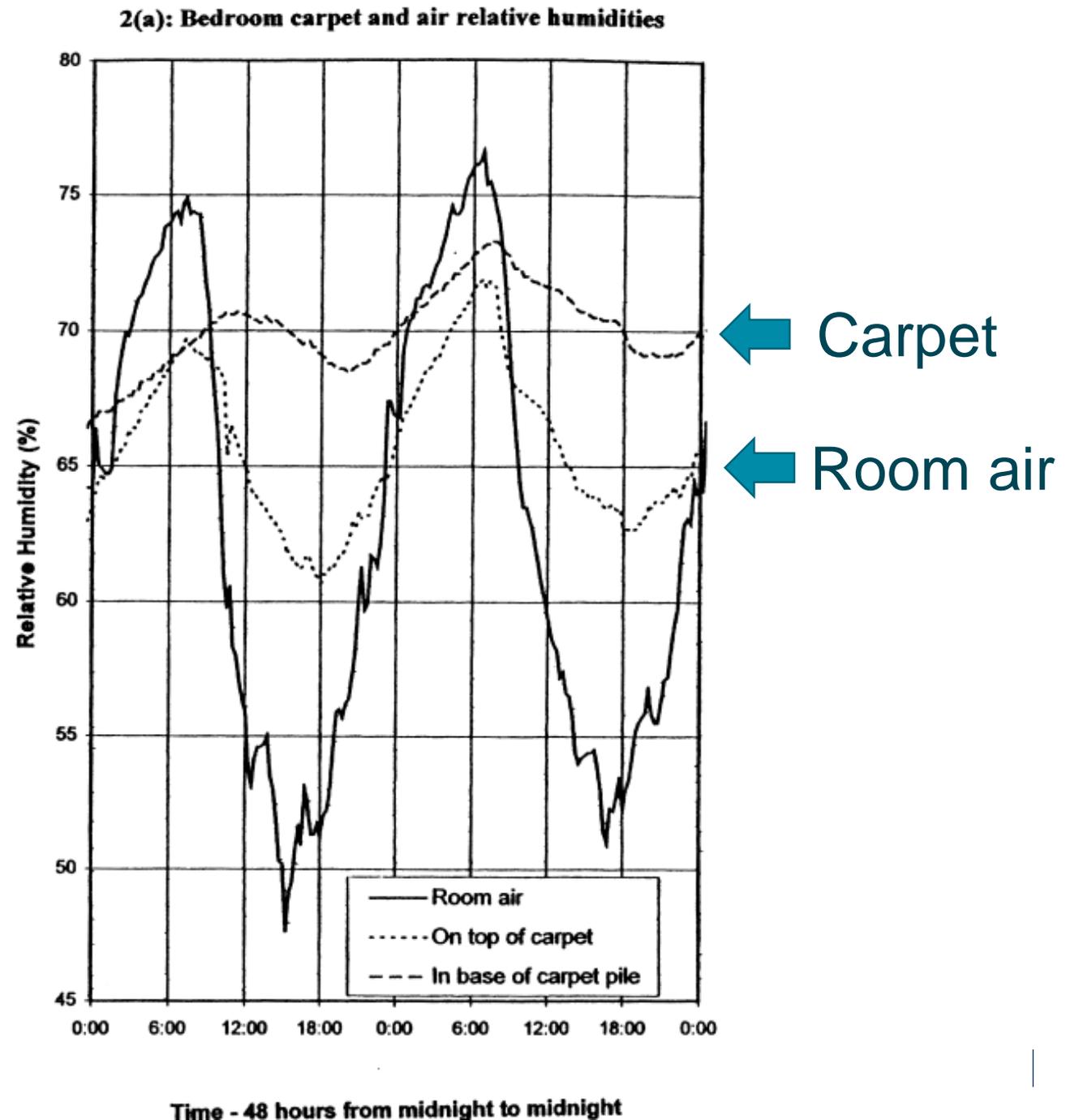
Artwork by Daniele Del Nero

My research focuses on the **relationship between moisture, microbes and chemicals indoors** and their impact to **human health**

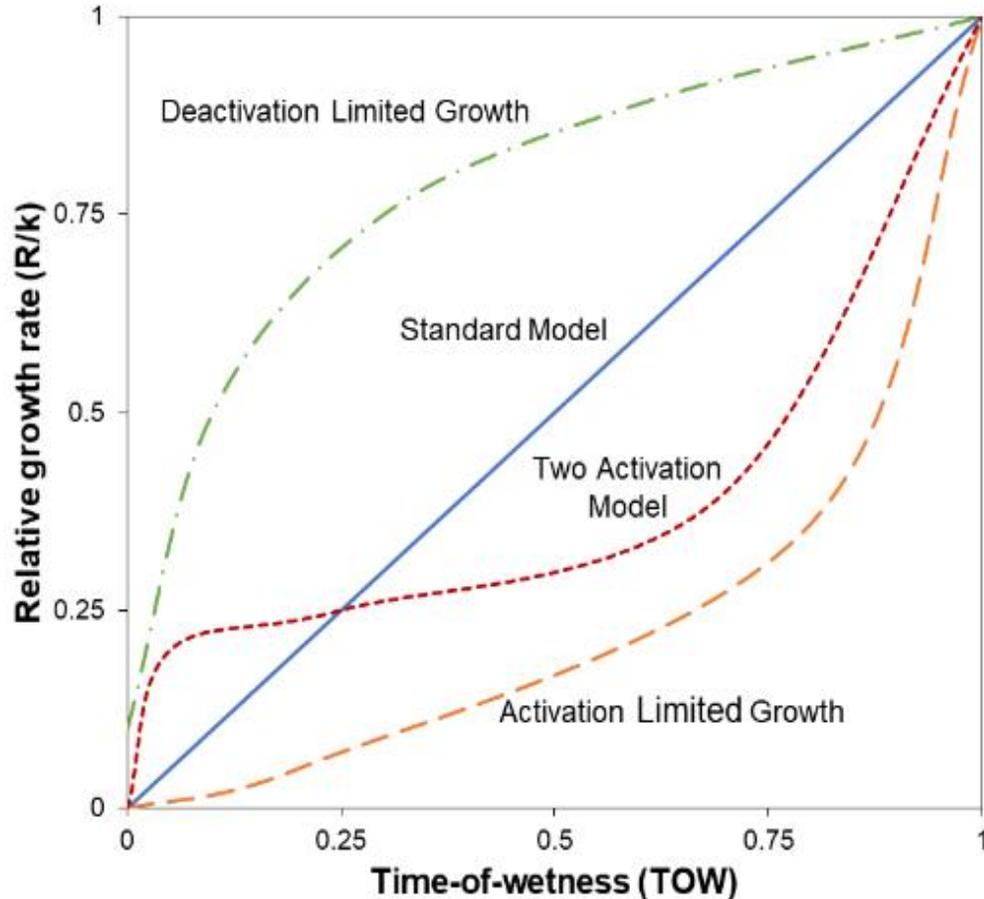


Under creative commons from Noun Project
Microbes: Warunk Icon, Dima Lagunov.
House: Thomas Uebe

The home environment does not stay at a constant RH throughout the day



Can we model fungal growth in carpet using the Time-of-wetness framework?

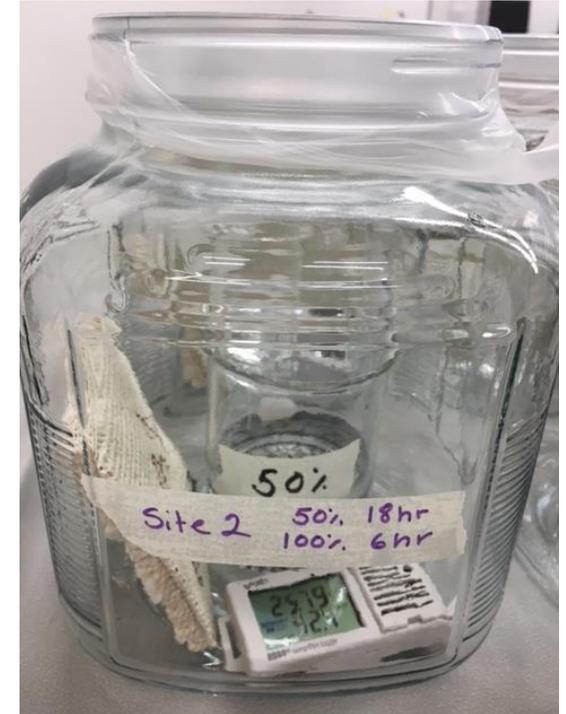
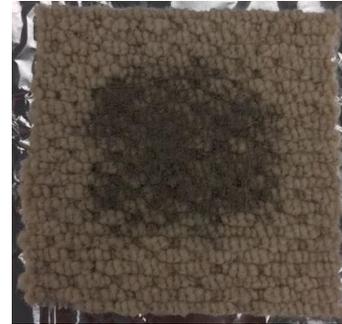
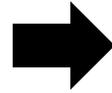


- Previous work (in drywall) found that as you increase the time above an 80% relative humidity threshold the fungal growth rate increases

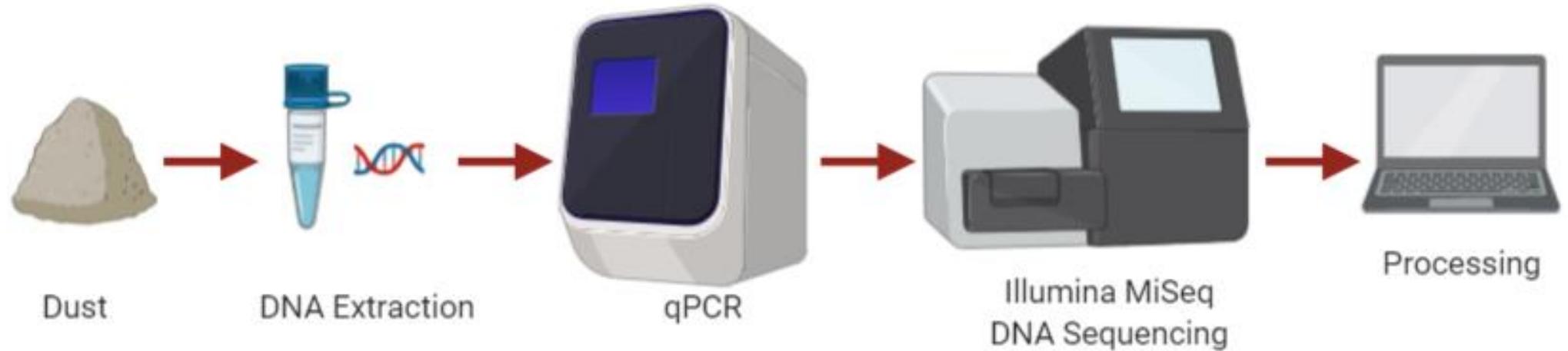
Carpet and dust were collected and incubated at varying relative humidity conditions



Vacuum
bag dust

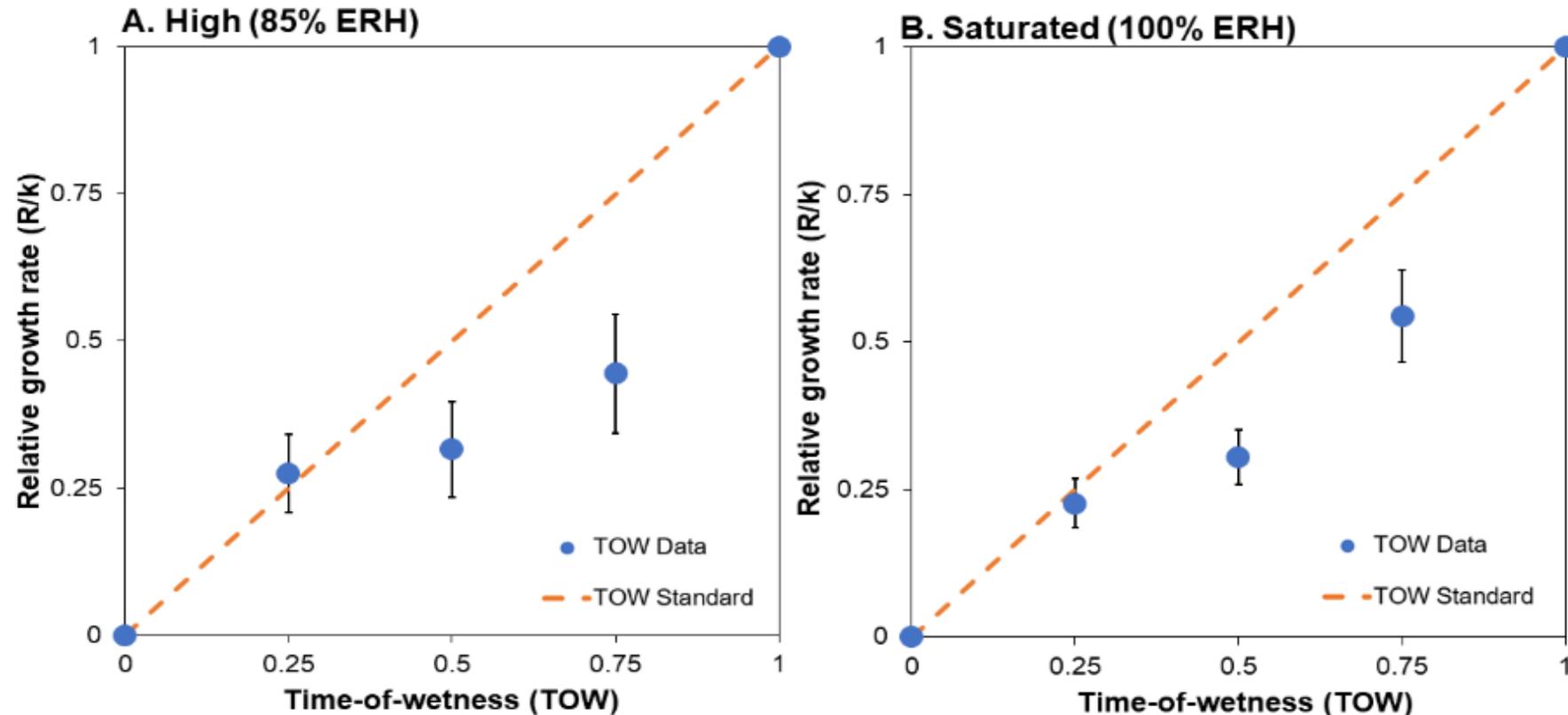


DNA based measurements and processing

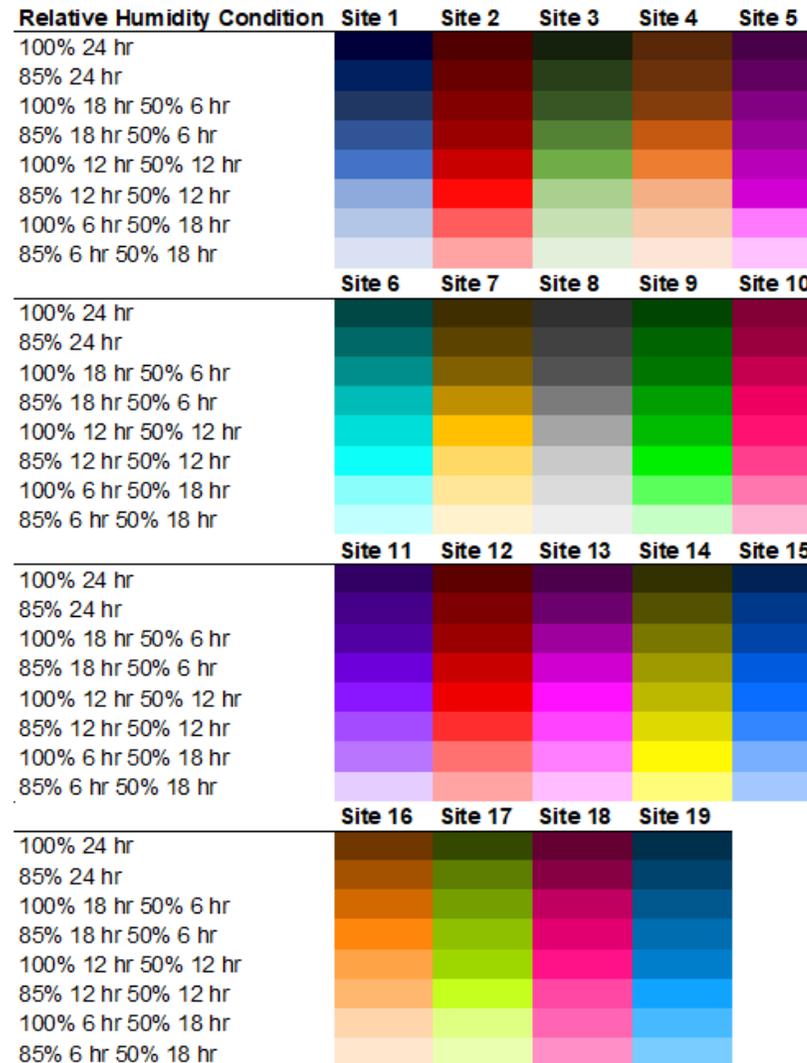
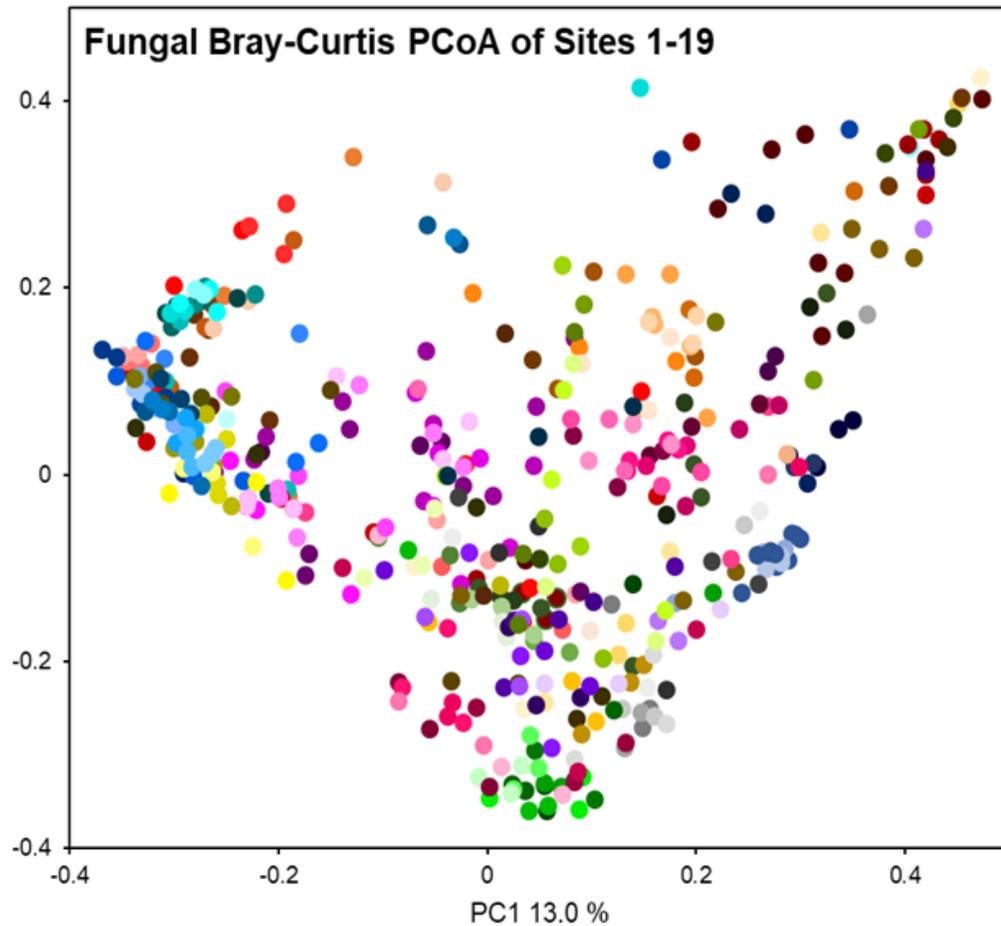


Created in BioRender.com

Fungal growth in dust in carpet follows the two-activation regime model

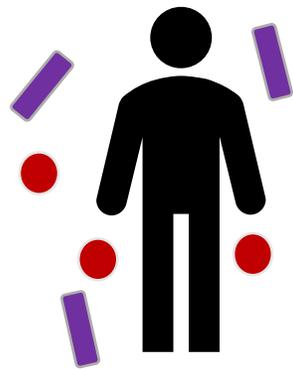


Home environment is the greatest indicator of species composition in carpet dust ($p=0.001$, $r^2 = 0.461$)

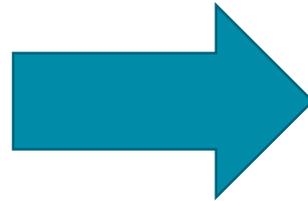


However, within a home, moisture level influenced the microbial communities

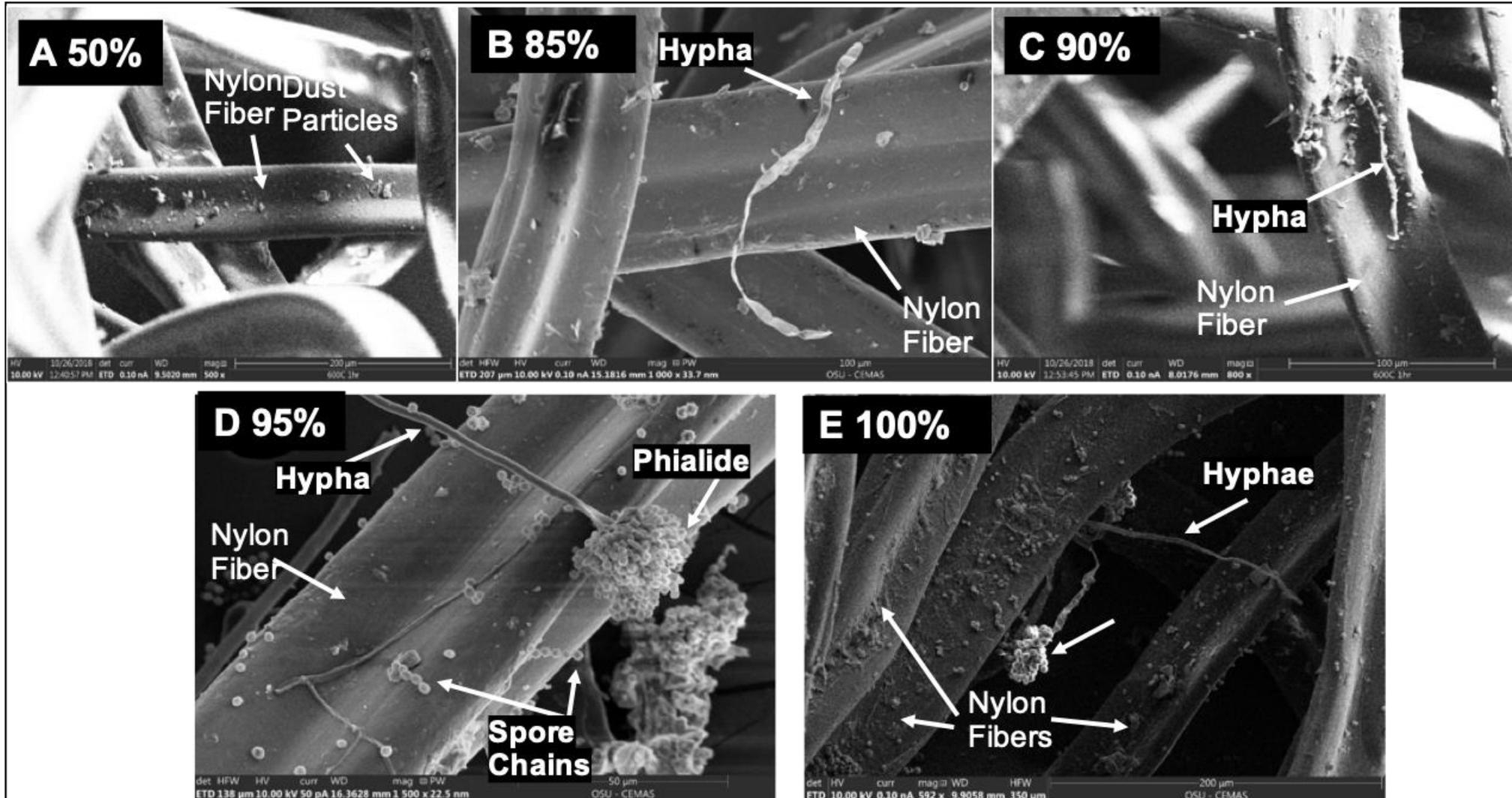
The home microbiome is influenced by human occupants - we leave a human finger print



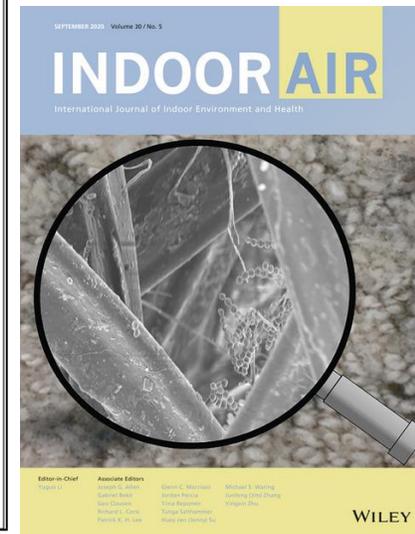
Humans introduce skin/host associated microbes



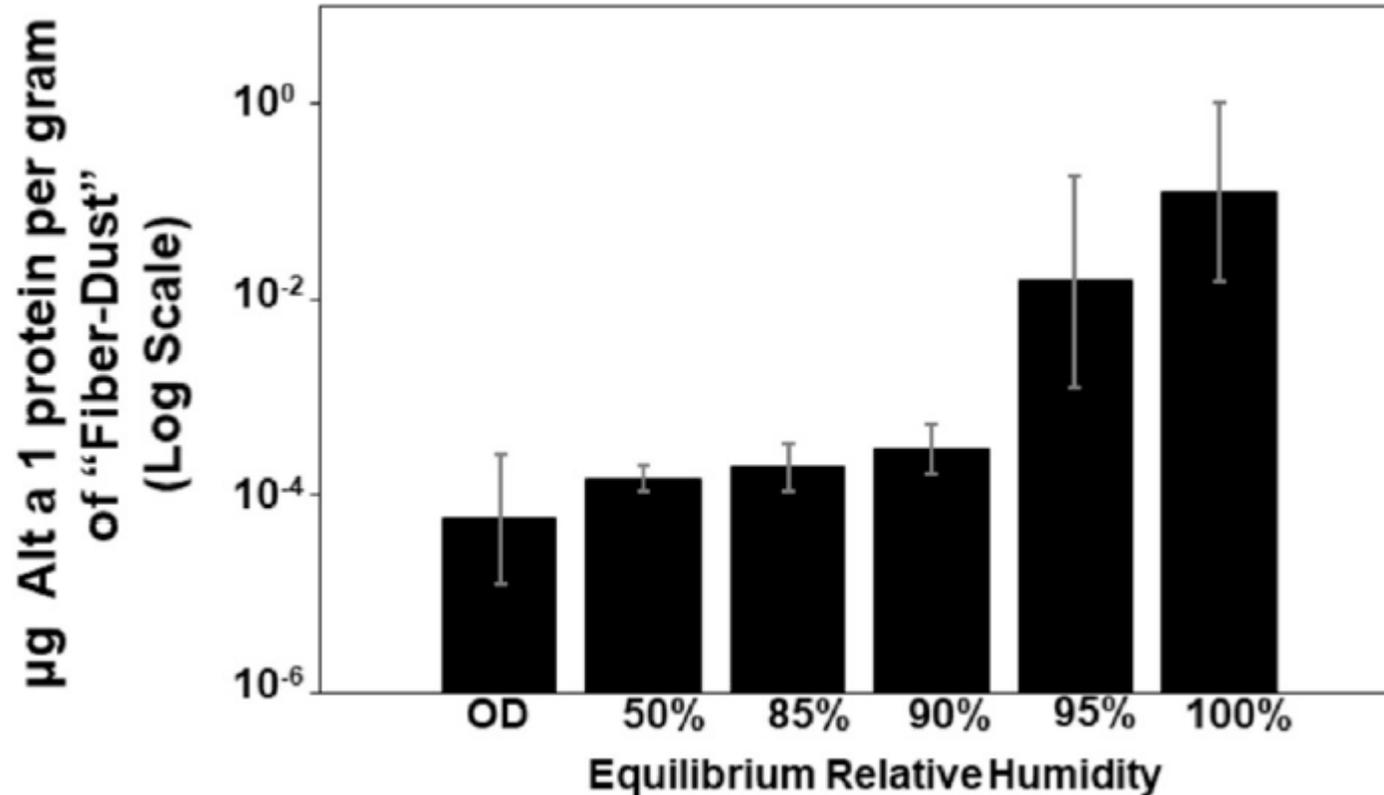
What does fungal growth in carpet look like?



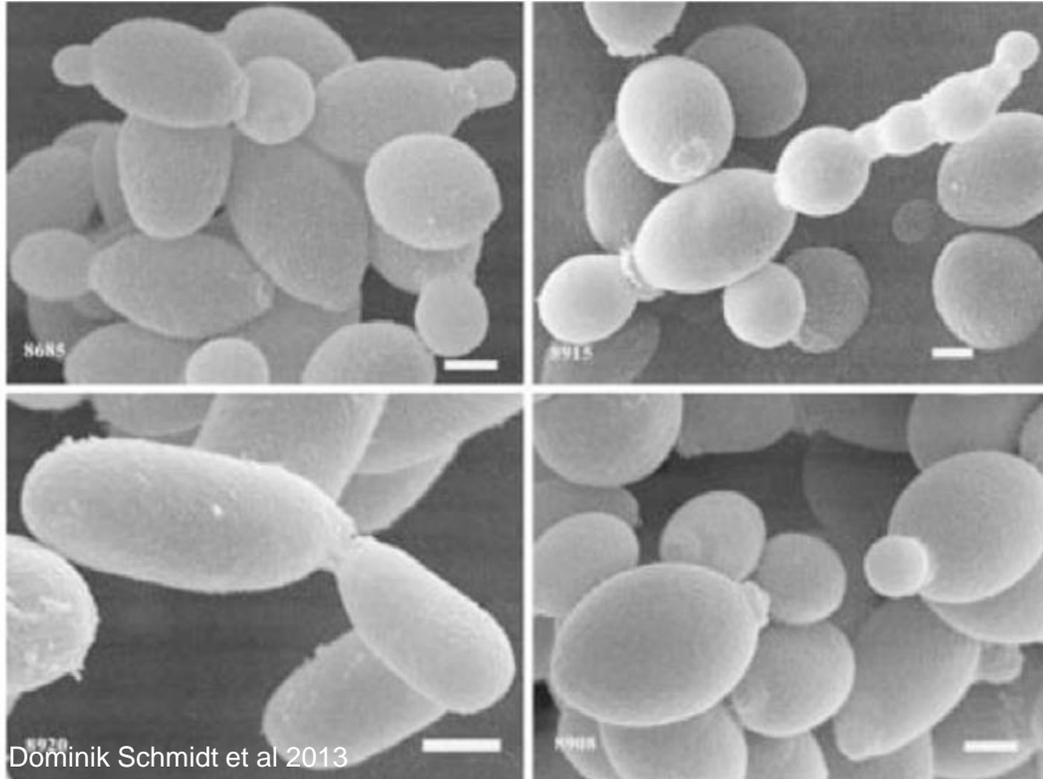
Nick Nastasi



Increasing relative humidity is associated with increasing allergen concentration

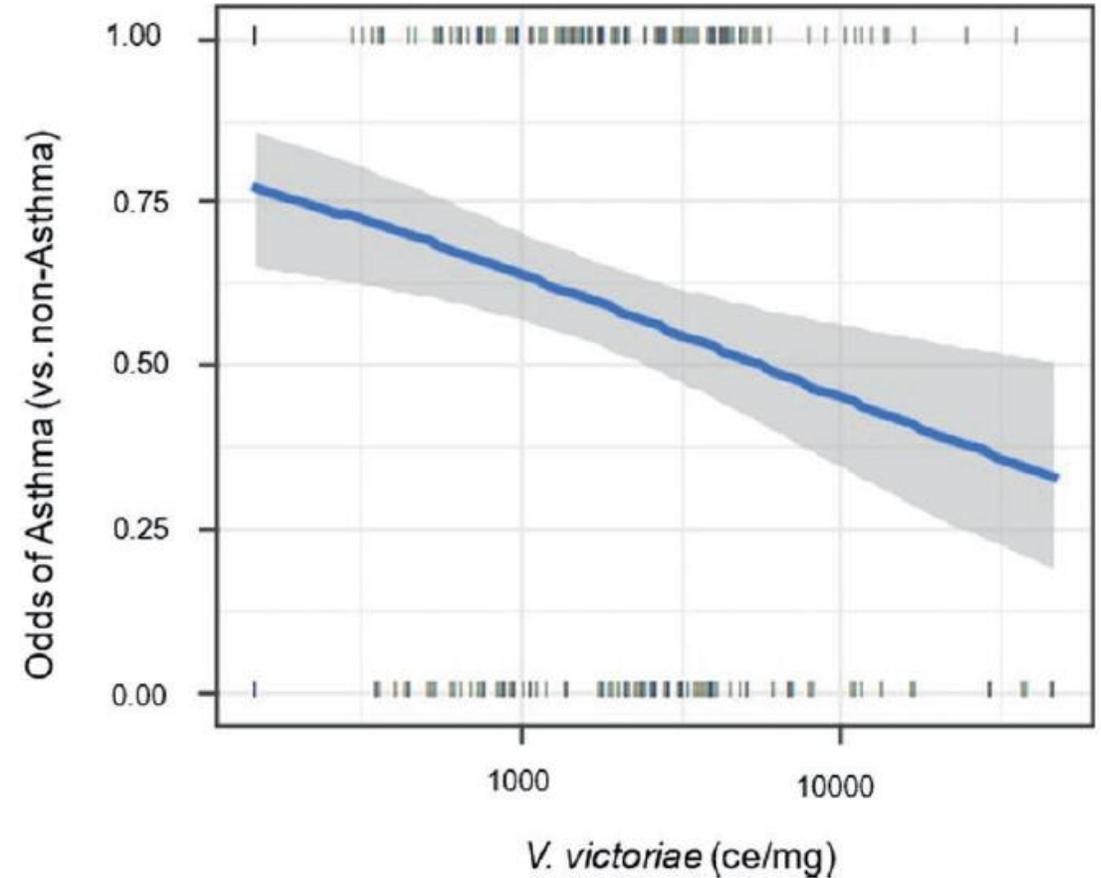


Repeated fungal exposures may protect against allergic airway diseases



Dominik Schmidt et al 2013

Vishniacozyma victorae



V. victoricae is associated with dog mycobiome – dogs **may** aid in protecting against asthma



Daniela Jovanovska-Hristovska/Getty Images

WHAT ABOUT CHEMICALS IN DUST?

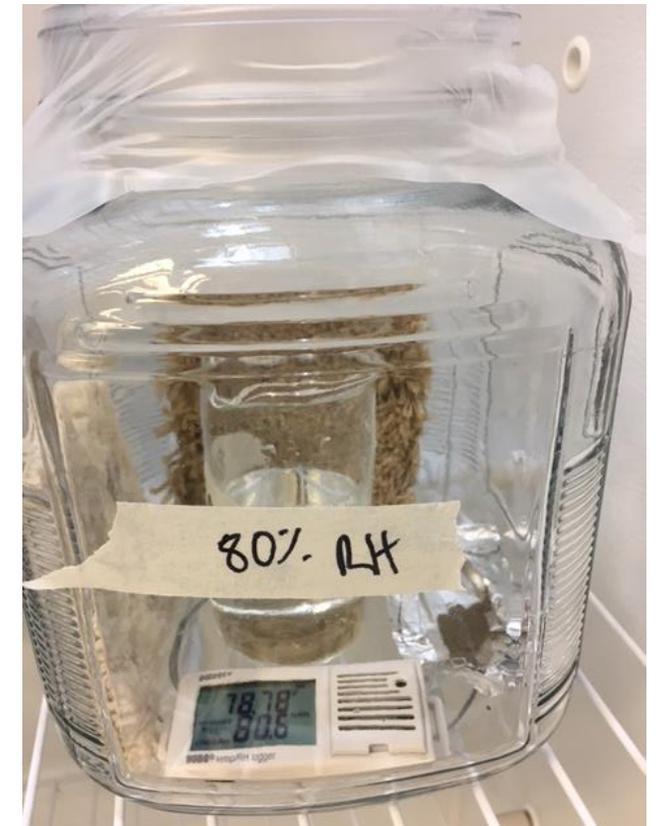
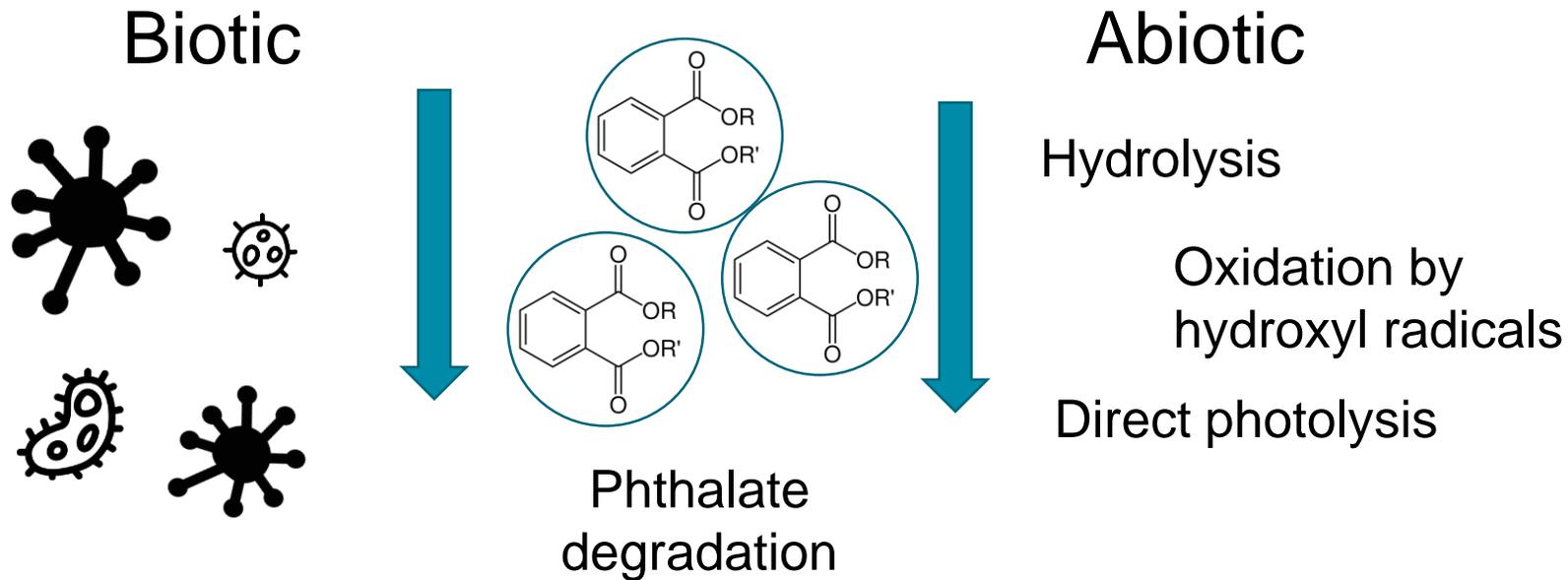


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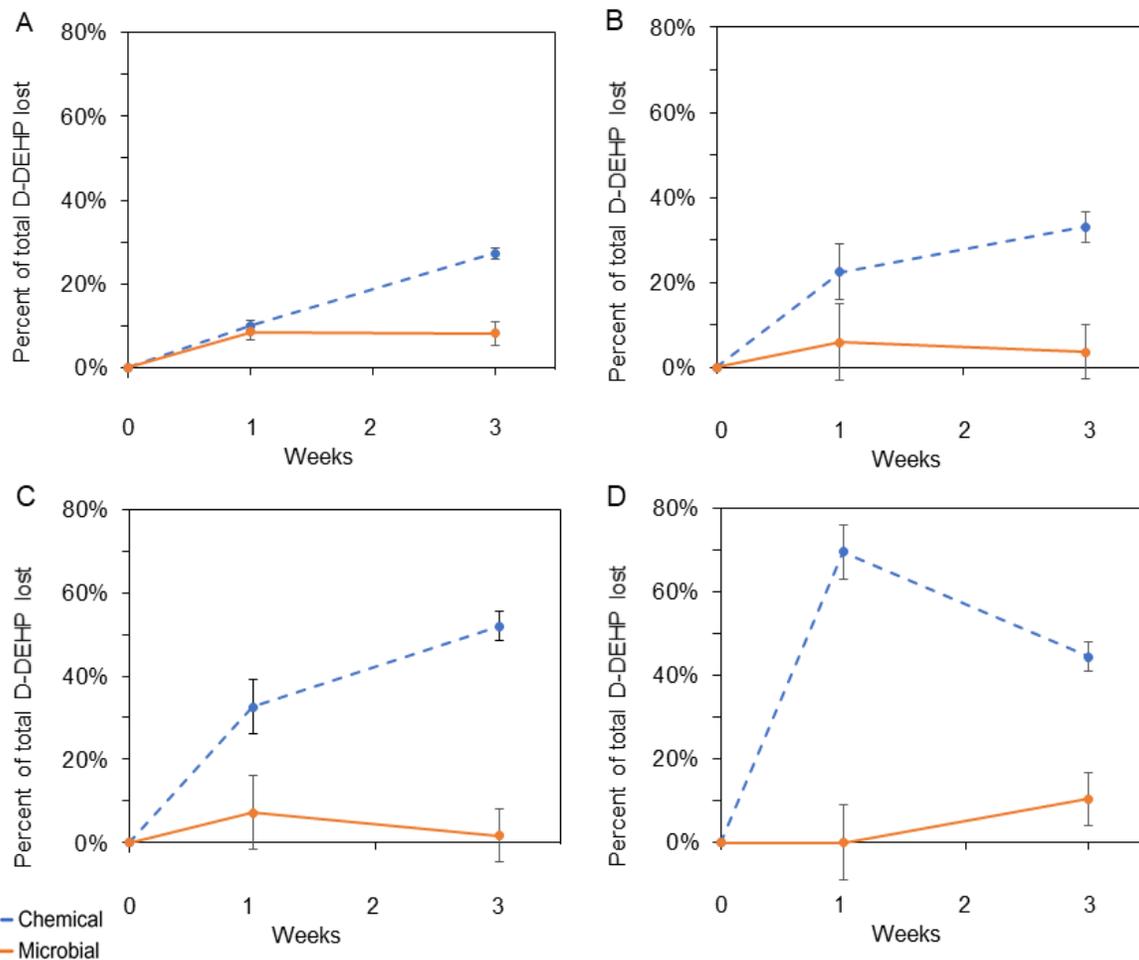
Dust contains phthalate esters a common plasticizer and endocrine disrupter



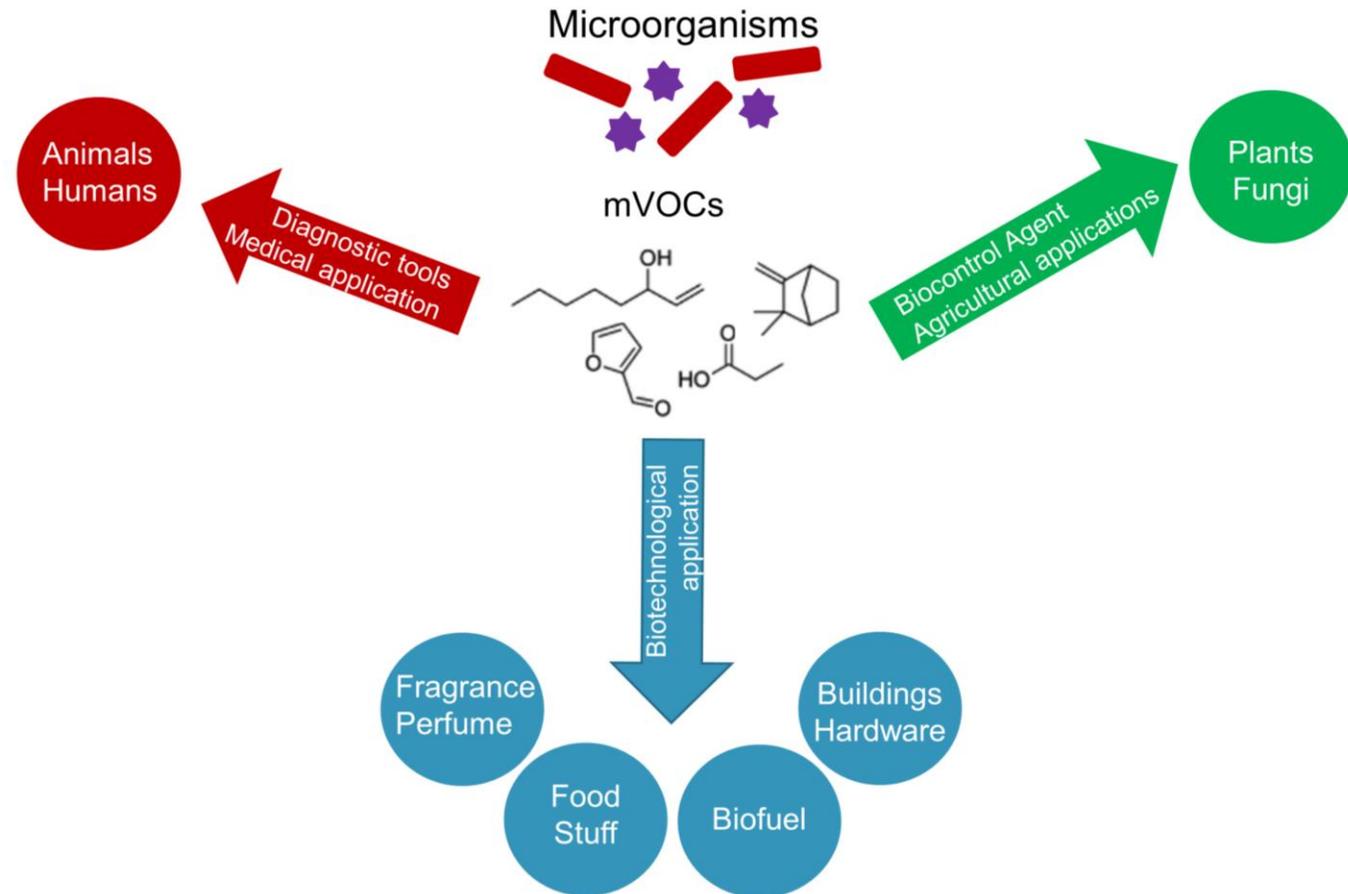
Are phthalates (DEHP) in dust degraded due to microbial or chemical processes?



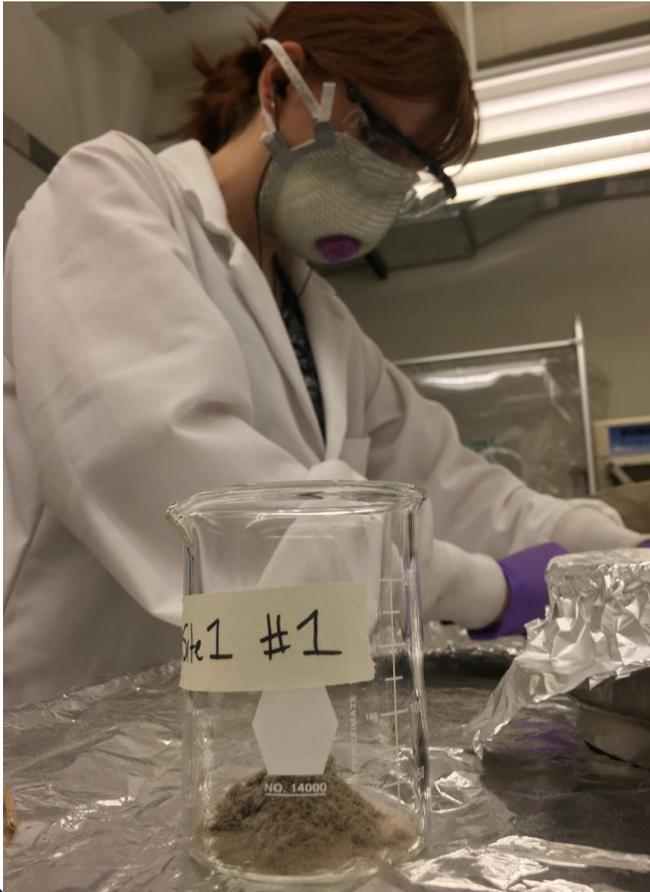
d-DEHP was degraded due to both abiotic and biotic processes



Microbes may also release microbial organic compounds (mVOCs)



Dust was collected from Ohio, Florida and California, sieved to obtain fine particles and embedded in carpet



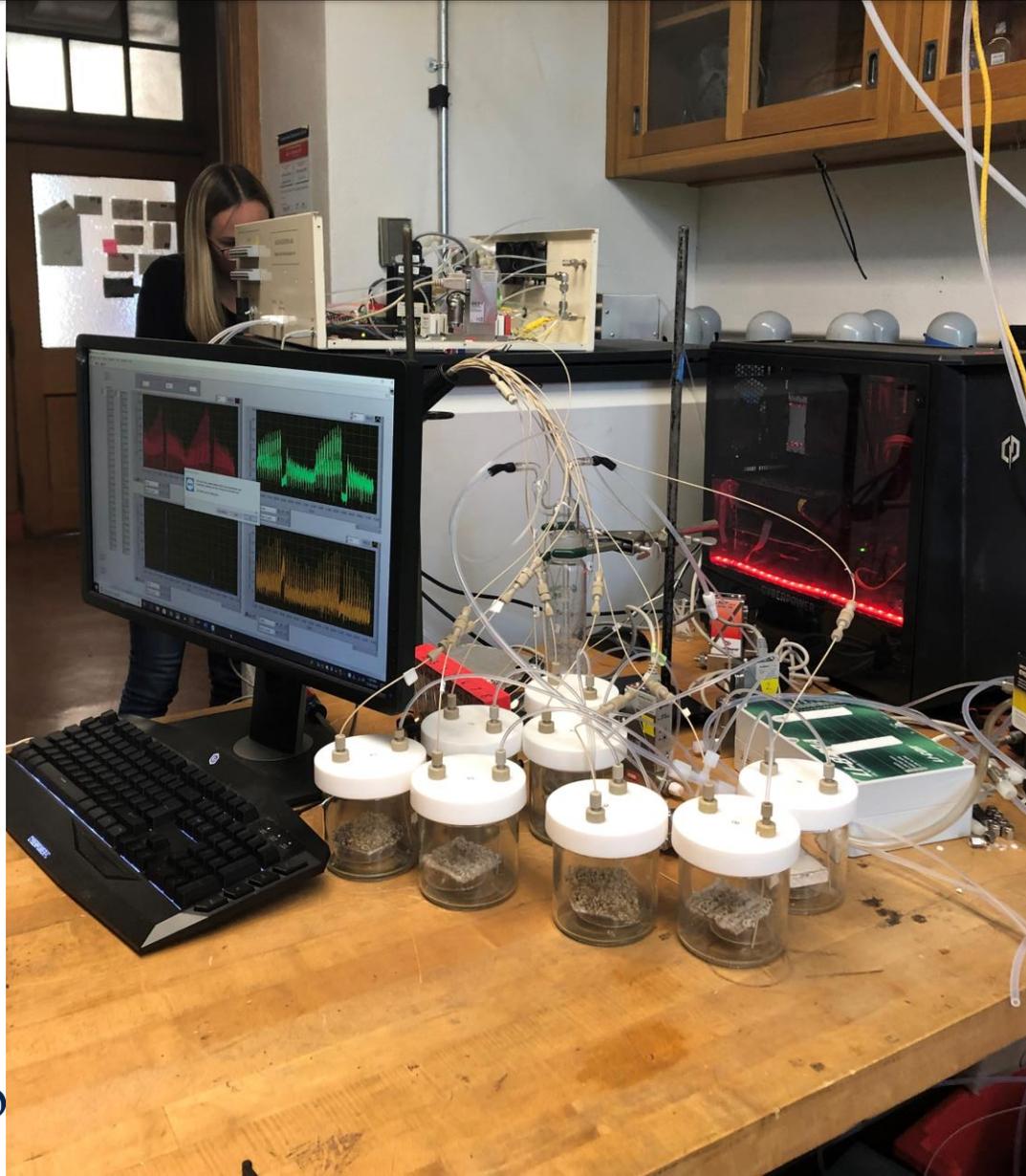
Carpet with dust and drywall were incubated in triplicate at 50%, 65%, 70%, 75%, 80%, 85% and 95% RH



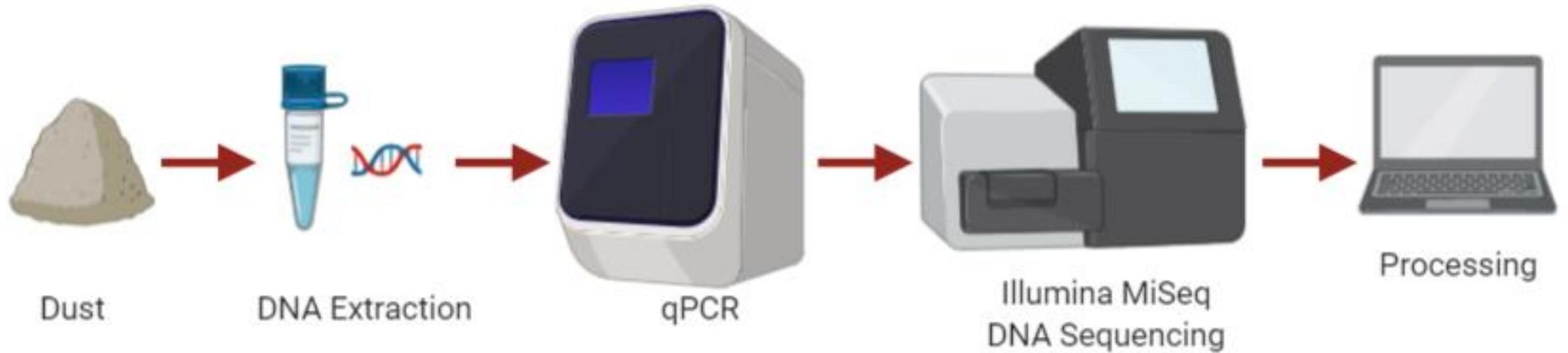
Incubated 4 weeks, 25°C



Proton Transfer time-of-flight Mass-spectrum (PTR-ToF-MS)

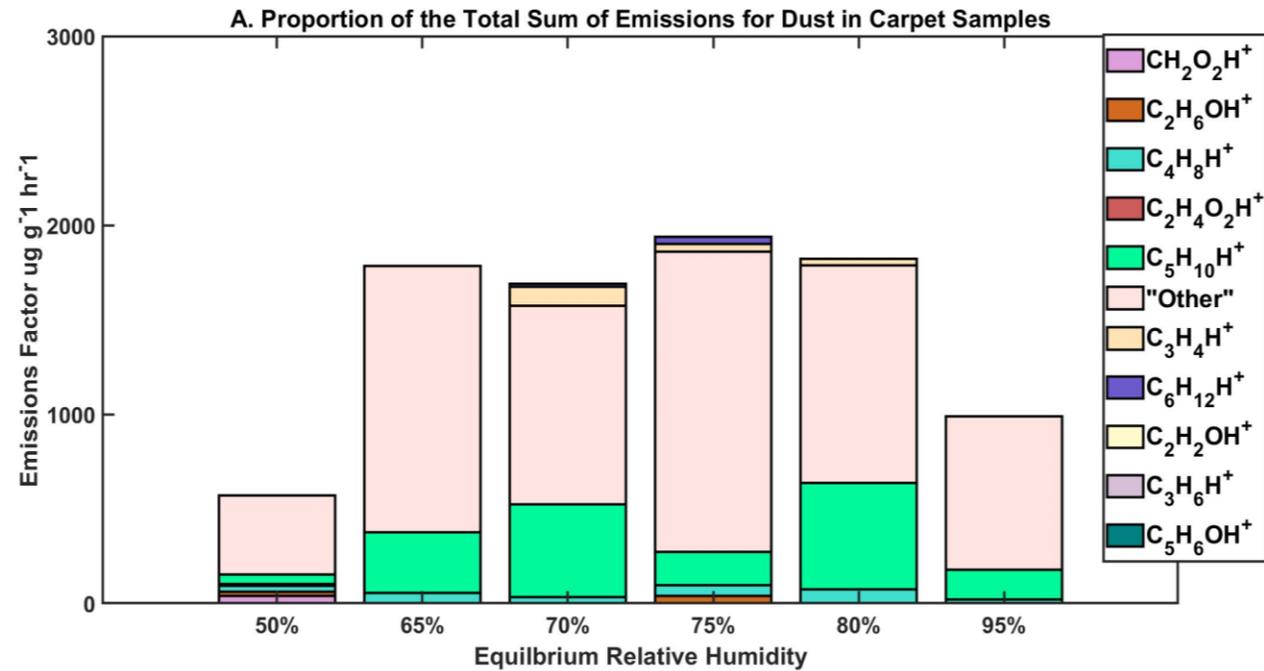


DNA based measurements and processing

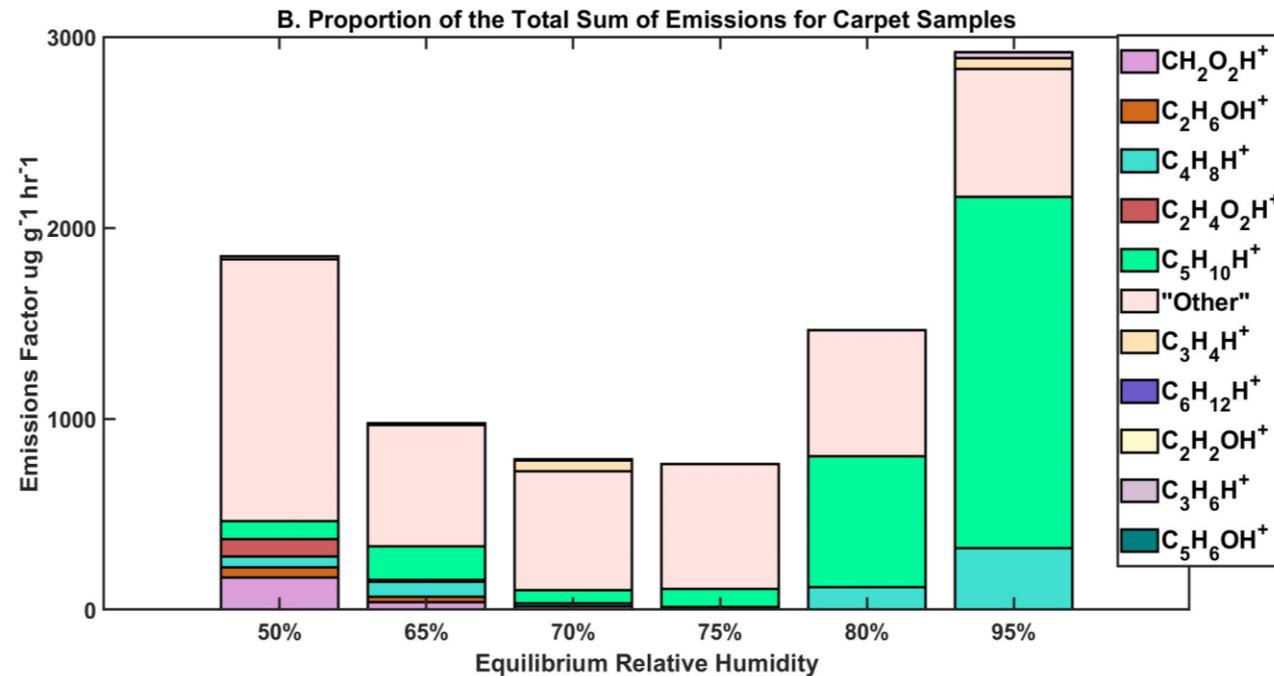


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Moisture and presence of dust influences concentration and emissions type



Likely includes microbial VOCs



Non-microbial VOCs

Certain mVOCs maybe associated with harmful health implication

- Limonene – may react with ozone and produce allergenic compounds
- Odor irritation and comfort of residents
- mVOCs could be used to detect mould in housing in future

Technological advances in chemical detection may lead to mVOC and mold detection indoors



Smartphone App for Residential Testing of Formaldehyde (SmART-Form)

Siyang Zhang^a, Nicholas Shapiro^{b,c}, Gretchen Gehrke^b, Jessica Castner^{d,e}, Zhenlei Liu^f, Beverly Guo^f, Romesh Prasad^f, Jianshun Zhang^f, Sarah R. Haines^{g,h,i}, David Kormos^h, Paige Frey^j, Rongjun Qin^{h,k}, Karen C. Dannemiller^{h,i,*}

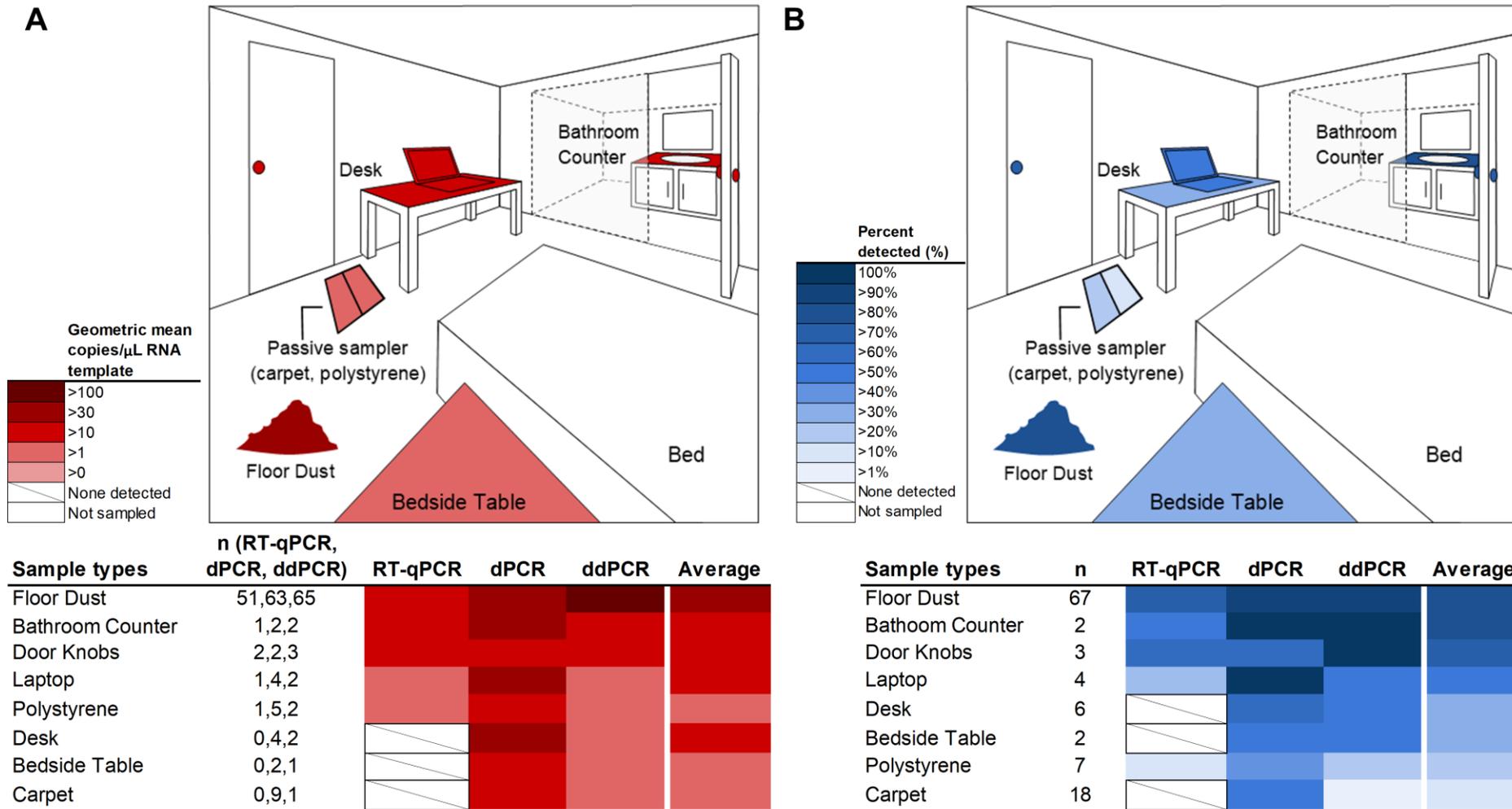


ONGOING WORK

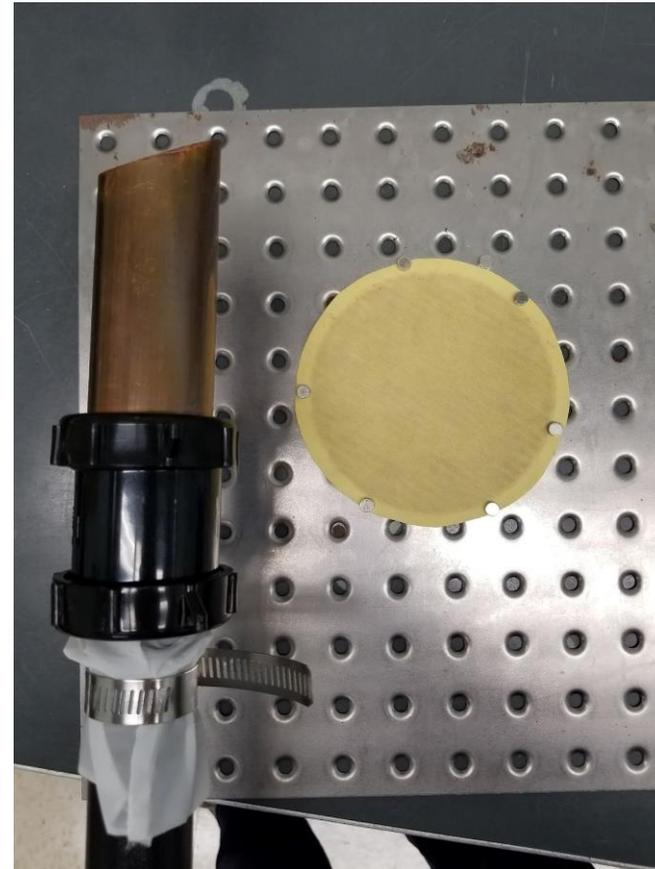


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Bulk floor dust is a potential matrix for monitoring viral disease outbreaks in high-risk populations and buildings



Estimating airborne concentration of SARS-COV-2 using filter forensic techniques



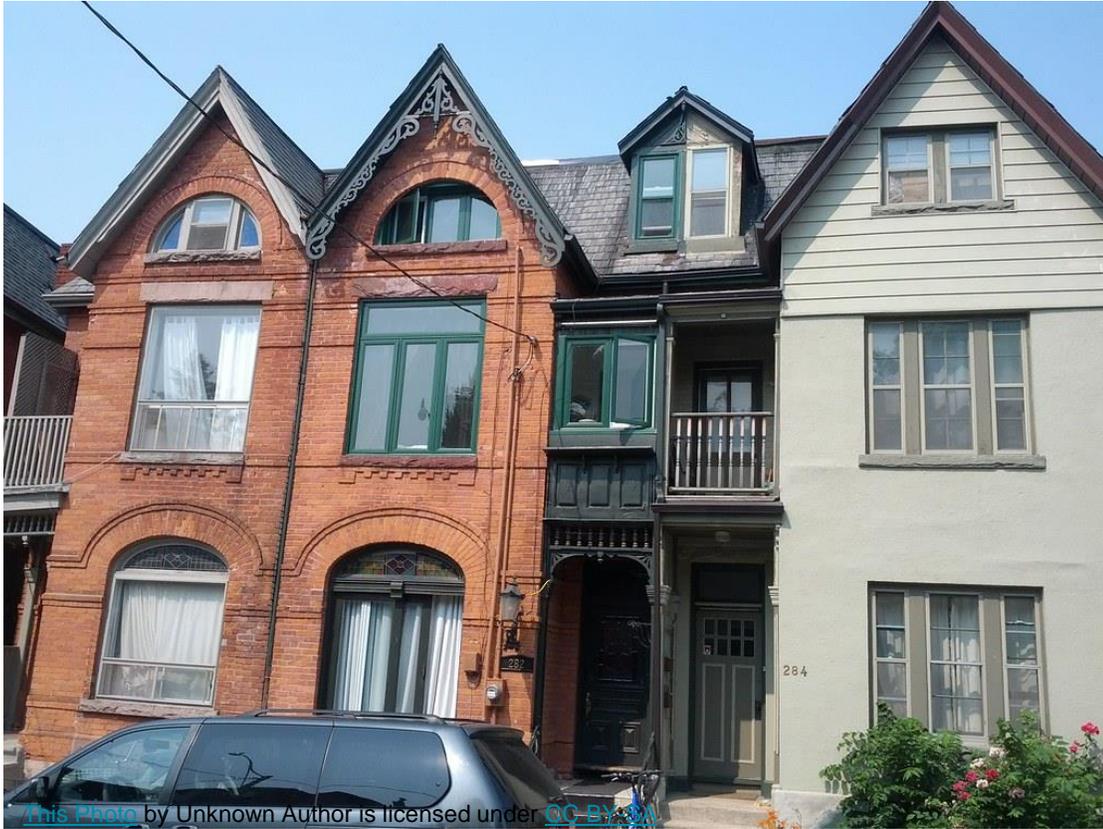
Zoe Hoskin – UofT MSc student



Dr. Jeffrey Siegel, UofT

Toronto Sampling locations – December 2021 – July 2022

~ 1 week sampling

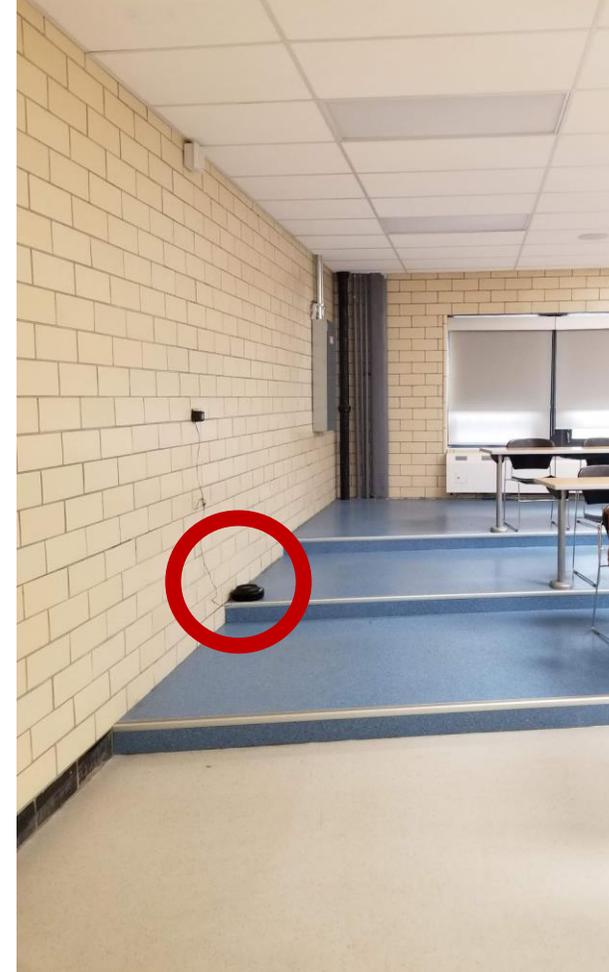
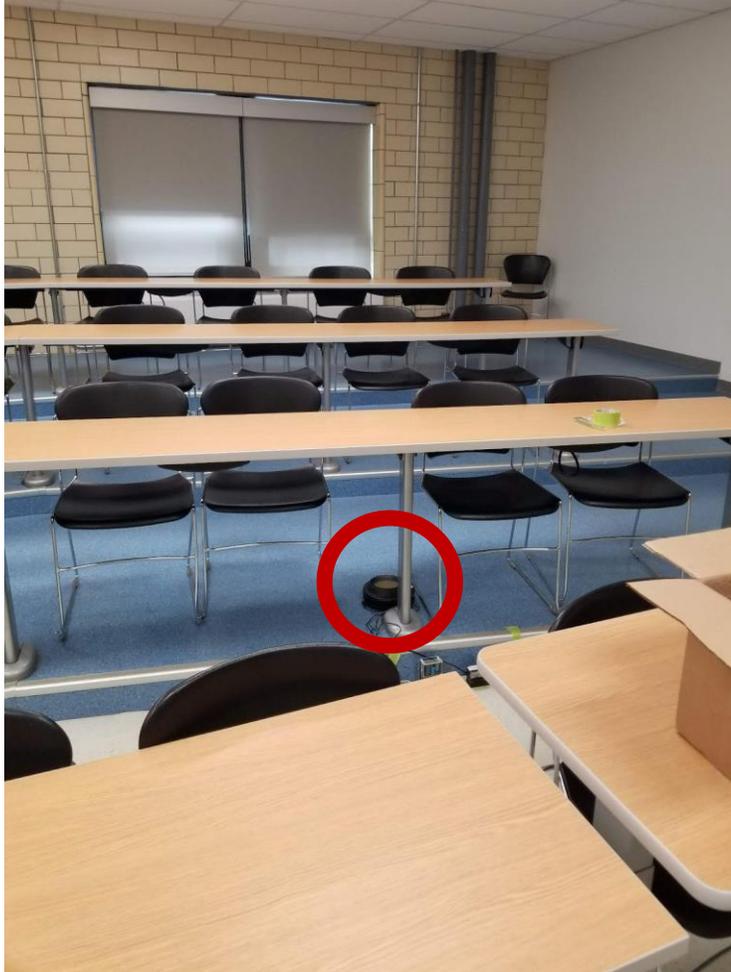


Deployed 3 portable air cleaners (PACs)
in 6 different houses

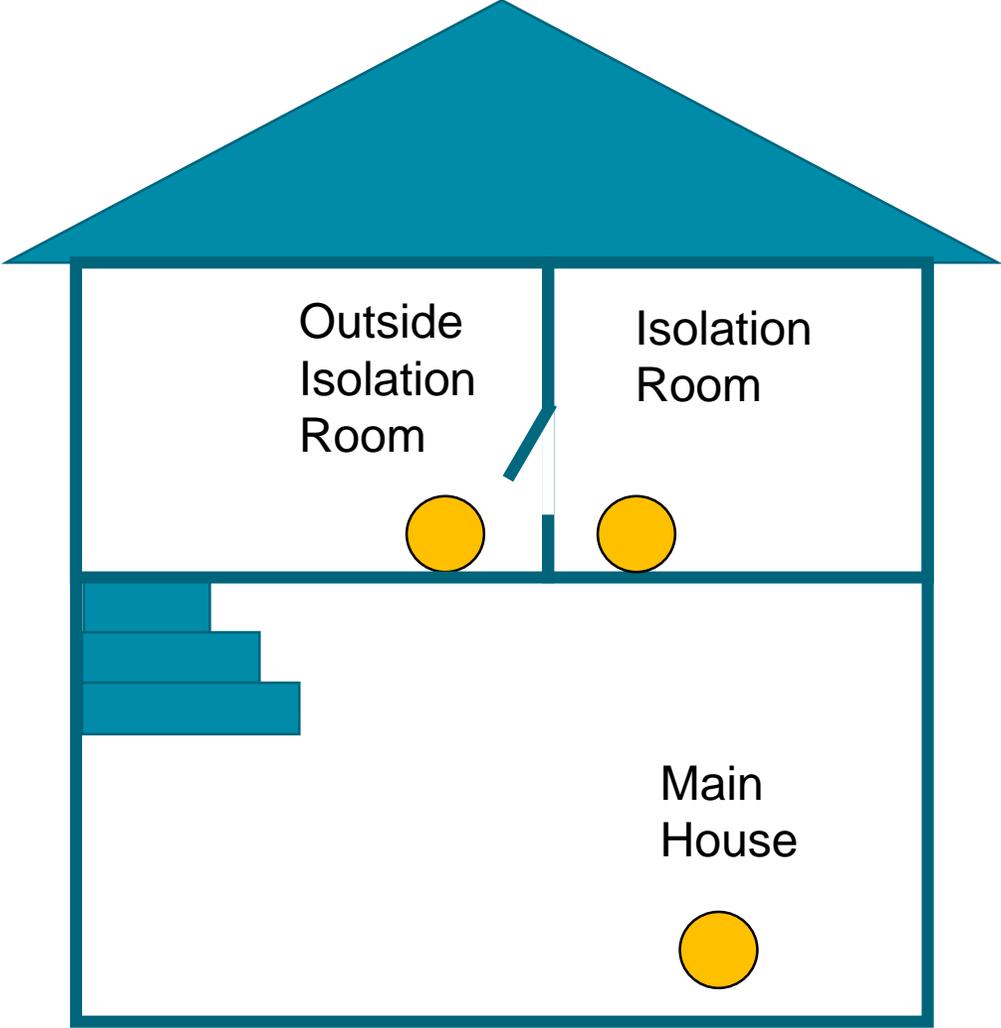


Deployed 2 PACs in 5 different
classrooms

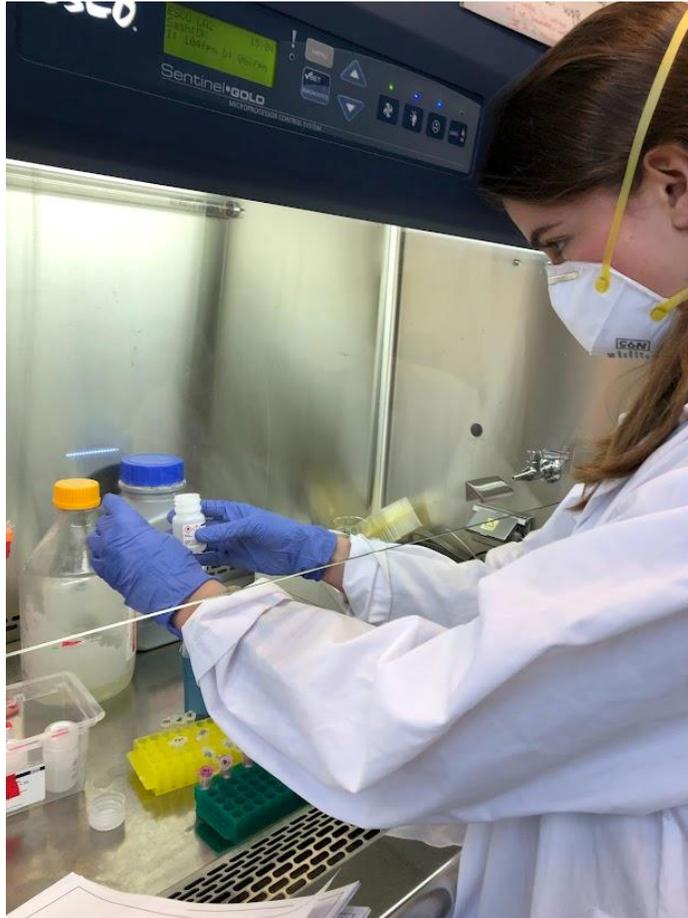
PAC 1 and 2 put in different locations in the classrooms

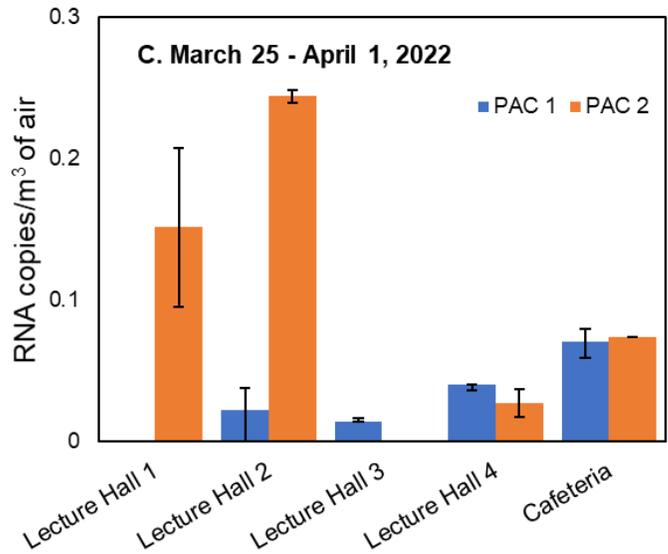
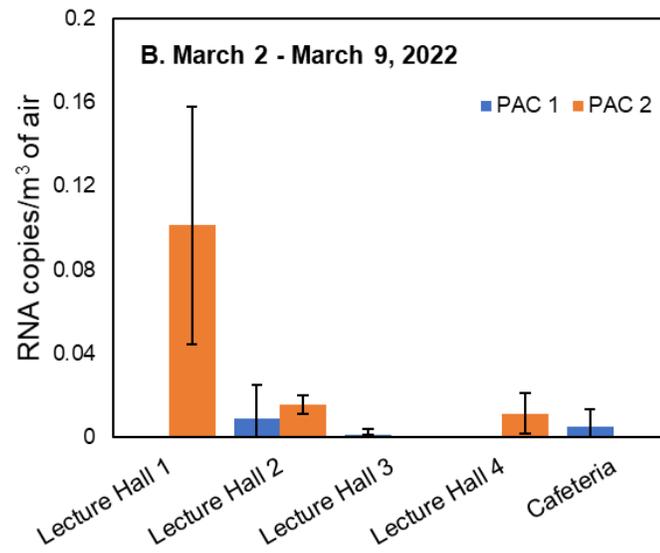
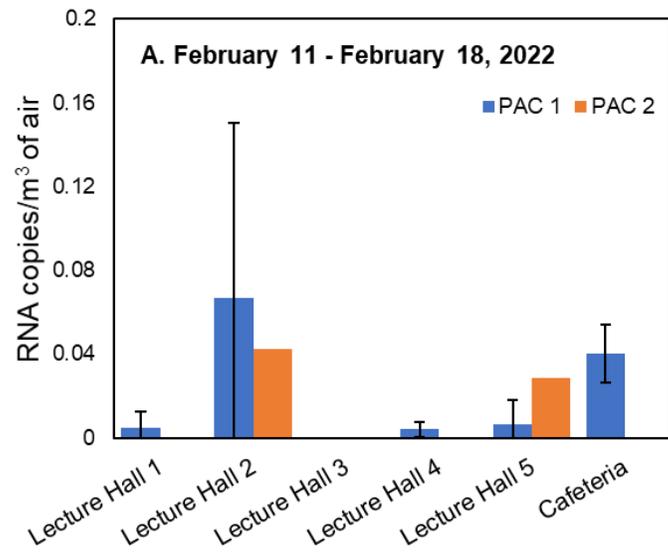


Home environments PACs placed inside isolation room, outside isolation room, in main living space



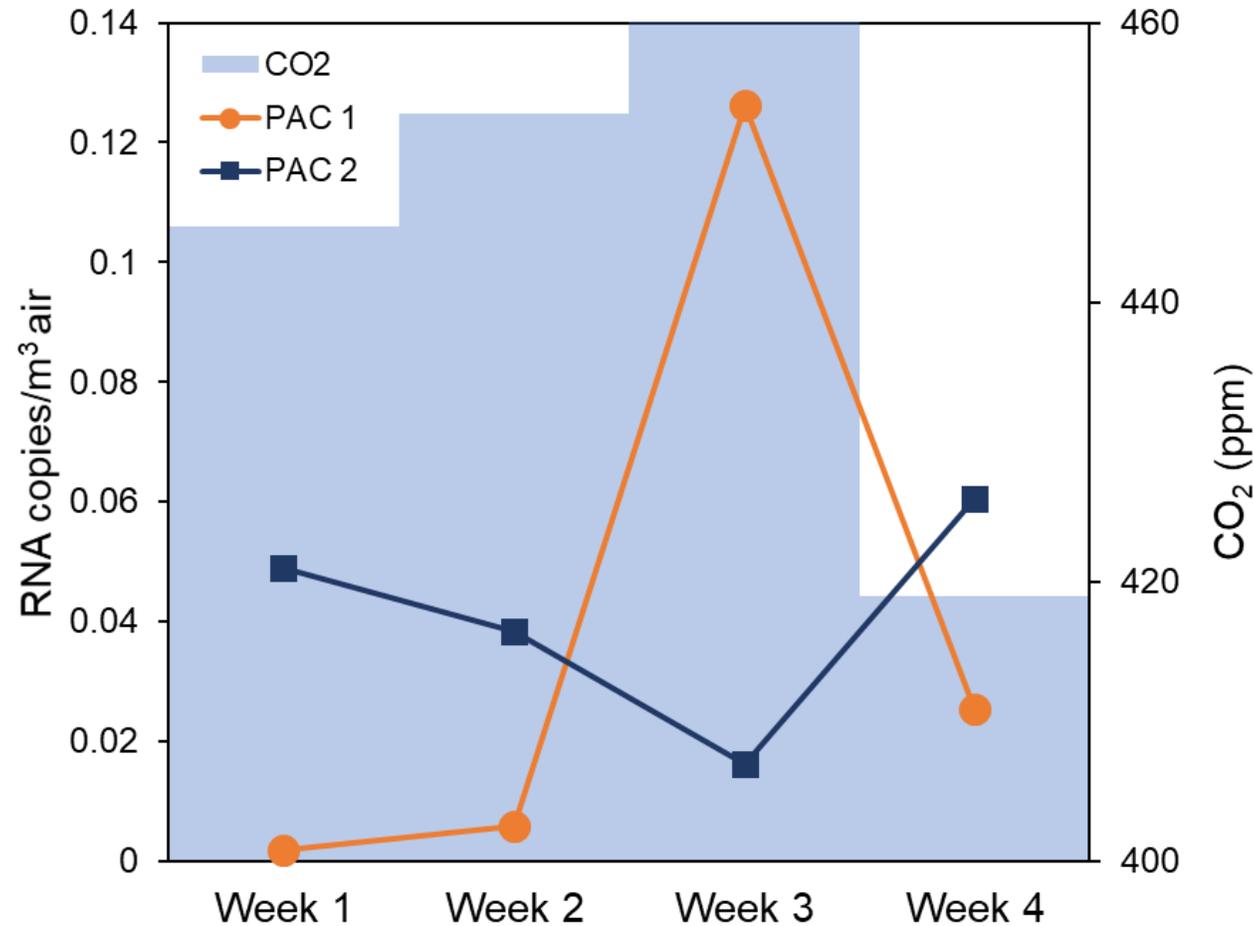
RNA extractions and qPCR to determine quantity of SARS-CoV-2 RNA in dust samples



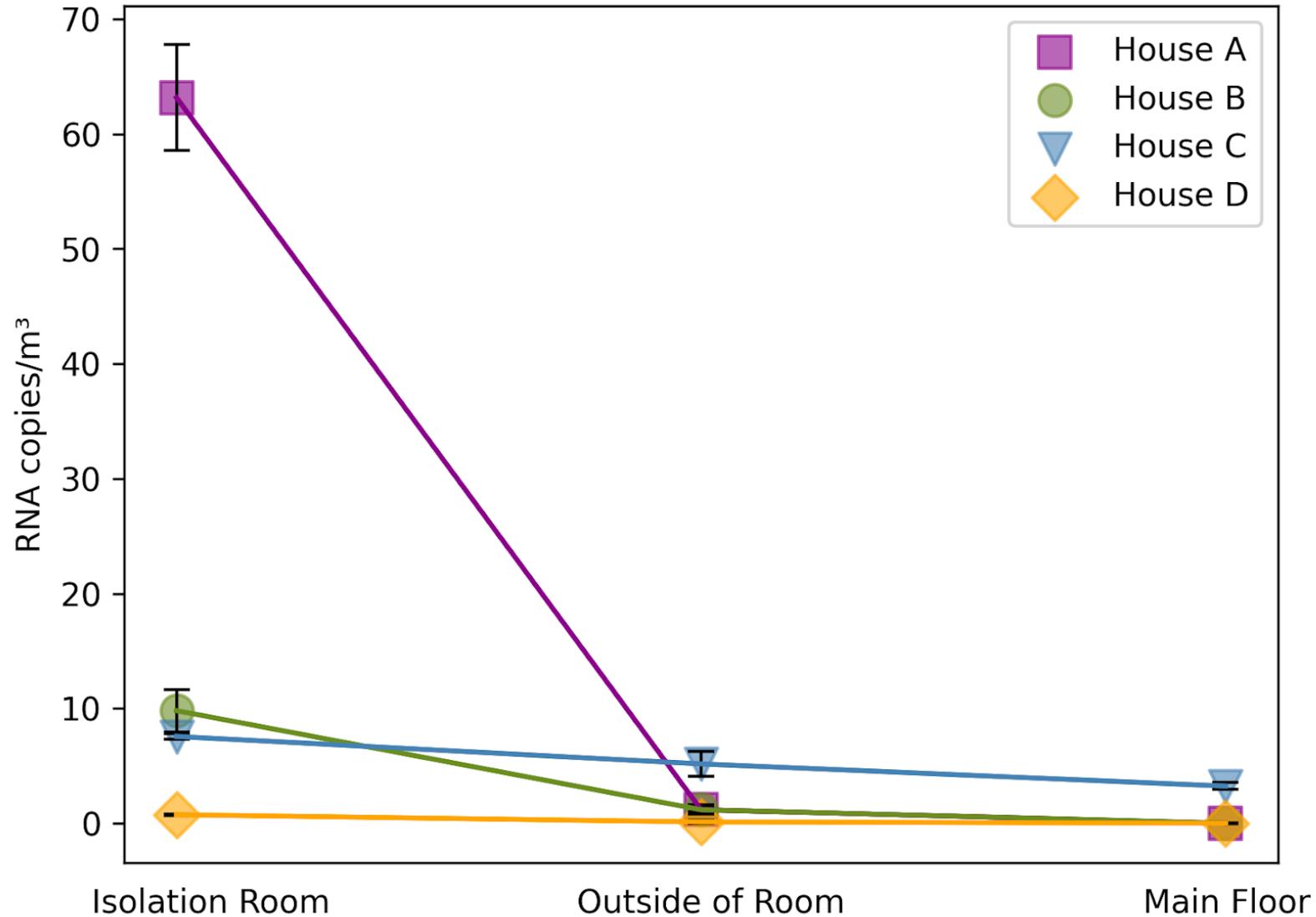


SARS-CoV-2 RNA detected in classroom dust samples

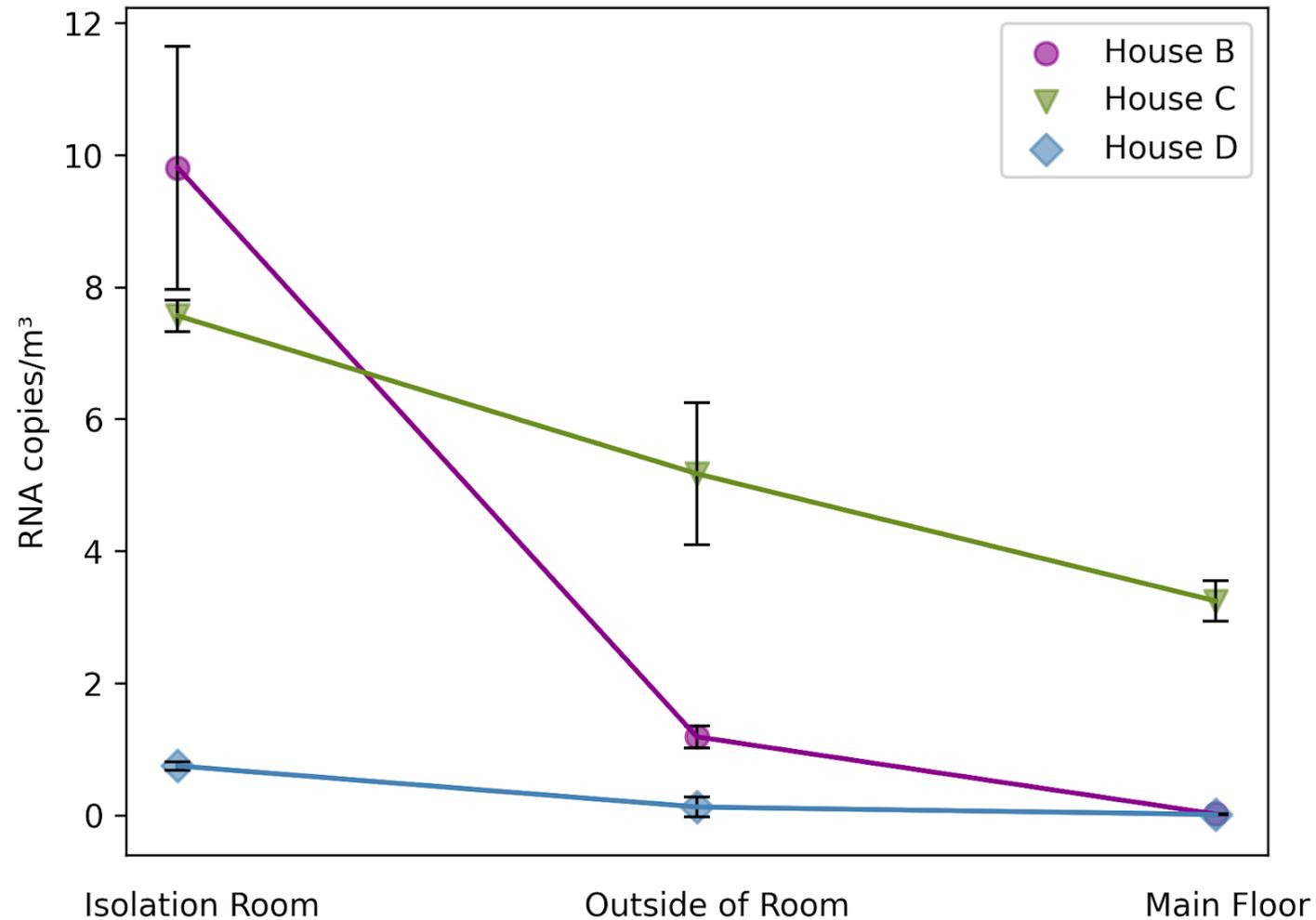
CO₂ levels used as basic marker of occupancy in one classroom



Airborne concentration of SARS-CoV-2 in COVID+ homes



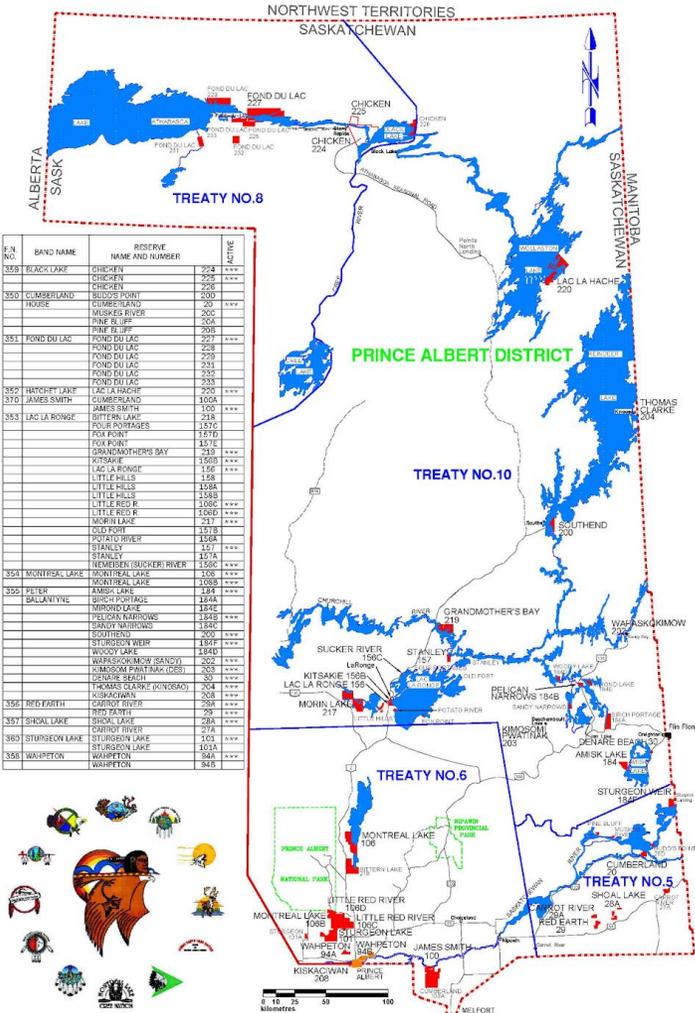
Airborne concentration of SARS-CoV-2 in COVID+ homes



MOULD IS PREVALENT IN NORTHERN INDIGENOUS HOUSING



COLLABORATION WITH PRINCE ALBERT GRAND COUNCIL AND HOUSING NWT TO IMPROVE HOUSING QUALITY IN THE NORTH



Natalie Clyke
House 1 Solutions



Helen Stopps
Toronto Metropolitan University

ACKNOWLEDGEMENTS



ALFRED P. SLOAN
FOUNDATION



Berkeley
UNIVERSITY OF CALIFORNIA



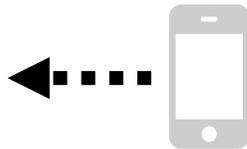
TEXAS
The University of Texas at Austin



THE OHIO STATE UNIVERSITY



Ohio Supercomputer Center
An OH·TECH Consortium Member



Take a picture to
stay up to date with
my research



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QUESTIONS?

SYSTEM OF DATA VALIDITY

- LOD: 1 copy of RNA per 4uL reaction
- LOQ: 4 copies of RNA per 4uL reaction
- 3 wells of PCR per sample

Validity label	Definition
Valid	2-3 wells above LOQ
LOQ flag	2 wells had LOD and one well has LOQ
LOD flag	2 wells had at least LOD, one well has < LOD