Healthy house – 40 years of lessons learned

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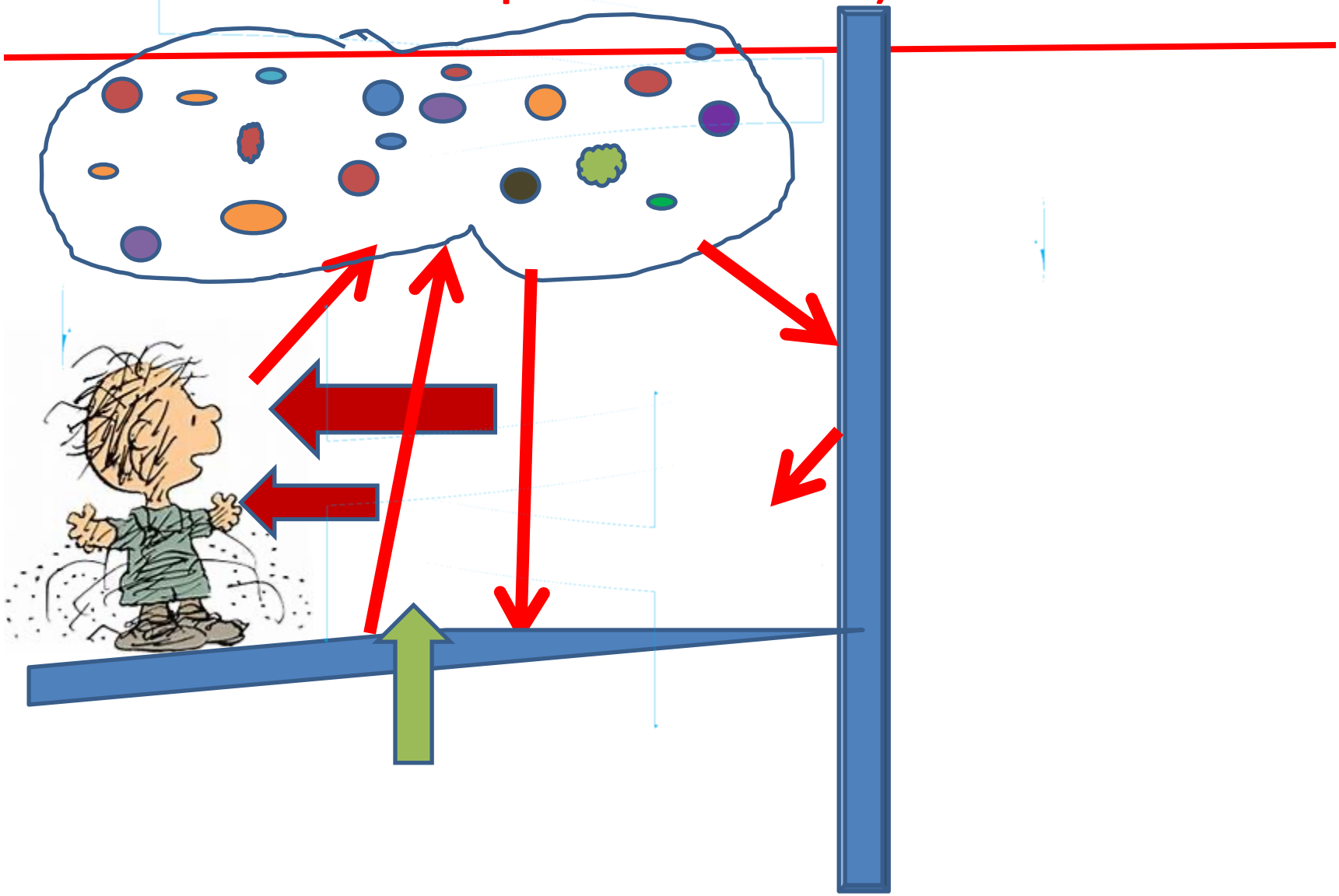
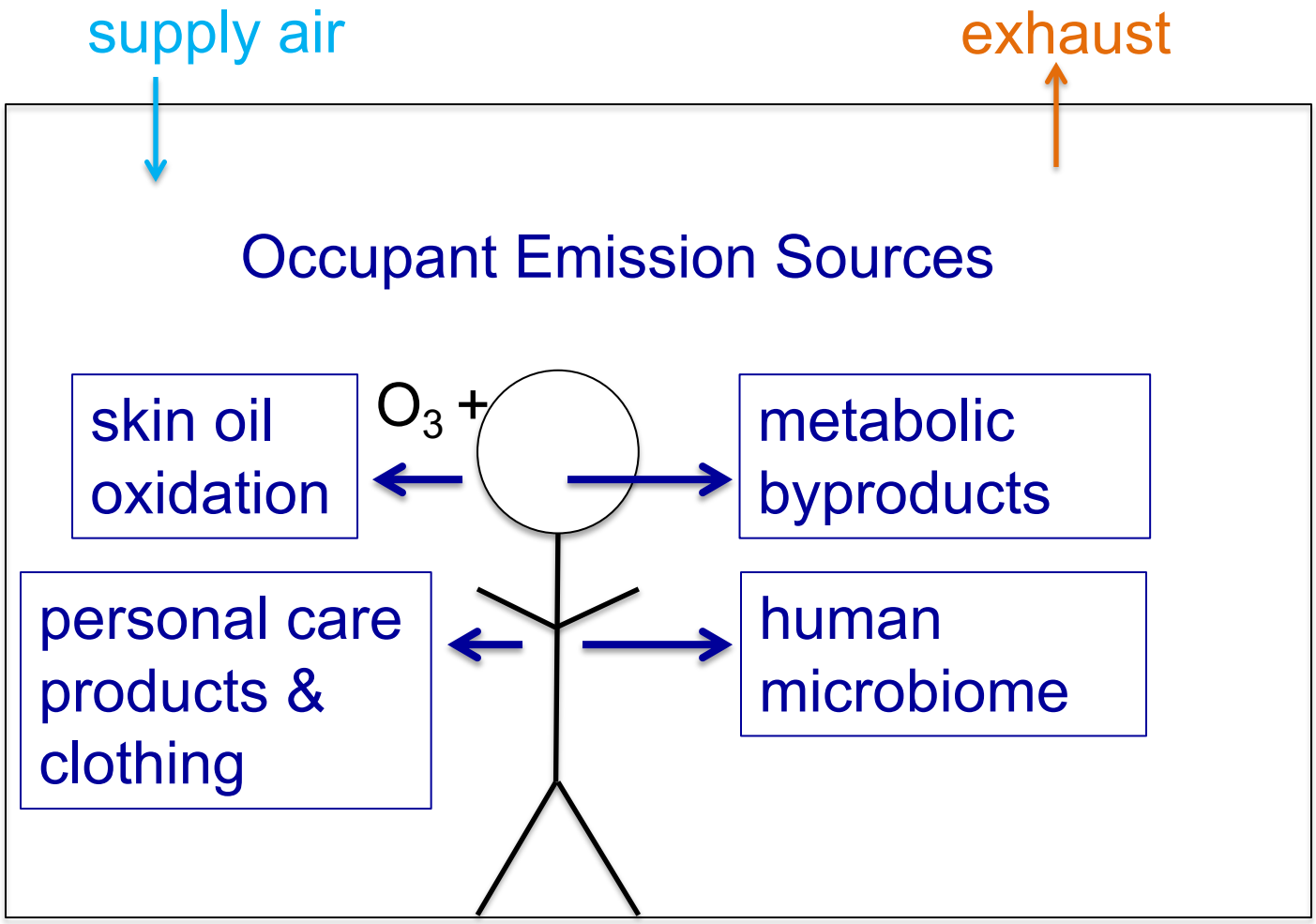
Slides will be available for download from BuildingEcology.com tomorrow

It’s all about people: physiology, metabolism, and behavior (the elephant in the room)



Slide from presentation by the senior author, Allen Goldstein

Human Emissions Indoors



Why is IAQ important?

- **We inhale more air per day by weight than we eat and drink by weight.**
- How much air do you breathe in one breath?
  The **average** adult, when resting, **inhales** and exhales about 7 or 8 liters of **air** per minute. That totals about 11,000 liters of **air** per day. 5% of that is for oxygen used to produce energy at the cellular level. 11,000 liters of air 0.05 * 60 * 24 ~ 2,000 liters of oxygen from air per day. 0.05 * 40,000 = 2,000 liters (or roughly 440 gallons) of oxygen per day.

  1 ppb = .000,000,001 (10^{-9})

  1 ppt = .000,000,000,001 (10^{-12})

Why are you here?

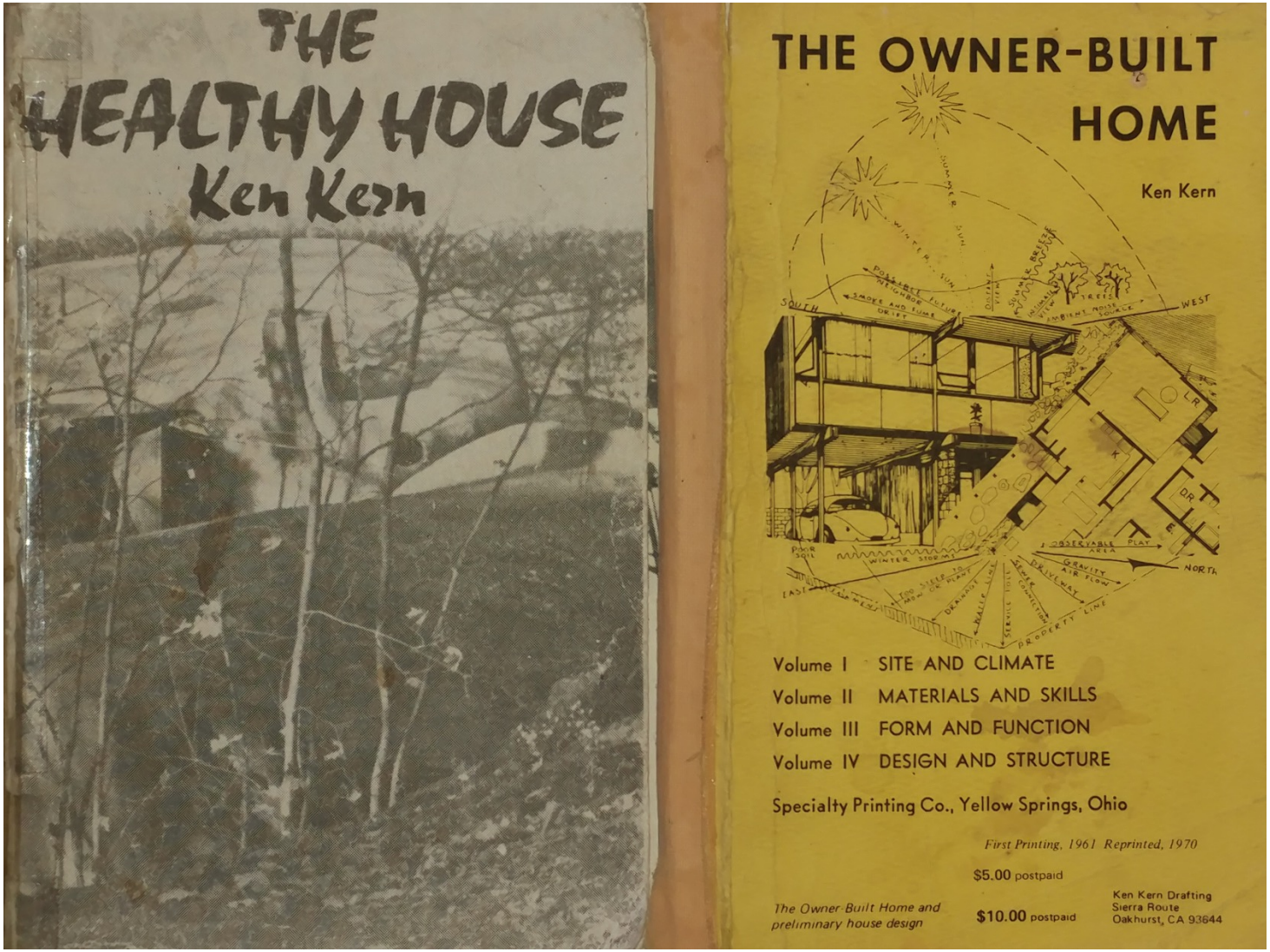
- Asthma
- Allergy
- Sick building syndrome (SBS)
- Curiosity – looking for ways to improve health
- Green envy: what's the best material for….
- Children coming, renovation planned
- Children gone – special problems of old age and indoor environment (more time spent at home)
- Other: ?????

40 years ago this month

- Robert Roskind, co-founder of the Owner-Builder Center, Santa Cruz and Berkeley, presented points from Ken Kern's final draft of his self-published book *The Healthy House: An Owner Builders Guide to Biological Building.*
  TOC- everything including the kitchen sink

- Based on translation of two European books on Baubiologie
- Influenced me (Changed the course of my career) due to my work to help owner-builders design and build their own houses and my service in Colombia as a PCV – working with and living with rammed earth and bamboo construction materials. And my position as a member of the State Board of Architectural Examiners.
- Who knew buildings could make people sick?

“The Healthy House, an owner-builder’s guide to biological building” (Ken Kern)



Who was Ken Kern?

- Author of the owner built home – ca. 1970
- I bought my copy for $5.
- For $10 Ken would draw a design for the purchaser
- Kern perished when the experimental earth-based house he built collapsed on him during a storm.

Major Health Effects of Indoor Pollutants

- Infectious disease:
  - flu
  - cold
  - pneumonia (Legionnaires' Disease)
  - Pontiac fever
  - Tuberculosis
  - NorovirusCancer, other genetic toxicity, teratogenicity - (Ecotoxicity)
- Asthma and allergy
- Other – potentially all the illness caused by skin and gut microbiome
- Chemical sensitivity (or insensitivity)
- Non-specific symptoms (SBS)

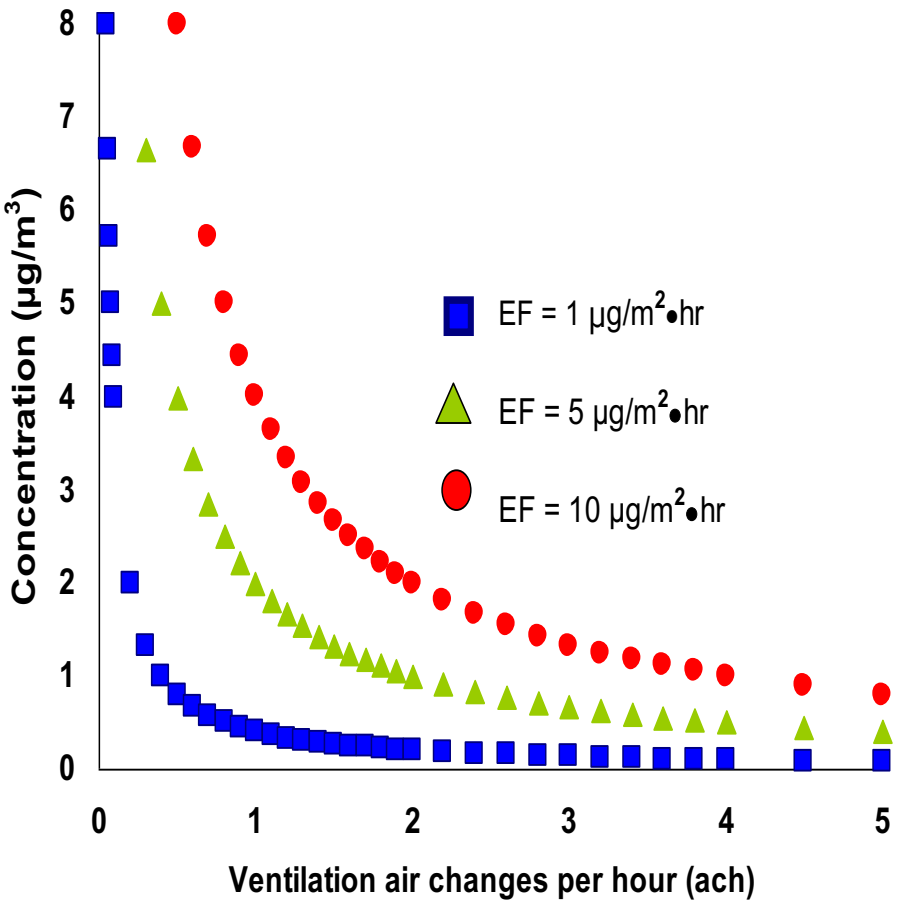
Summary of what we know about … indoor environment and health

- Thermal control and energy drive design, operation, and sometimes maintenance.
- Summary of what we know - Not very much, but more than 40 years ago.
- Not all people are alike
- Not all buildings are alike
- The same building minutes or hours apart is different
- Two buildings built to the same design on adjacent sites can be very different from each other
- Ventilation is not the answer
- Source control is the most effective strategy for healthy Ind Envt
- Science is not going to answer practical questions – scientists are pushed toward generalizations, but your house and my house are not just units in large datasets (larger dataset >>> smaller *p*-value .. Higher stat. significance)
- therefore, the greater the statistical significance
- Statistical significance is not the same as importance

Concentration = approximately ER/Q

[Concentration = Emission rate/ventilation rate]

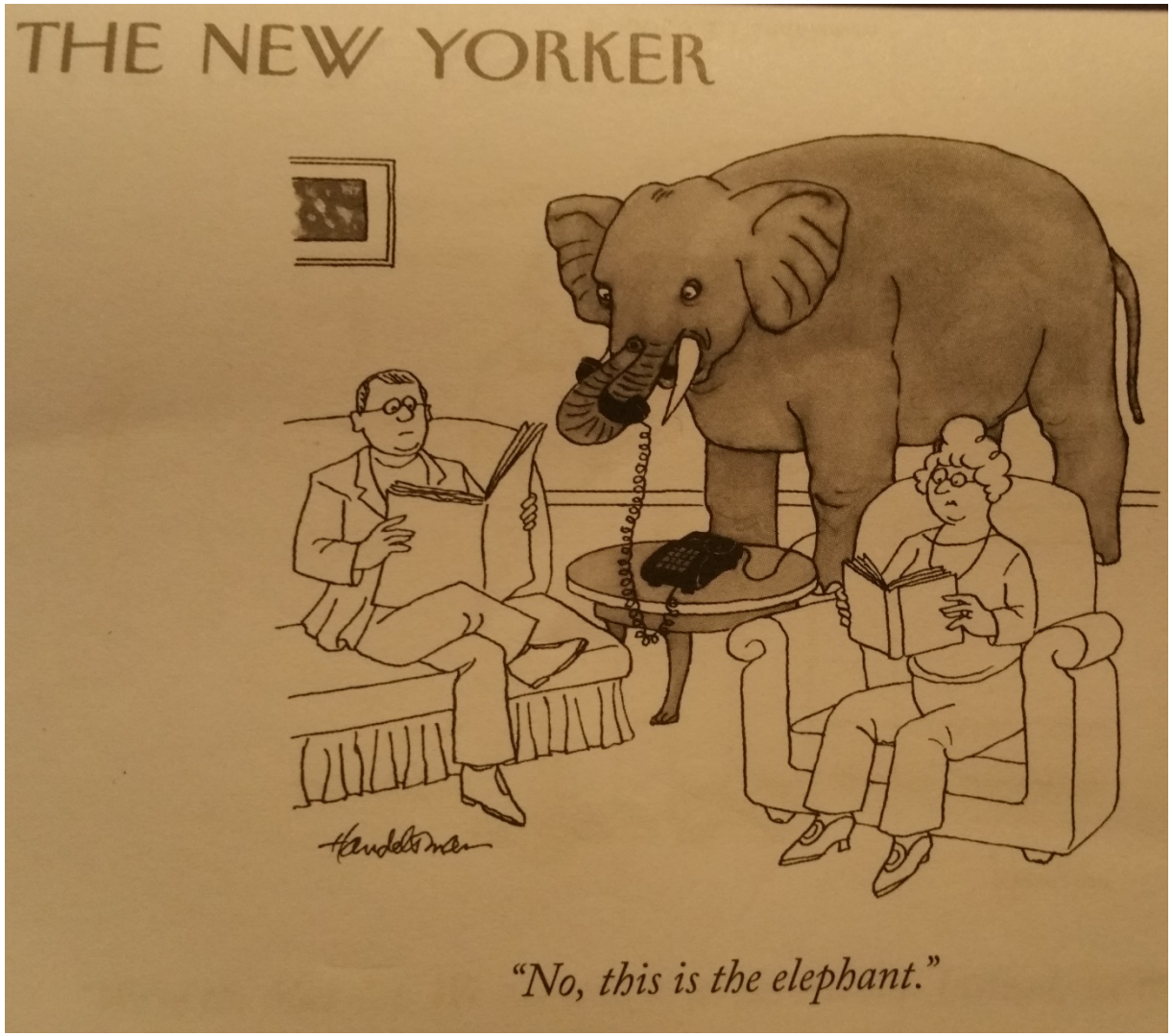
[used by permission from Hal Levin]



What's new?

- Indoor air chemistry: previously unobserved ROCs now observed- advances in scientific instruments: OPTR-TOF ppt real time concentrations
- Improved air cleaning devices and vacuums
- Microbes as part of the dynamic, constantly evolving indoor ecosystem
- People as the main source of chemicals, biologicals
- Behavior as the main factor
- Climate change

It’s the Elephant in the room



“hard” science vs “soft” science

- IEQ science driven by chemistry, physics and engineering. Biology plays a minor role, psychology almost none.
- Form follows funding – scientists must get funded
- Much disrespect for soft science – behavior largely ignored
- IMHO - The most important factor is human behavior: What we buy, how and when and where we use it, and how we operate our household equipment: exhaust fans, windows, stoves, heaters, etc.
- Most important single measure; restrivting smoking in public access buildings.
- Still no protection from ETS exposure for children at home

Clean house = happy house?

Are so-called green products any better.

Smells good too!

- Research done for the California Air Resources Board shows that reactions [illegible] O3 [illegible], large quantities of UFP, acidic aerosols, formaldehyde, and higher molecular weight aldehydes.

- (Nazaroff and Weschler)

VOC Source strengths in pre- and post-occupancy periods of a new California state office building

Figure 1. 6th floor TVOC source strengths (µg/m² h)

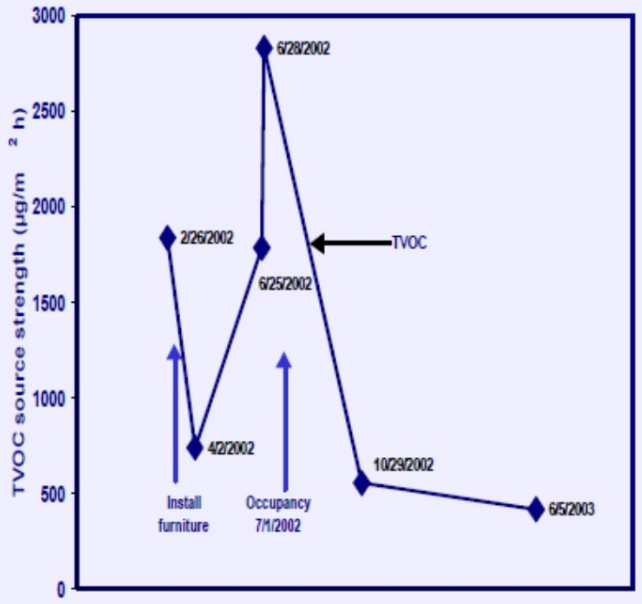
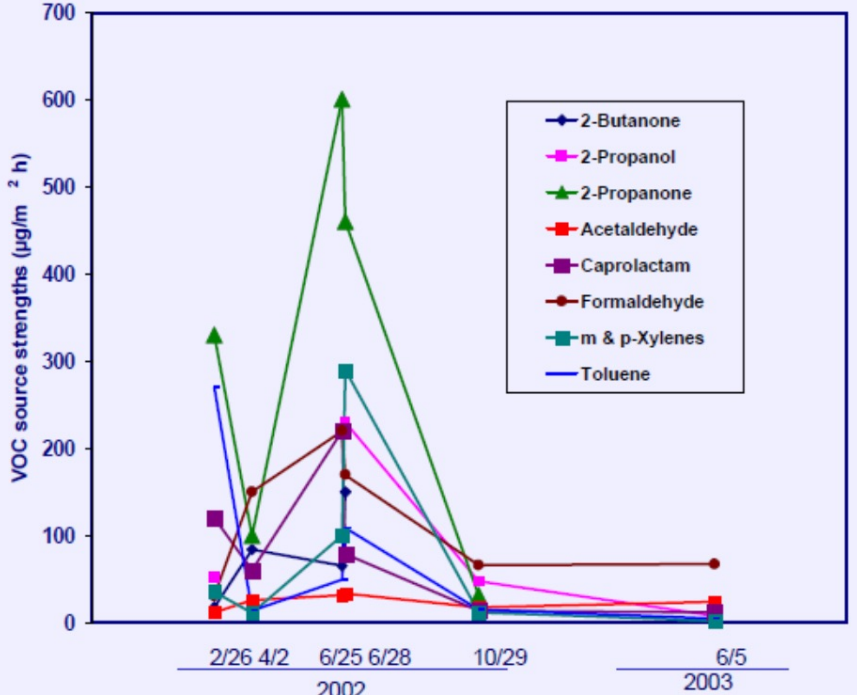


Figure 2. 6th floor VOC source strengths (µg/m² h)

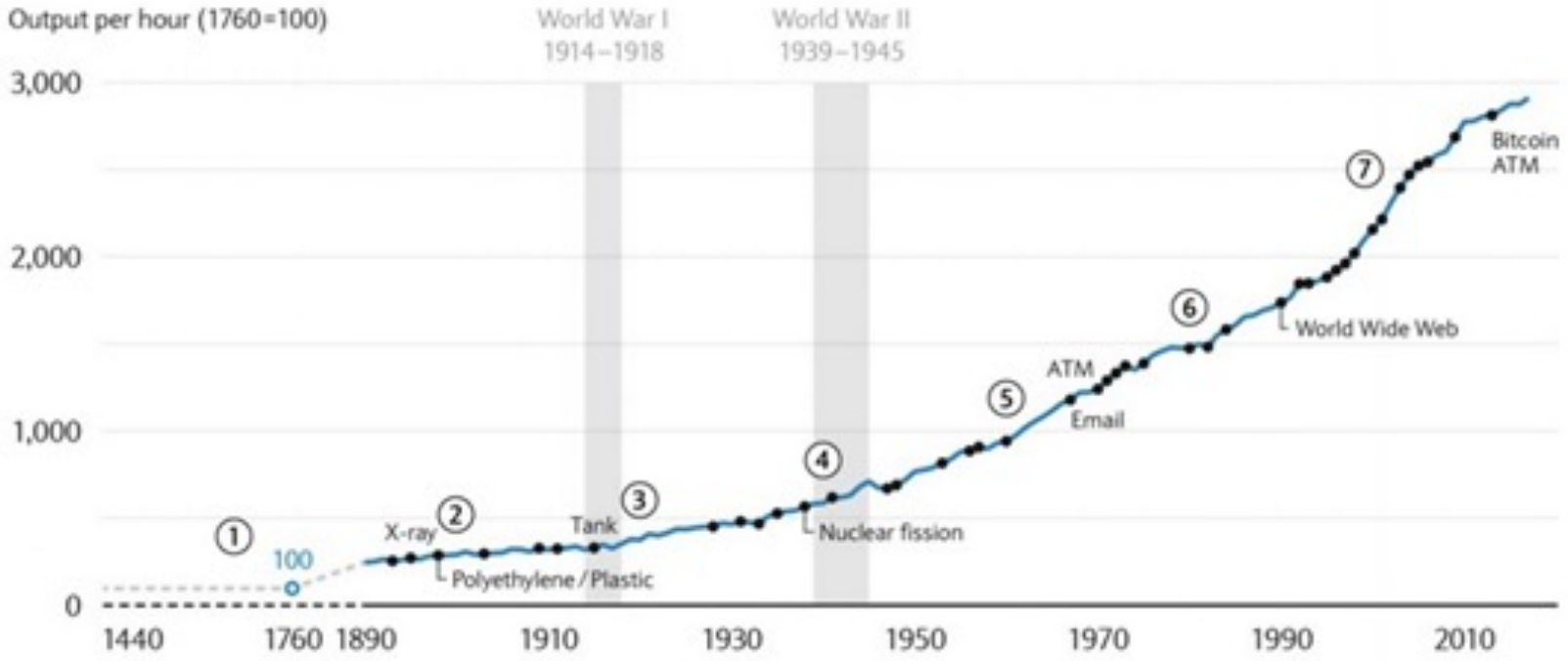


(Levin and Hodgson, 2003, International Society of Exposure Science Annual conference, Stresa, Italy)

Co-Evolution of technology and society

FIGURE 1

From the printing press to the global internet, technology has evolved, and human societies with it



Evolution of Indoor Air Quality reearch and applications

- Printing press > literacy > night illumination > combustion by-products (smoke)
- Industrialization – urban pollution
- Electrification: fossil fuel combustion > more air pollution

What's the problem?
Leading causes of early death and disability in the US, 2016*

- **1** Ischemic heart disease
- **2** Lung cancer
- **3** COPD
- **4** Diabetes
- **5** Low back pain
- **6** Alzheimer's disease
- **7** Opioid use disorders
- **8** Other musculoskeletal
- **9** Major depression
- **10** Migraine

What's the problem?

Does indoor environmental quality affect any of these (other than COPD)?

What's the problem:
Major indoor environmental hazards

- Fine particulate matter (<2.5 µm in Mean Aerodynamic diameter)
- Volatile organic chemicals
- Formaldehyde
- Asbestos
- Lead
- Semi-volatile organic chemicals
- Microbes: bacteria, fungi, viruses
- Dust mites

What's the problem:
Major indoor environmental hazards

Fine particulate matter ($PM_{2.5}$)

1. Problem: these small particles penetrate into the deep respiratory system
2. Not a lot known about their mechanism of adverse health effects based on occupational exposure
   - Hazardousness based on health effects of occupational exposure: Shipyard workers; Car brake mechanics; HVAC maintenance workers
3. not all asbestos fibers cause health effects (shape and size are critical determinants but can't be learned from light microscope determination, requires electron microscopy).
4. Control: avoid products containing asbestos, extreme caution in removing asbestos containing products (usually resilient flooring.

What's the problem:
Major indoor environmental hazards

- **Volatile organic chemicals** (can become airborne at indoor environmental conditions. (BP, VP concepts)

1. Very diverse adverse health effects, target organs, and mechanisms. Guidance insufficient, Mixtures are important but very poorly understood.
2. Hazardousness based on occupational exposure studies – much higher concentrations, factory settings, guidance(ACGIH, OSHA) has been shown to be inadequate and misleading.
3. Sources: consumer products, furnishing, toys, clothing
4. Control: *caveat emptor*

What's the problem:
Major indoor environmental hazards

Formaldehyde

1. Problem related to fact that these formaldehyde is very water soluble, dissolves in the watery lining of the upper respiratory track, eyes, mucus membranes
2. Not a lot known about their mechanism of adverse health effects. Suspected carcinogen. Known irritant.
3. Hazardousness based on occupational exposure studies
4. Lots of publicity and attention in the late 1970s due to UFFI disasters. Front page *NYT*.
5. CHMC studies, regulations. Remediation in New England homes.

What's the problem:
Major indoor environmental hazards

ASBESTOS

1. Problem related to fact that these elongated mineral particles penetrate into the deep respiratory system
2. Not a lot known about their mechanism of adverse health effects
3. Hazardousness based on <u>outdoor</u> $PM_{2.5}$ exposure studies – 'not enough known about indoor PM2.5 composition' (J. Schwartz, HSPH)

What's the problem:
Major indoor environmental hazards

LEAD

1. Problem related to ubiquity
2. Affects nervous system, brain development in children.
3. Not a lot known about their mechanism of adverse health effects
4. Hazardousness based on many studies of exposure and health

What's the problem:
Major indoor environmental hazards

SEMI-VOLATILE ORGANIC COMPOUNDS

1. Problem related to ubiquity , longevity, lethality to living organisms
2. Affects nervous system, brain development in children.
3. Not a lot known about their mechanism of adverse health effects
4. Hazardousness based on many studies of exposure and health

What's the problem:
Major indoor environmental hazards

MICROBES

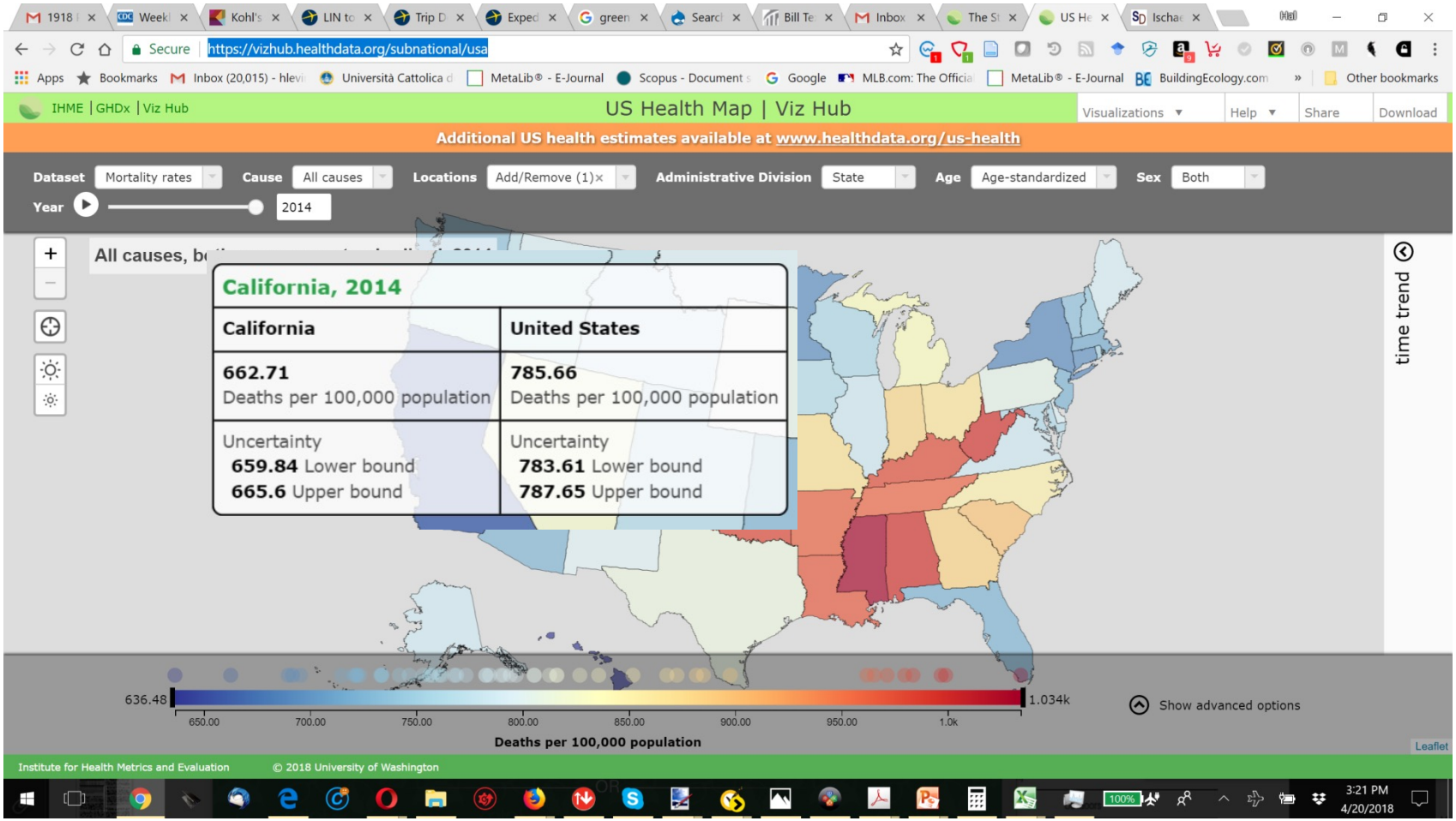
Fungi, Bacteria, Viruses

1. Problem related to ubiquity? No. good germs, bad germs.
2. Affects nervous system, brain development in children.
3. Not a lot known about their mechanism of adverse health effects
4. Hazardousness based on many studies of exposure and health - one

Lessons Learned

- Exposure is complex
  - Multiple exposures
  - Serial exposures
  - Cumulative exposures
- Buildings are ecosystems
- Science is evolving, imperfect
- The human body is not the same in all people
  - Wide range of sensitivity to odor, irritants
  - Yofgi Berra was right; It's 95% mental, the other half is physical
- WEcontrol our own exposures:
- Air, water and surfaces are all sources of pollutant exposure as a result of what we do.

Lucky to live in California, lower risks



Buildings are ecosystems

- When will they ever learn?

Complexity

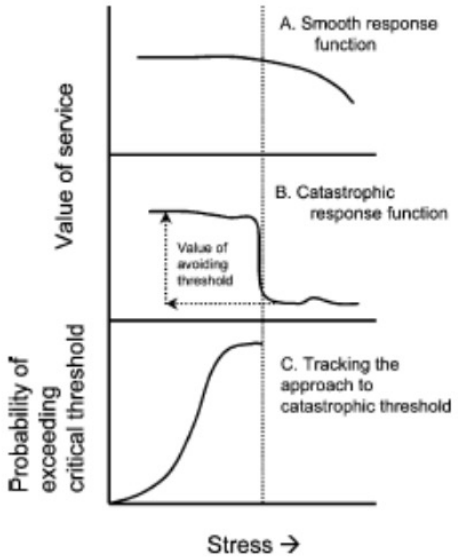


Fig. 2. Value responses to stress under 'marginal' (well-behaved dynamics) and 'non-marginal' (nonlinear, threshold dynamics) system behaviors.

Complex systems - emergence

- Emergent properties: As changes occur, the system becomes a fundamentally new system with no precedents.

- In philosophy, systems theory, science, and art, emergence is a process whereby larger entities, patterns, and regularities arise through interactions among smaller or simpler entities that themselves do not exhibit such properties.

Buildings are ecosystems

- Dynamic
- Interconnections among the parts and the occupants
- High variability
  - Texas tract houses designed and built the same have ventilation rates that differed by a factor of 2
- Occupant behavior is highly varied
- Weather influences passive ventilation
  - Old leaky houses > 5 air changes per hour (no wind)
  - New energy efficient houses < 0.1 air changes per hour (No wind)

It depends

- Answer to most questions about Indoor Environmental Quality

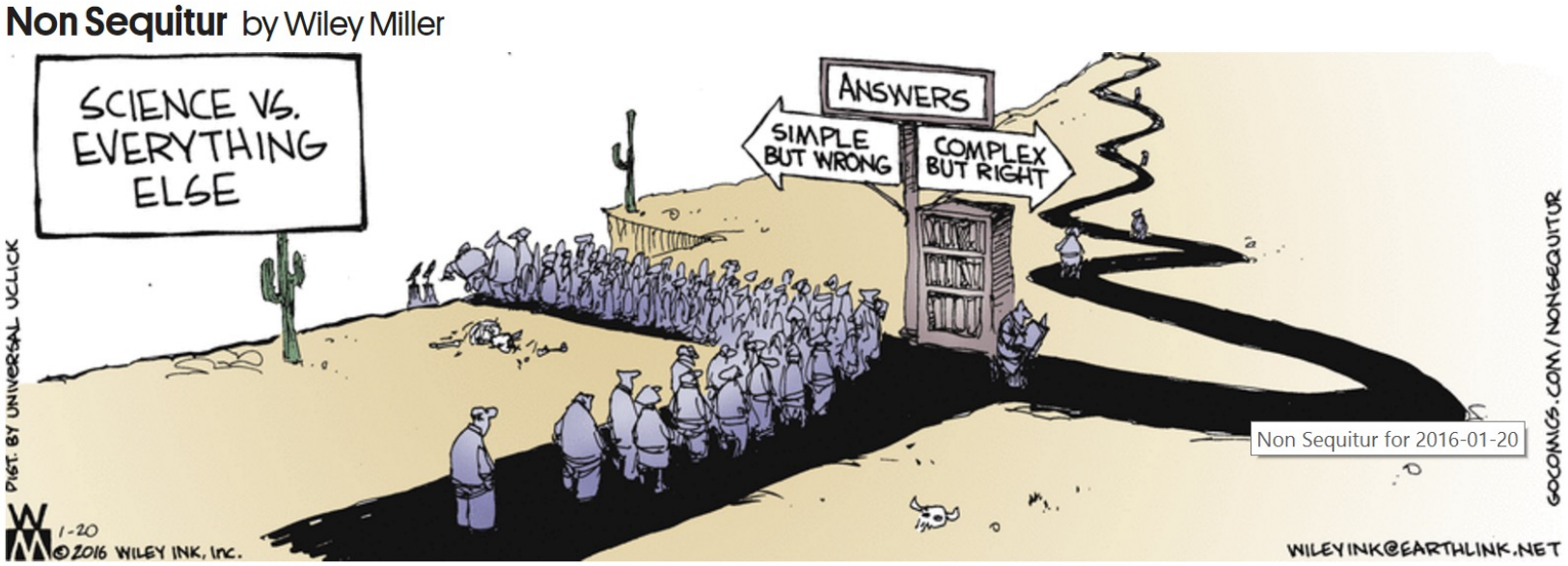
It depends

It depends

It depends

On what?

Simple



but wrong

Knowledge developed and stored in silos

Nothing is created,
Nothing is destroyed
Everything is changed

- Antoine Laurent de Lavosier

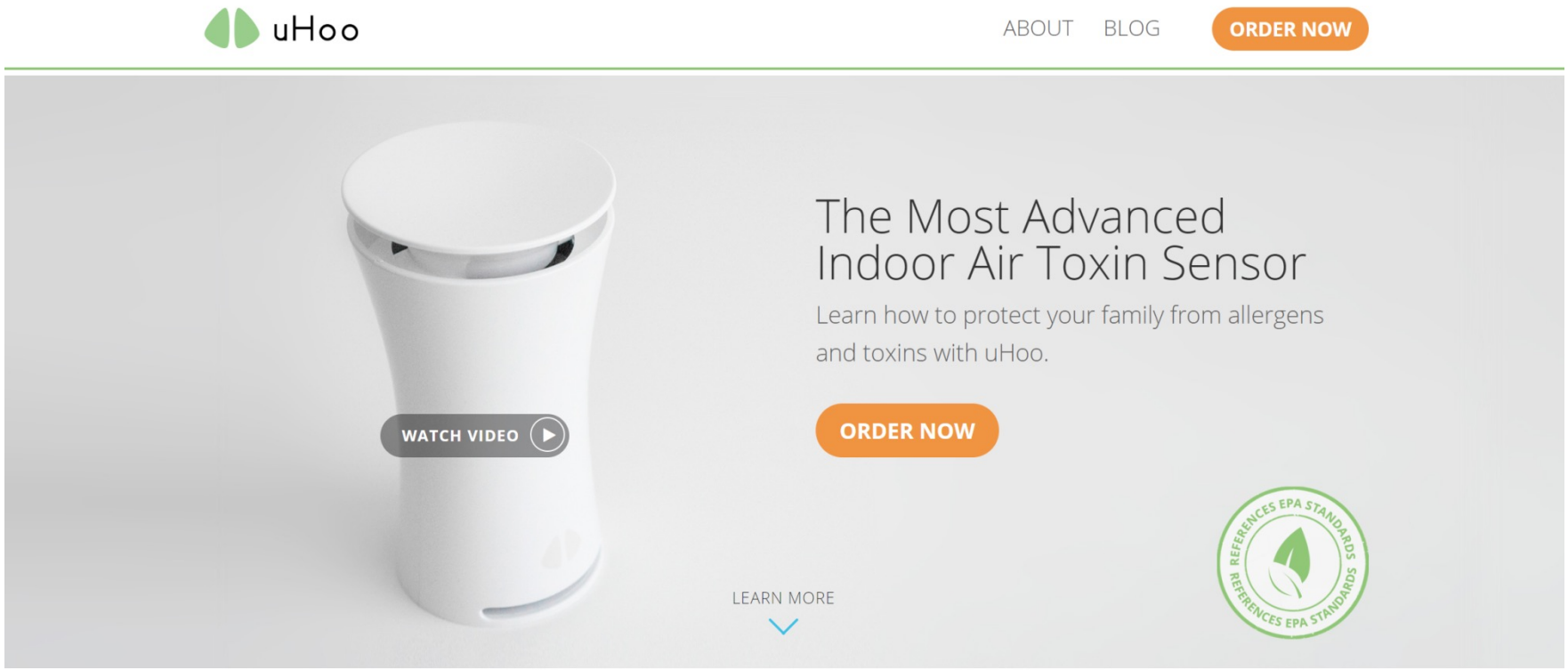
Next


NULLA SI CREA,
NULLA SI DISTRUGGE,
TUTTO SI TRASFORMA
ANTOINE-LAURENT DE LAVOISIER
Amsa
Gruppo a2a

Next

IAQ – a new market

- Air cleaners – focuses on Asthma, allergy market
- Smart sensors
- Air Filters
- Cleaning equipment
- Good vacuum cleaners
- Quiet exhaust fans
- Low emitting wet products (paints, adhesives, coatings, wax, polish, solvents)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Genetics and biodiversity

- People are not as alike as scientists once thought
- How copy number variation is changing genetics

- You may have heard that humans are 99.9% the same as each other. Well, not anymore.
- New research is showing that we are less alike than this. There isn't an exact number yet but the new number is probably somewhere between 99.0 and 99.9%.

- People are not as alike as scientists once thought
- How copy number variation is changing genetics

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Biodiversity is actually genetic diversity

- What is that genetic diversity and what does it represent
- Our understanding of the ocean has changed dramatically – a vast reservoir of genetic and biological diversity.
- Most life in the ocean is microbial – 95 – 98% of the living material in the ocean is microbial and produces half the oxygen on the planet.
- 200 megatons of carbon in the ocean = 13 whales
- 10x as many viruses in the ocean than bacteria
- In a liter of seawater (and freshwater) has more viruses than there are people on the planet.
- 10 * 10^6 times more viruses in the ocean than there are stars in the universe. lined up end to end 10^7 light years away.
- What we have Avogadro's number
- Viruses kill 20% of the living maerial in the oceans every day
- Viruses drive
- 70% of the sequences pulled out of the ocean have no homologues in the available databases

Bioiversity is a lot more complicated than we thought

Contributions of Human Emissions to Indoor Air Composition

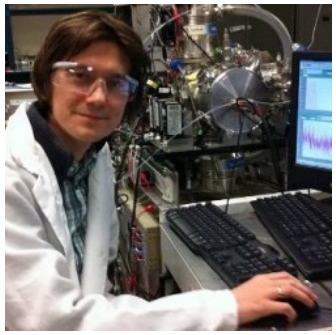
Allen Goldstein, **Xiaochen Tang, Pawel Misztal**, William Nazaroff

Department of Environmental Science, Policy and Management

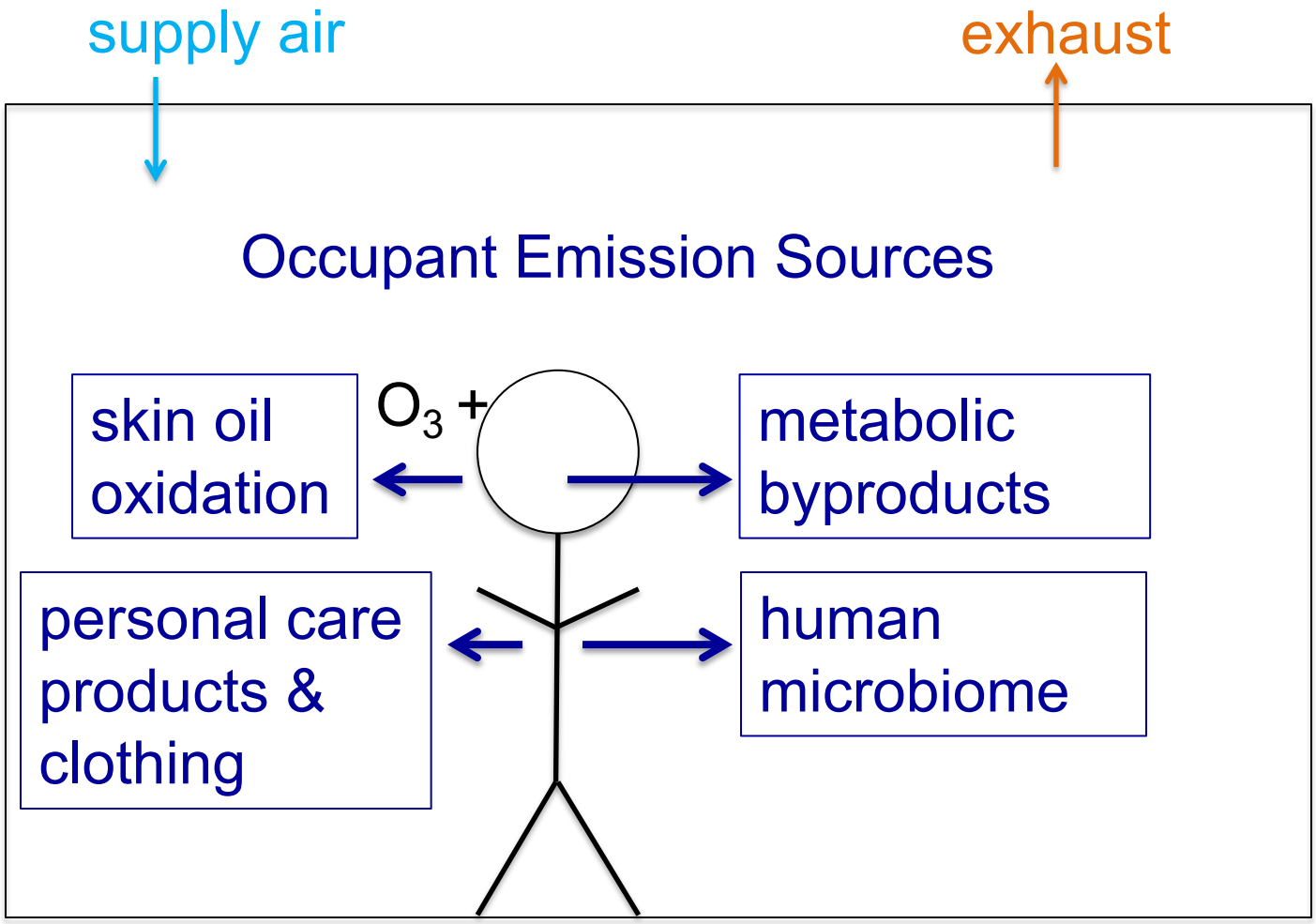
Department of Civil and Environmental Engineering

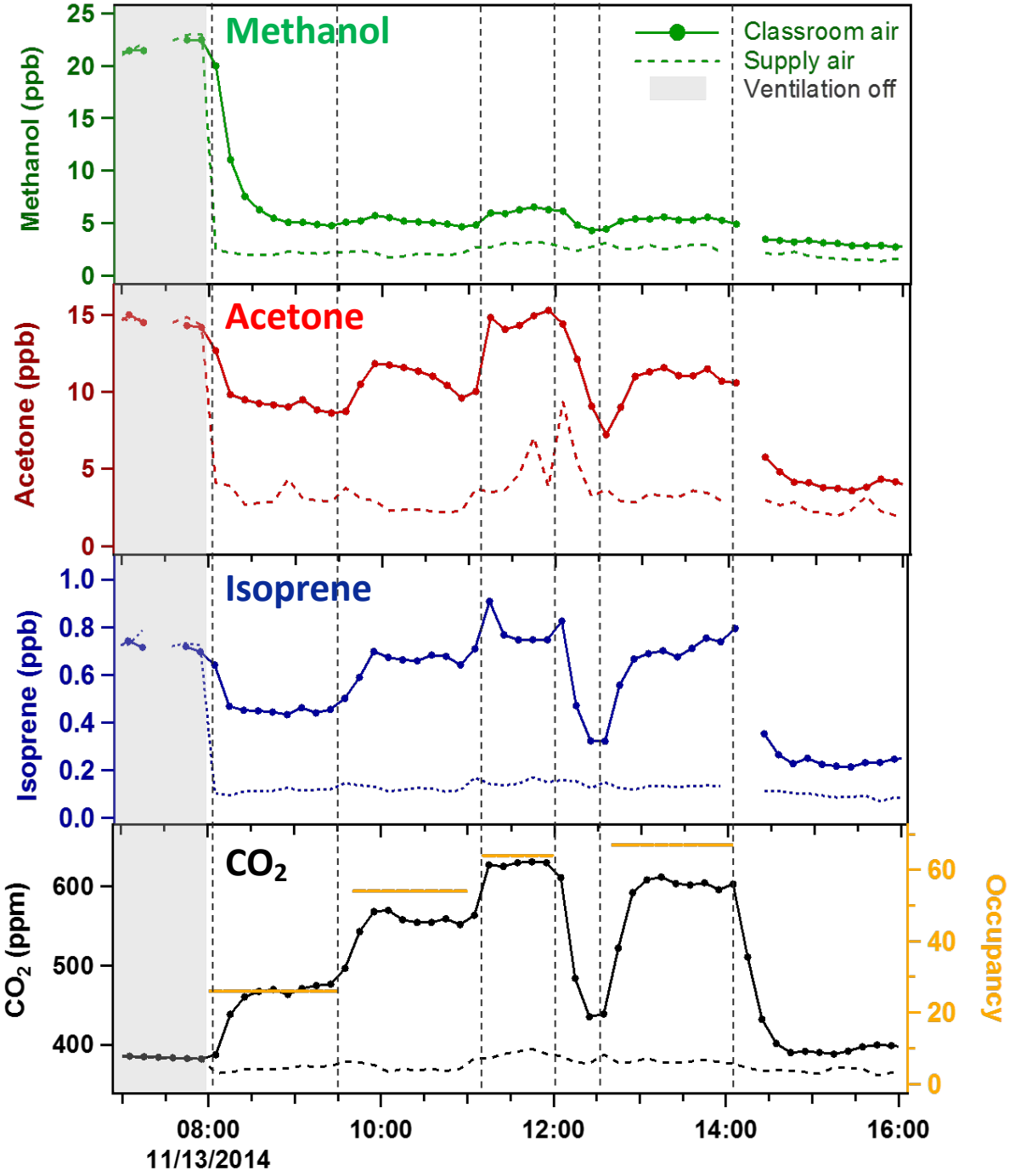
University of California, Berkeley






Human Emissions Indoors

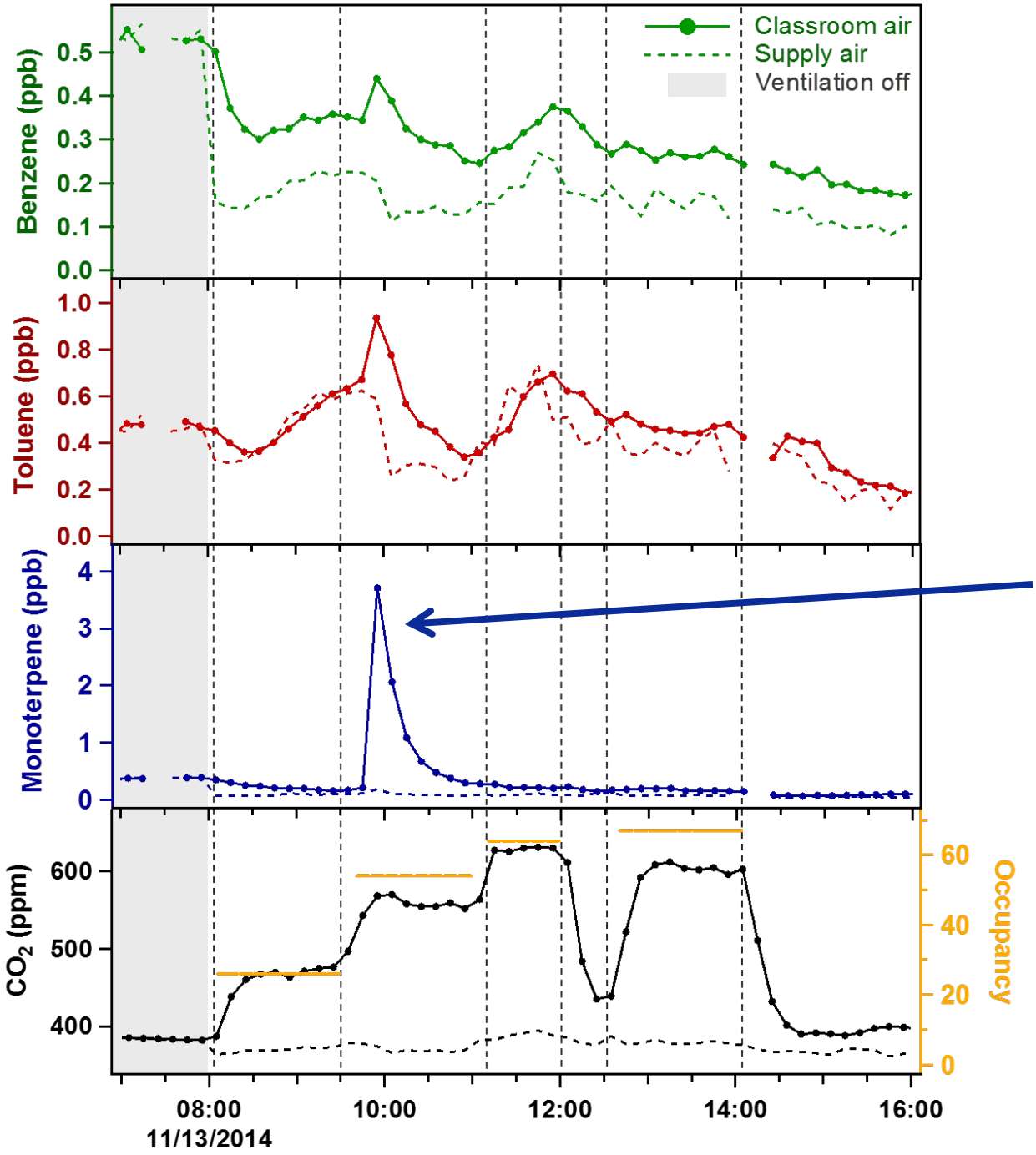




Human Metabolic Byproducts

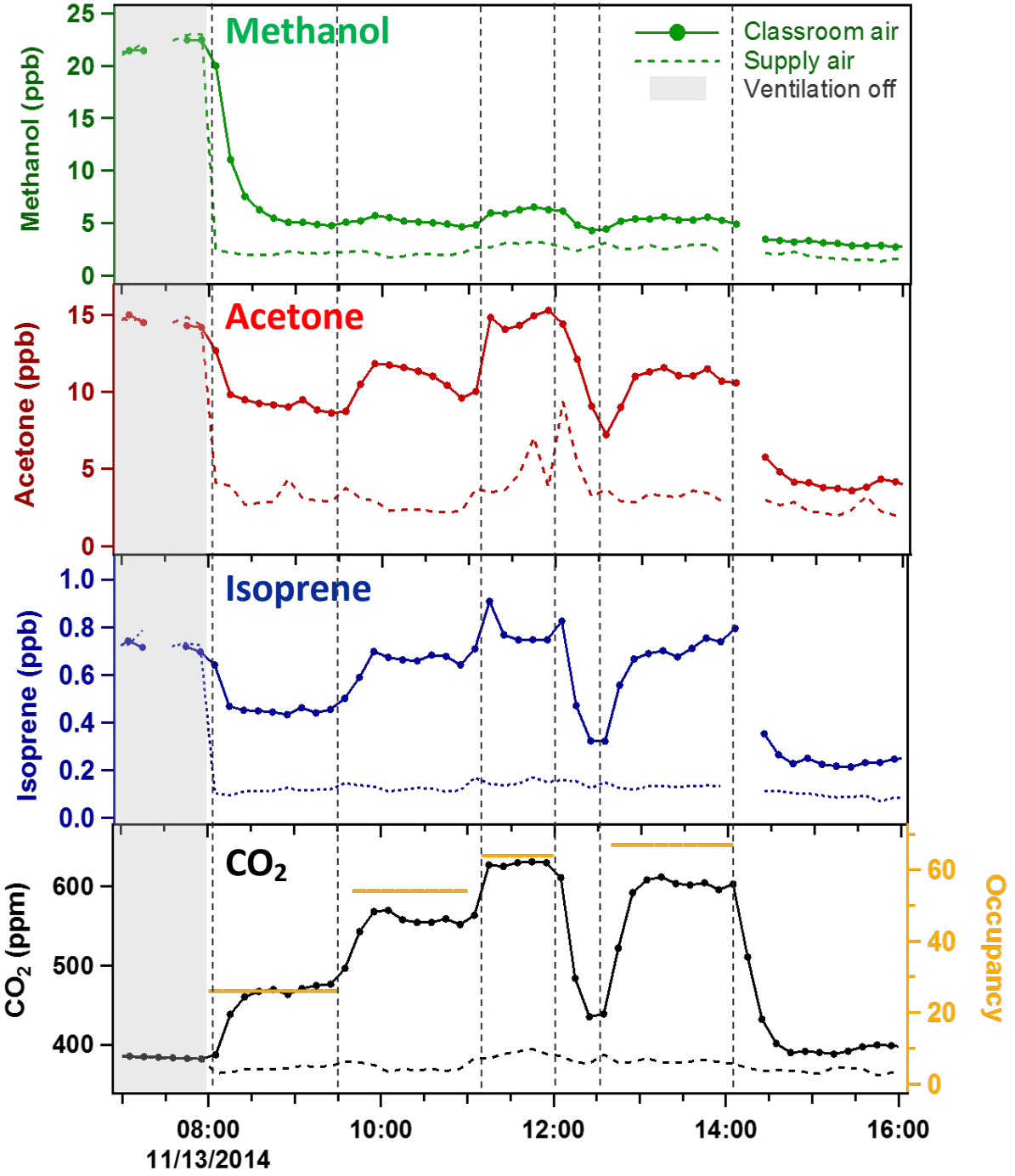
Methanol, acetone, isoprene, and carbon dioxide are known human metabolic byproducts.

Classroom Air concentrations vary with occupancy.



Outdoor Air plus some persistent or occasional indoor sources

Onetime emission: Looks like someone peeled an orange, … but in any case someone brought it in.



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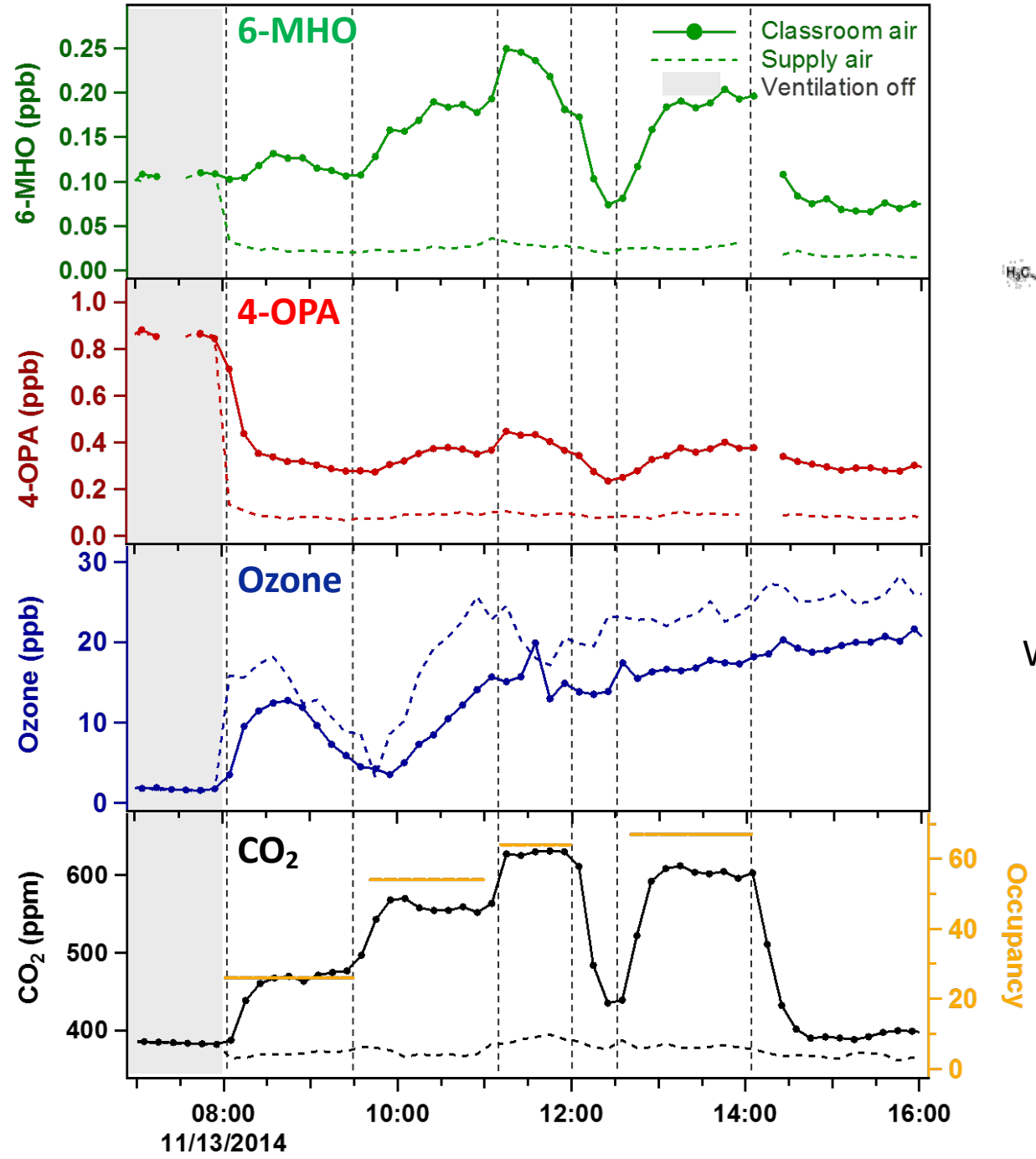
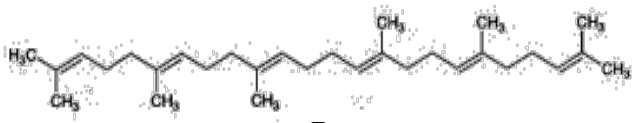
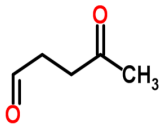


Human Skin Oil Oxidation

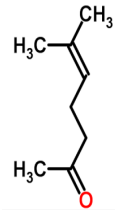
Squalene



+ O_3



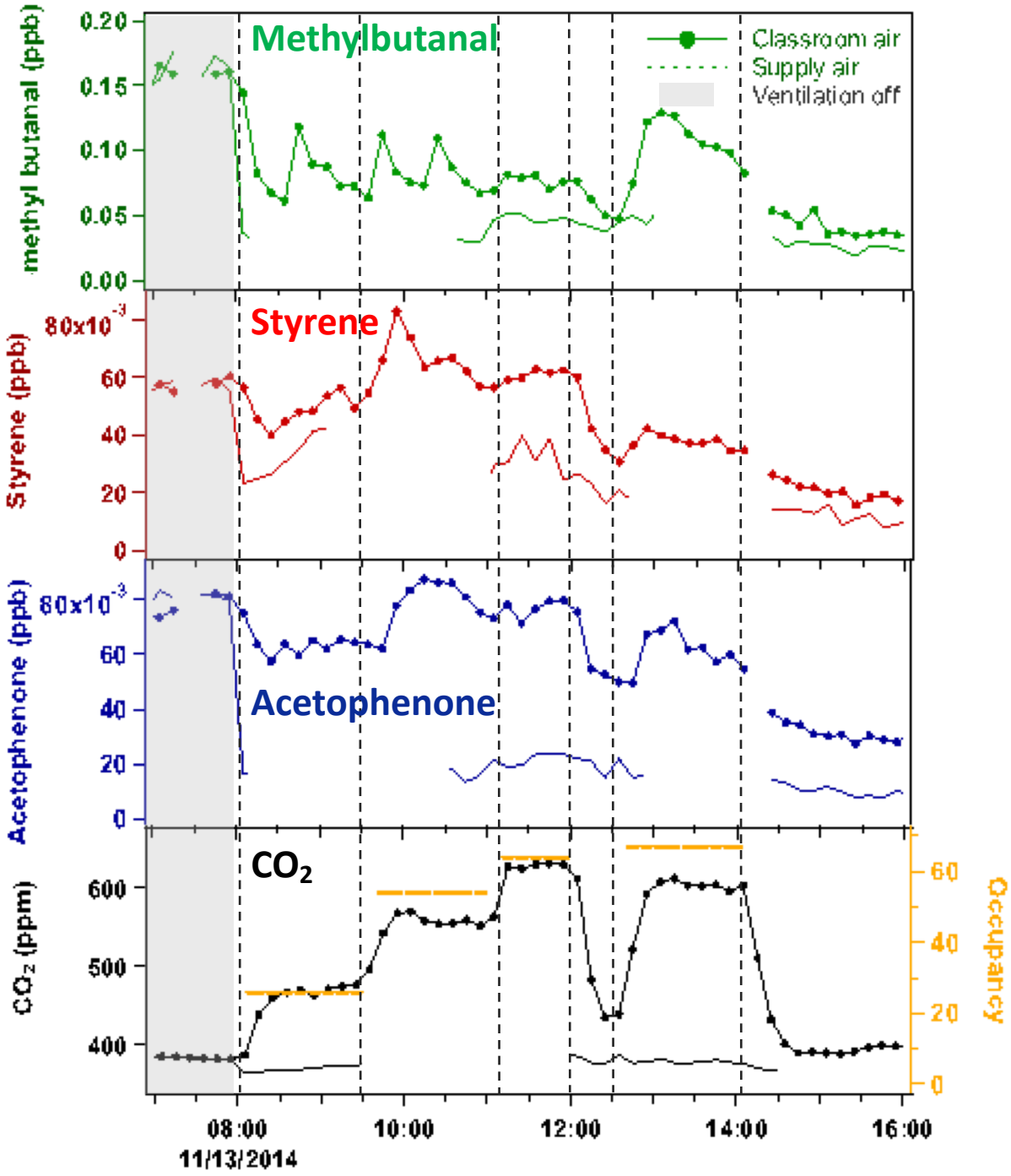
4-OPA



6-MHO

Wisthaler and Weschler (2010)

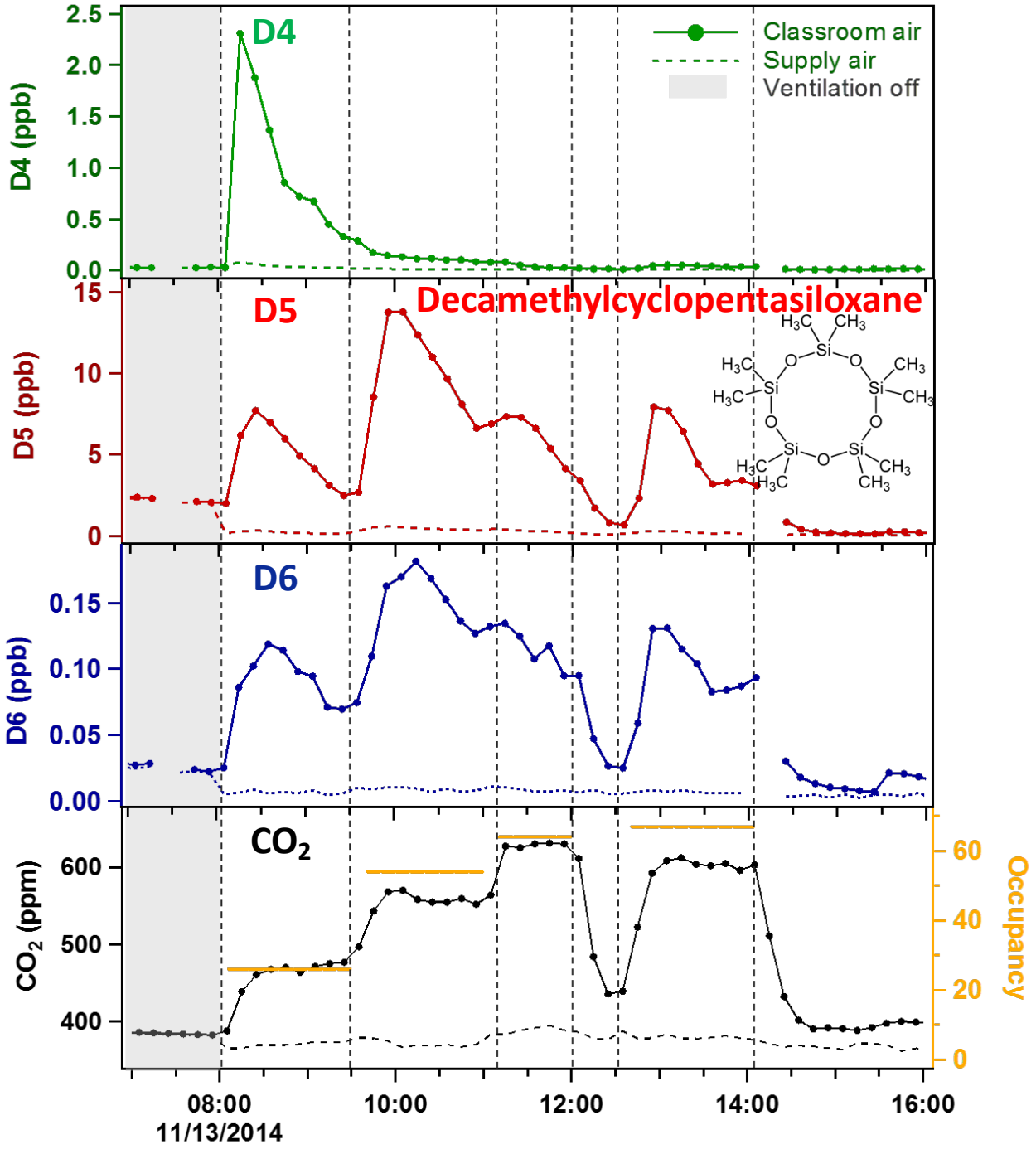
Concentrations vary with O_3 X Occupancy



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)



cVMS from Personal Care Products

D5 is dominant in classroom and dominant ingredient in anti-persperants.

Emissions decline from start to end of class, and start to end of day.

Supply and Classroom Air (> 20 Occupants) Mass Concentrations