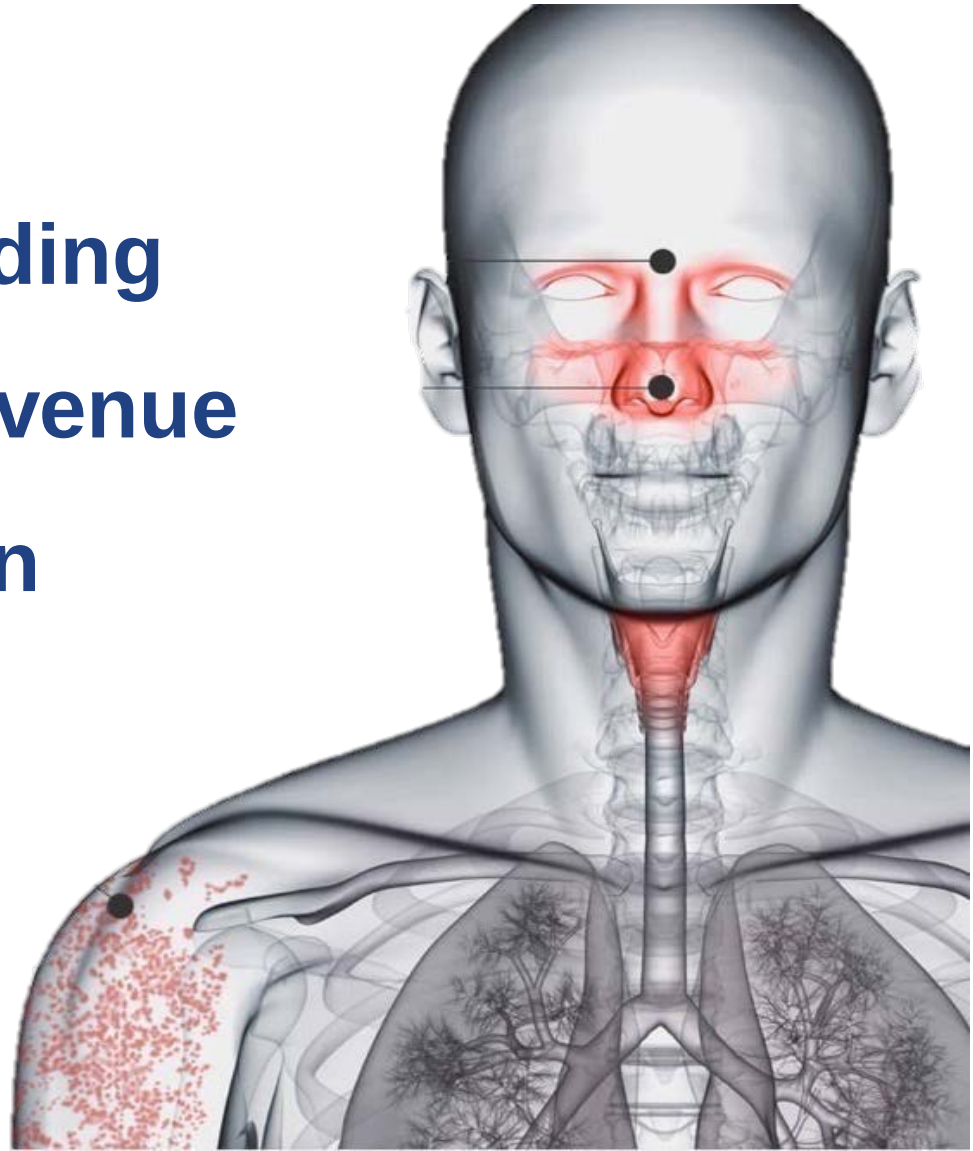
HARVARD MEDICAL SCHOOL

Optimize Occupant Health, Building Energy Performance and Your Revenue Through Indoor-Air Hydration



Stephanie Taylor, M.D., M. Arch

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EDUCATION PARTNER

COURSE TITLE

Optimize Occupant Health, Building Energy Performance and Your Revenue Through Indoor-Air Hydration

By Provider's Name - ASHRAE

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Course ID: 0090010881

Approved for:

1

General CE hours

X

LEED-specific hours

- LEED GREEN ASSOCIATE ☐
- LEED AP BD+C ☐
- LEED AP HOMES ☐
- LEED AP ID+C ☐
- LEED AP ND ☐
- LEED AP O+M ☐

Course Description

Why are human beings struggling with so many infections, allergies and chronic diseases? Are we simply becoming weaker creatures while microbes are evolving into more infectious and problematic germs? Or, we are missing something very important – some force or factor that is simultaneously increasing our vulnerability while strengthening micro-organisms that make us sick? Come to this seminar to learn how essential YOU, the professionals in designing, building and managing indoor environments, are in turning around these alarming health trends.

Understanding the powerful influence of indoor air on humans is not just theoretically interesting; it has become an urgent topic for all of us. For those unsure of the “return-on-investment” for buildings that support occupant health, financial data will also be presented.

Get ready to be totally amazed by the power of properly managed indoor air and learn actionable steps to improve your own health, productivity and learning.

Learning Objectives

1. Describe the impacts of humidity on occupant health, the microbiome of the built environment, and the transmission of germs.

2. Understand the relationships between water in the liquid and vapor state, and the human body.

3. Understand how humidity levels affect the infectivity of viruses and bacteria.

4. Learn the application of energy-saving and hygienic approaches to active humidification when supplementation is necessary as an intervention for dry air.

5. Provide building owners a cost-benefit analysis of occupant health as a building performance metric.

6. Participate in ASHRAE discussions on best-practice indoor humidification minimum and maximum levels for occupied buildings.

Presentation Summary

We are *Homo-indooris*	▪ Medicine is failing us ▪ Are buildings still shelters?
New understanding	▪ New tools and new data ▪ Hospitals, offices, schools
Please explain!	▪ Microbes indoors ▪ Humans indoors
New directions	▪ What should we do? ▪ Conclusions

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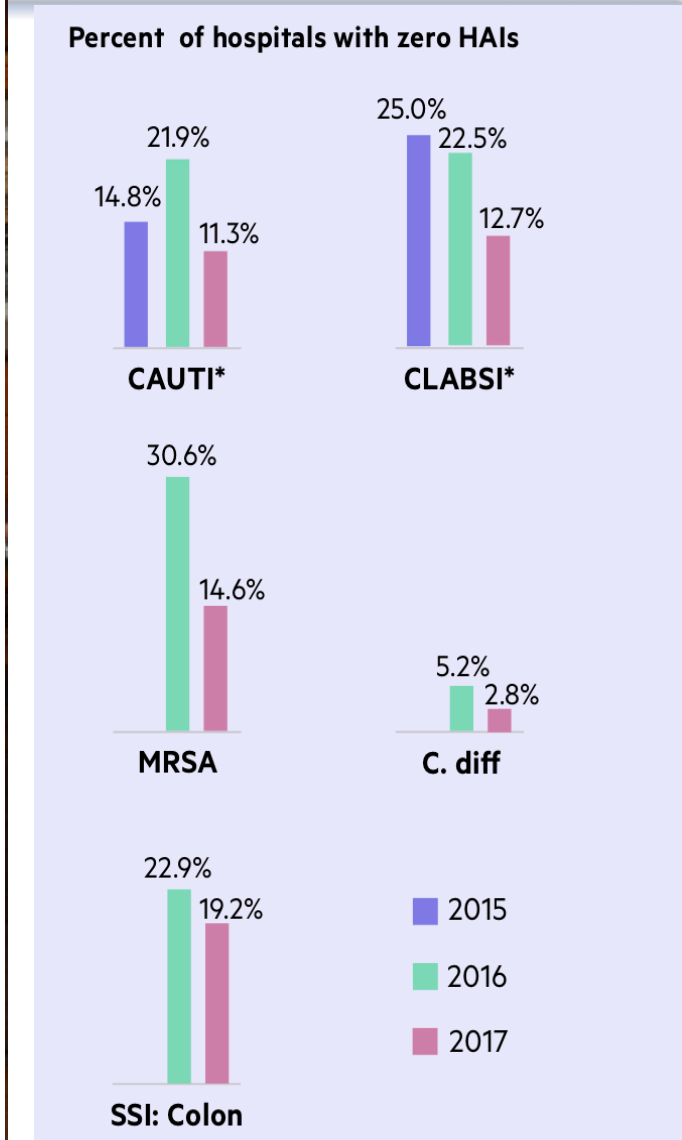
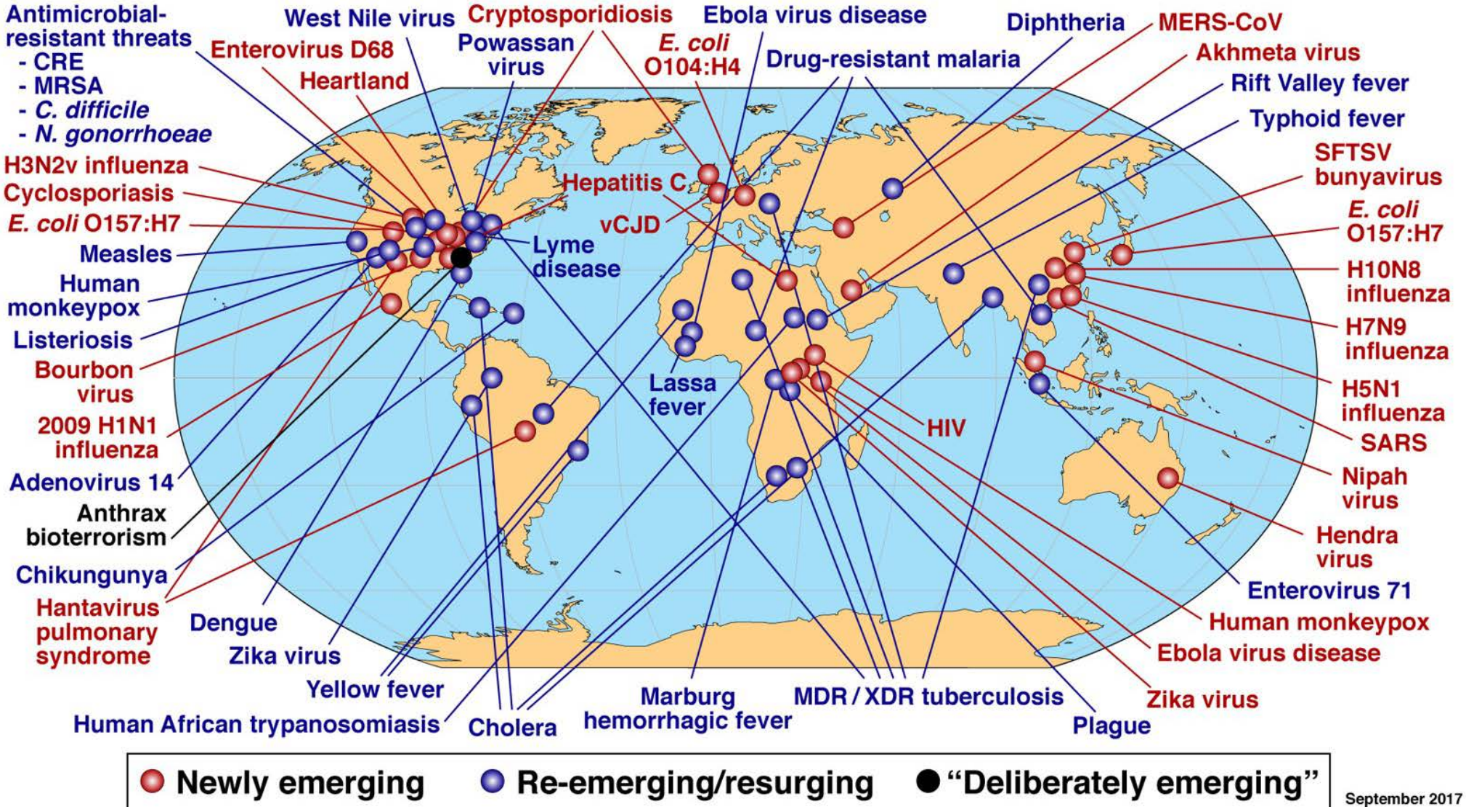
We are trying hard to decrease HAI rates, but these infections are still too common



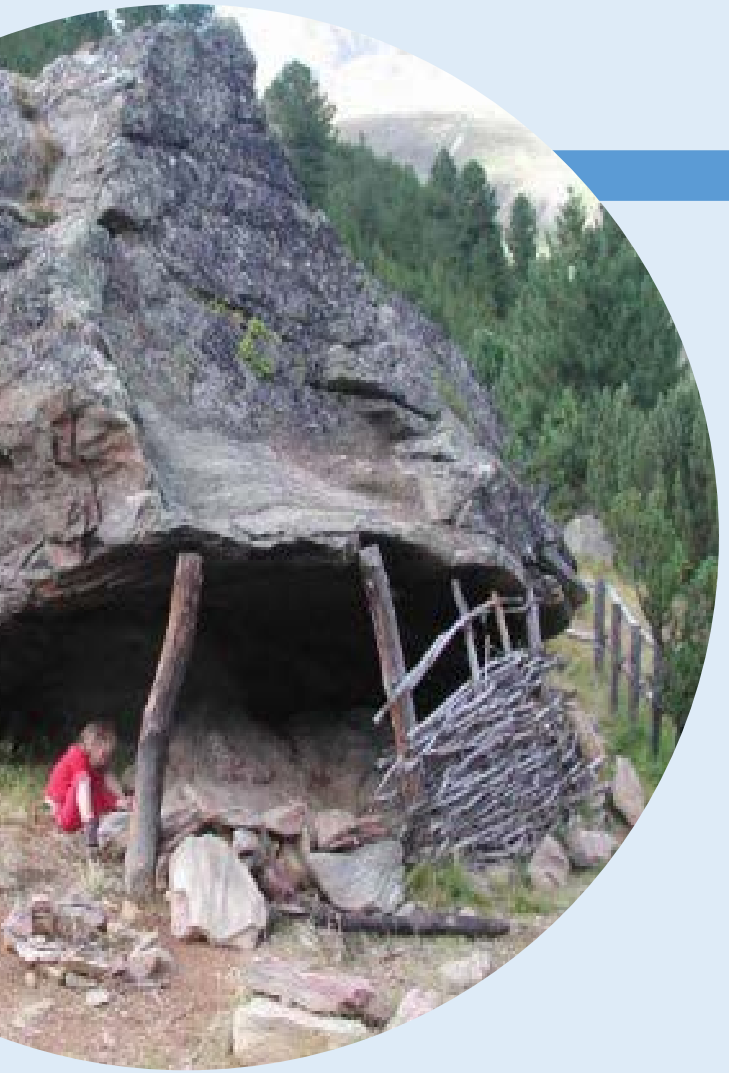
Autoimmune, inflammatory and many infectious diseases are on the rise



Domesticated dogs are now carriers of the quickly evolving influenza virus

We are NOT the problem!!

350,000 years ago humans lived and worked 100% outdoors

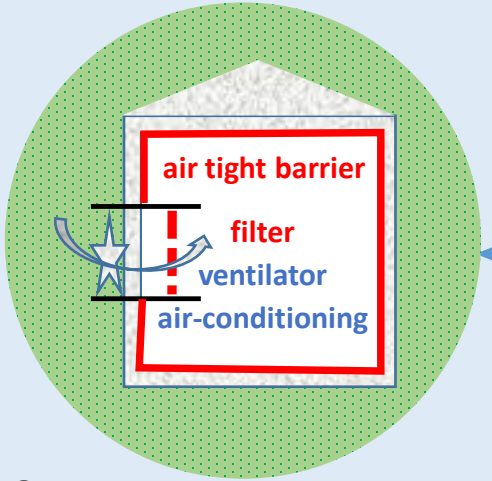


2,000 years ago humans lived in buildings, still spending 100% of lifetime outdoors

200 years ago working in factories and offices, living 90% indoors

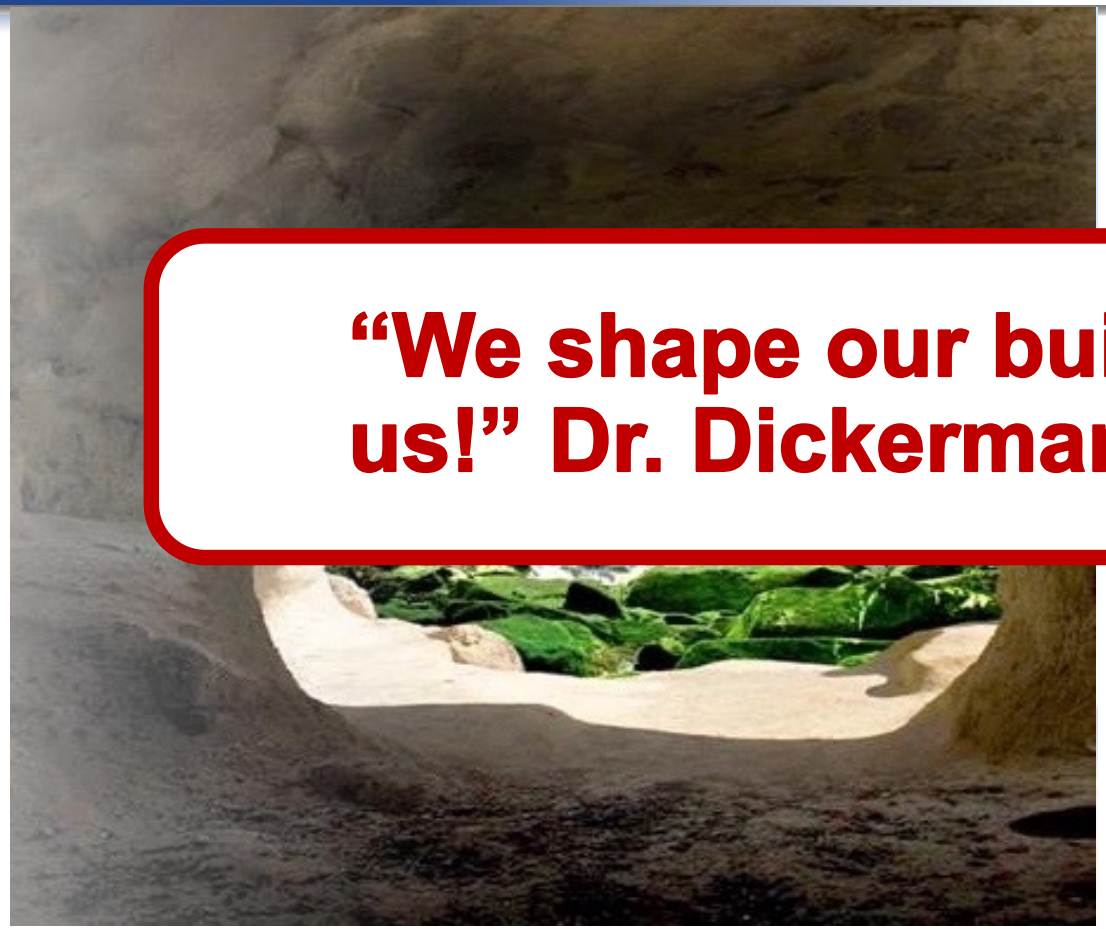
Industrial revolution

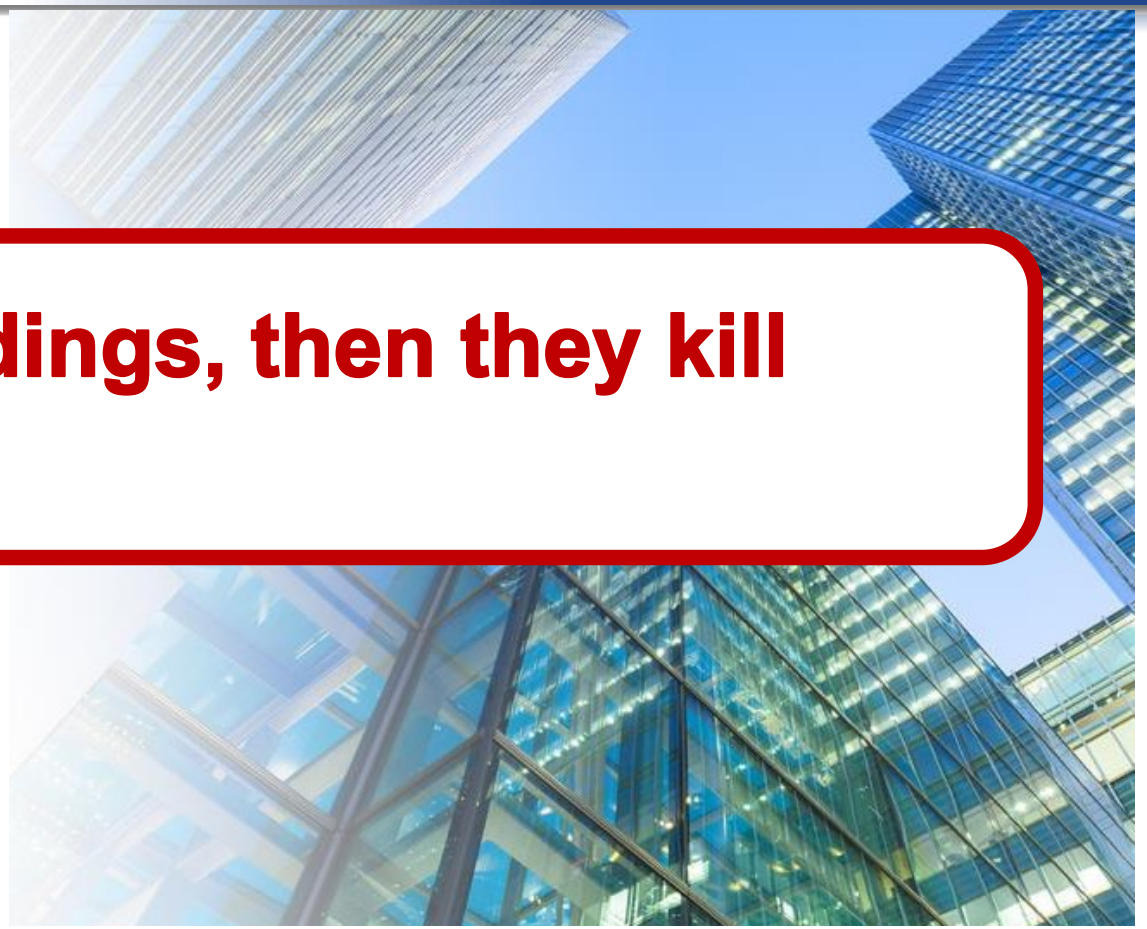
50 years ago live and work in centrally heated and ventilated buildings



Last **20 years ago** live and work in airtight, mechanically ventilated buildings

Homo Indooris - we are now inside 85% of our time





“We shape our buildings, then they kill us!” Dr. Dickerman

- Open dwellings
- Outdoor air exchange

- Tight building envelopes
- Mechanical air ventilation systems

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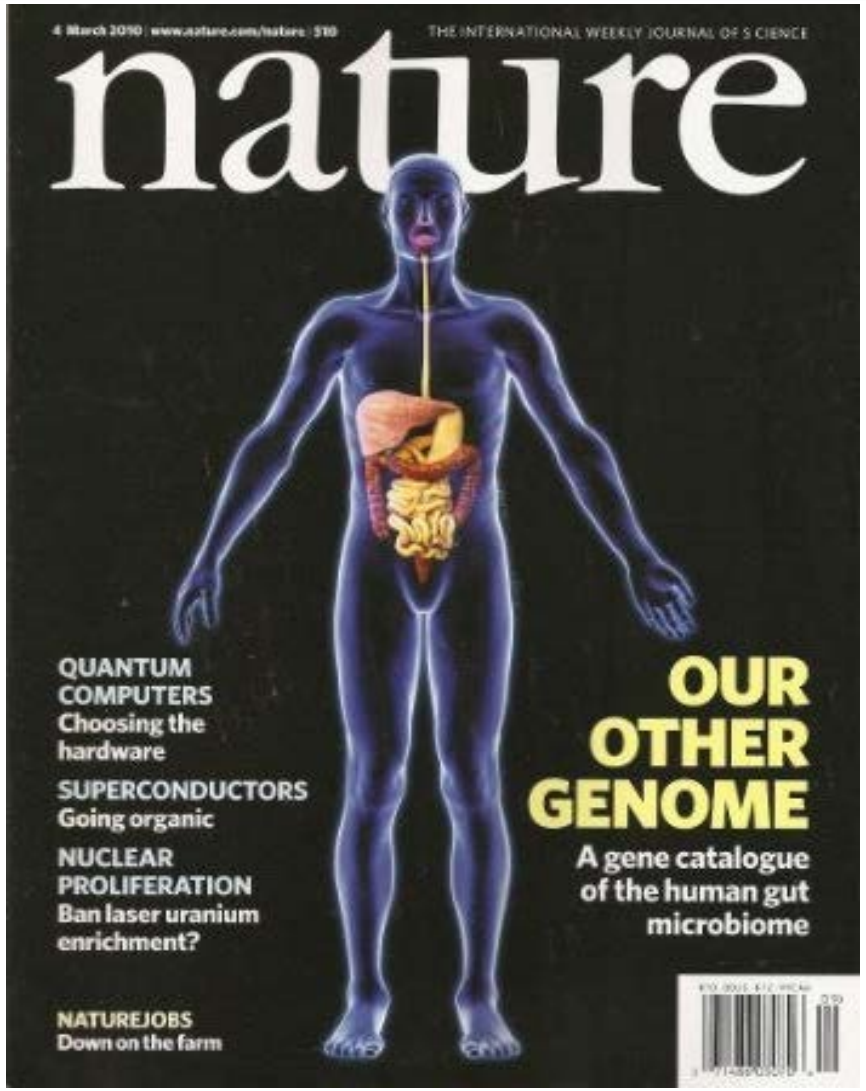
- Conclusions

Thankfully, we can now see if this is true

Tissue culture

Metagenomics 2018

Genetic analysis has shown us that each of us is an entire ecosystem!



Buildings have their own microbiome

by naked eye
we see nothing!

by microscopy
we can detect thousands of microbes

genome sequencing
has uncovered trillions of microbes that inhabit our buildings

A closer look at our surroundings

video clip

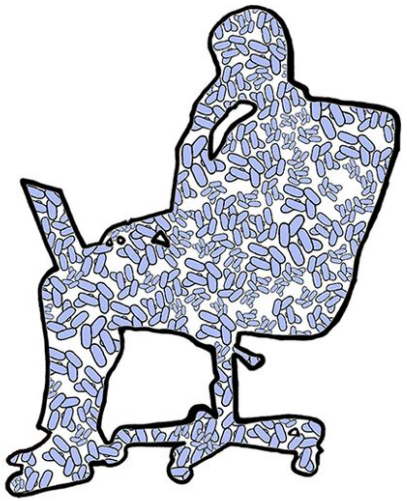
The indoor environment now drives natural selection

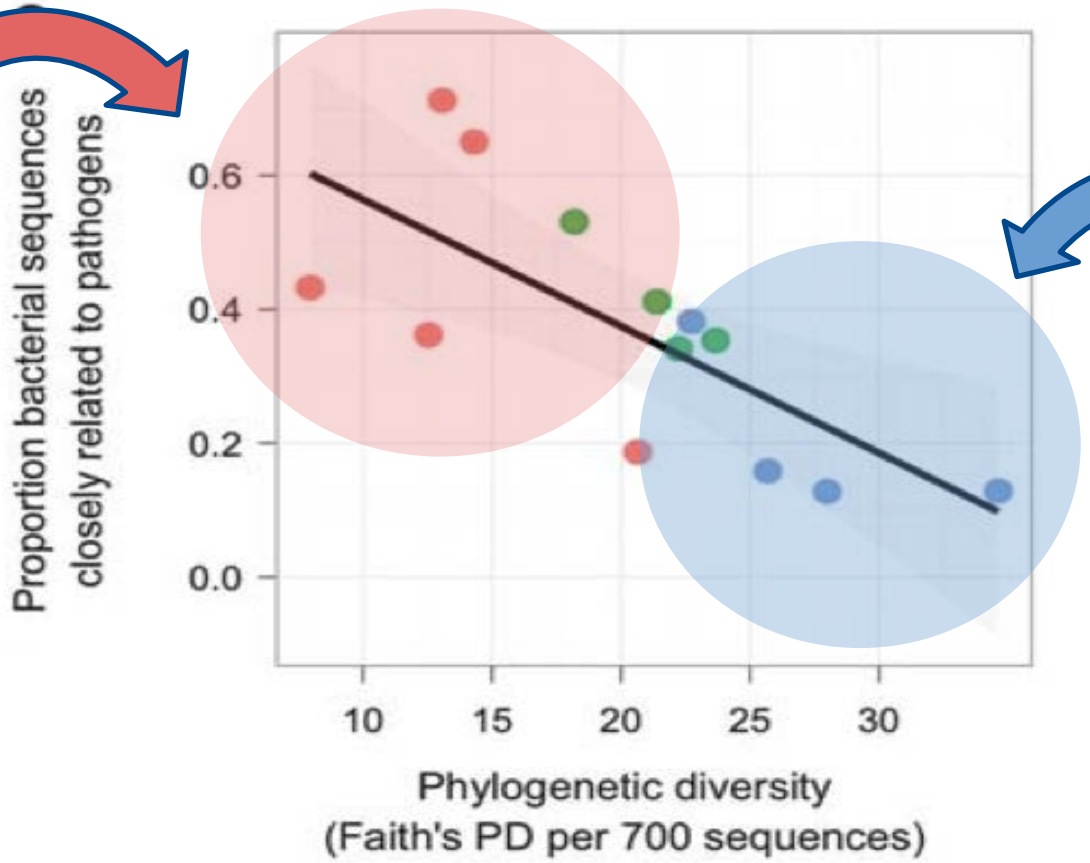
Occupants send microbes into buildings

Building design, use and ventilation “select” microbes which survive and interact with occupants

Microbes in mechanically ventilated buildings are more closely related to pathogens

Mechanically ventilated
- ***Low*** bacterial diversity
- ***High*** average pathogenicity

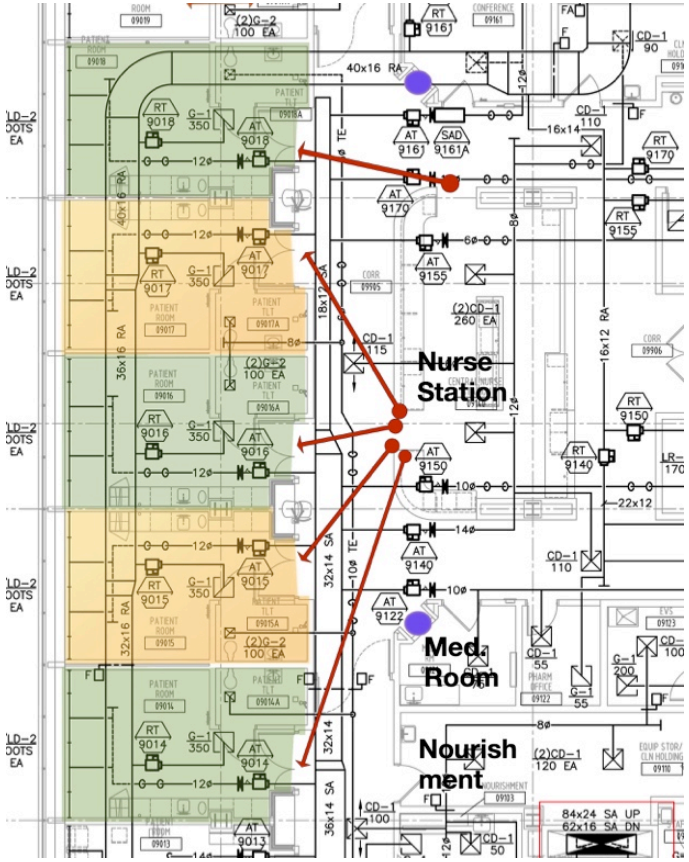


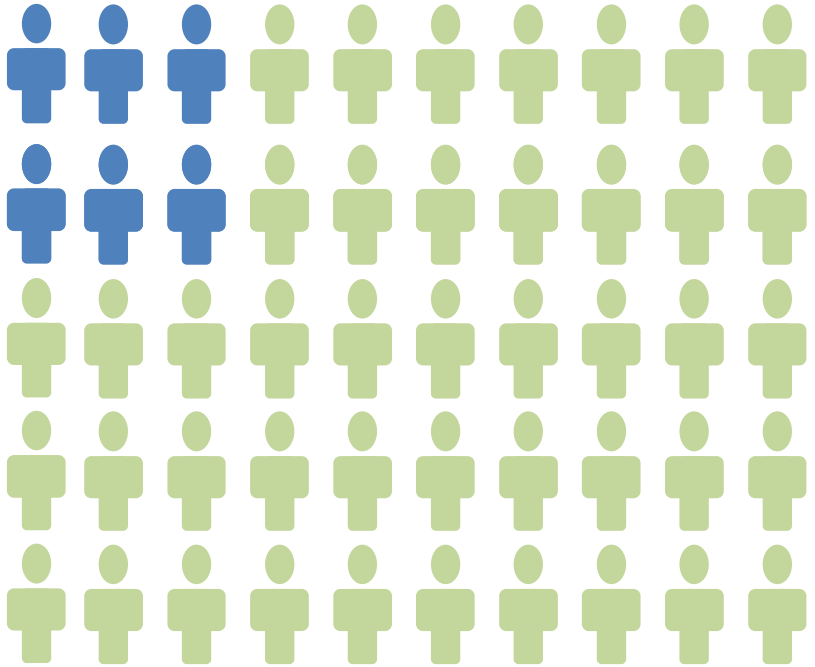


Outdoor Air
- ***High*** bacterial diversity
- ***Low*** average pathogenicity

A study to examine the impact of a building on occupant health

One year-long study to evaluate the patient room environment and HAIs



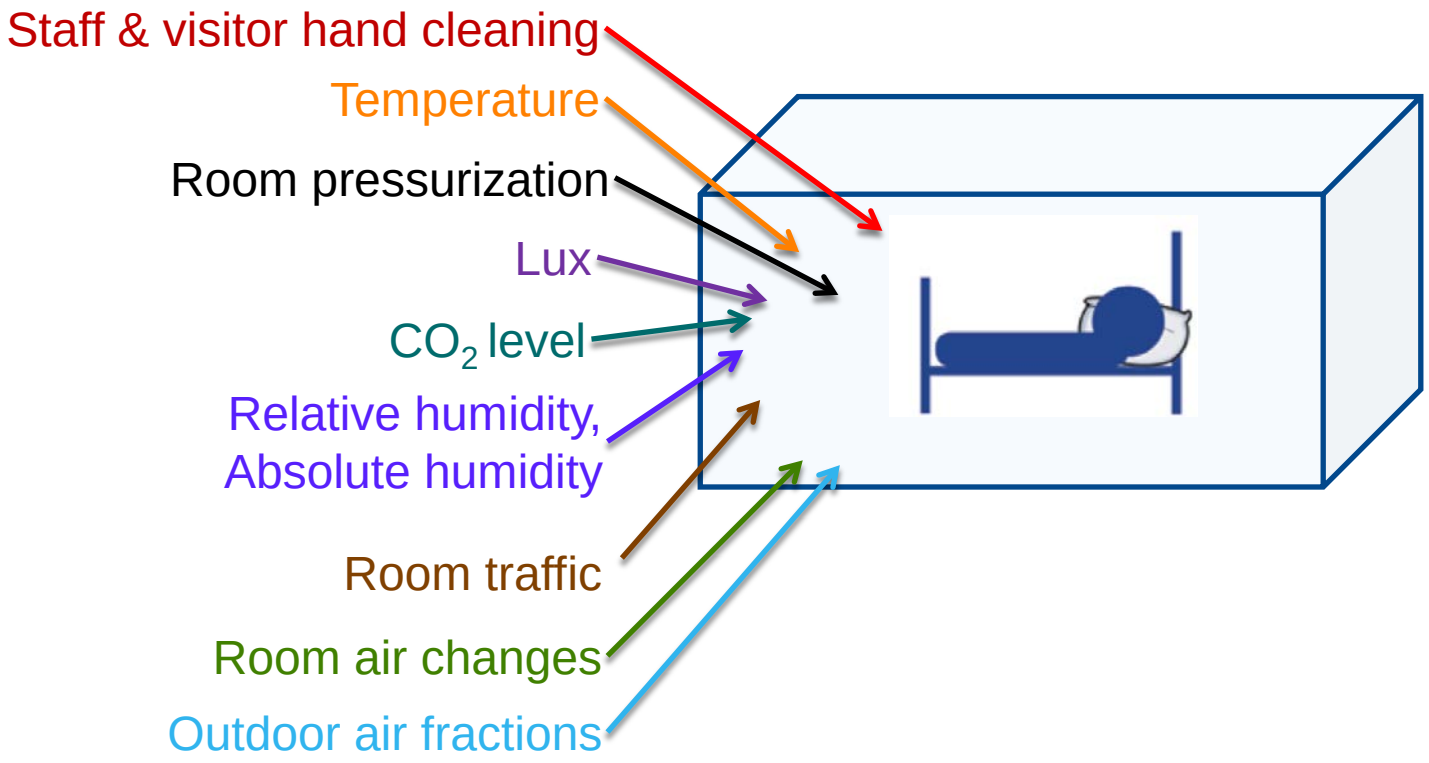


Correlate indoor conditions in 10 patient rooms and 2 nurse stations

With new patient infections

One year-long study to evaluate the patient room environment and HAIs

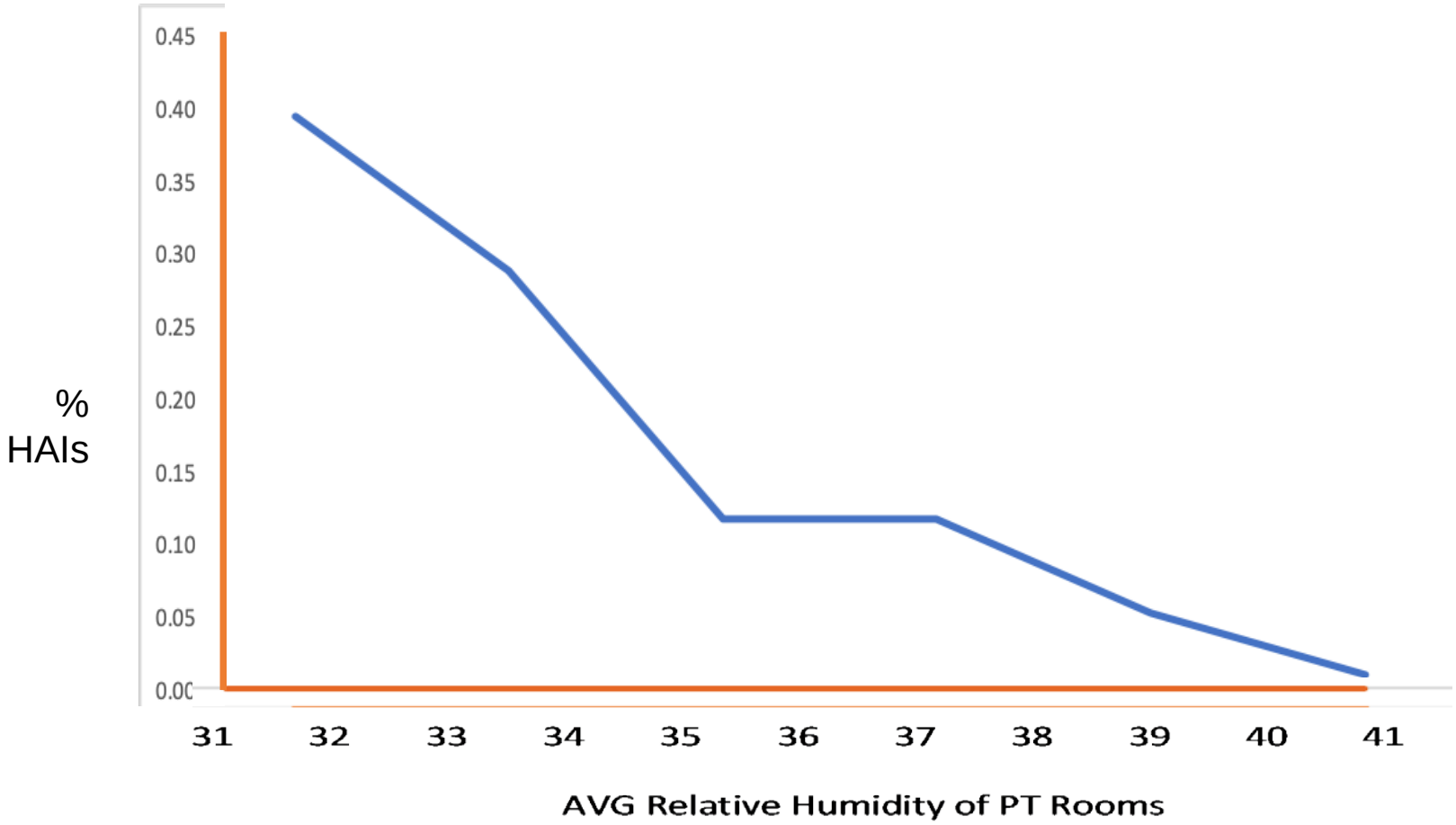
Patient room data *vs.* **Patient HAIs**



Room	Clinical symptoms	HAI Organisms (if indicated)
xx	pneumonia, viremia	Pseudomonas, Epstein-Barr virus
xx	pneumonia	Staphylococcus aureus
xx	open wound of head, neck, and trunk	
xx	bacteremia, organism unspecified	Citrobacter infection
xx	infection due to vascular device	
xx	cellulitis	Staphylococcus aureus
xx	sepsis, cellulitis, abscess	
xx	bacteremia, organism unspecified	
xx	pneumonia, organism unspecified	
xx	fever; bacteremia, organism unspecified	
xx	viremia	Cytomegalovirus (CMV)
xx	wound infection after surgery	
xx	urosepsis, organism unspecified	
xx	sepsis following cardiac surgery	
xx	pneumonia, organism unspecified	
xx	infection of skin and subcutaneous tissue	
xx	colitis and diarrhea	Clostridium difficile
xx	wound infection after surgery	
xx	urosepsis, organism unspecified	
xx	diarrhea	salmonella enteritis

8 million room data points **~ 300 patient outcomes**

As patient room RH went up, HAIs went down!



Coefficients[a]

Standardized Coefficients		
Beta	t	Sig.
	-2.348	.023
-9.060	-2.396	.020

2018 Study: Indoor-air RH and health outcomes in residents in a long-term care facility (over 4 yrs)

Patient infections

VS

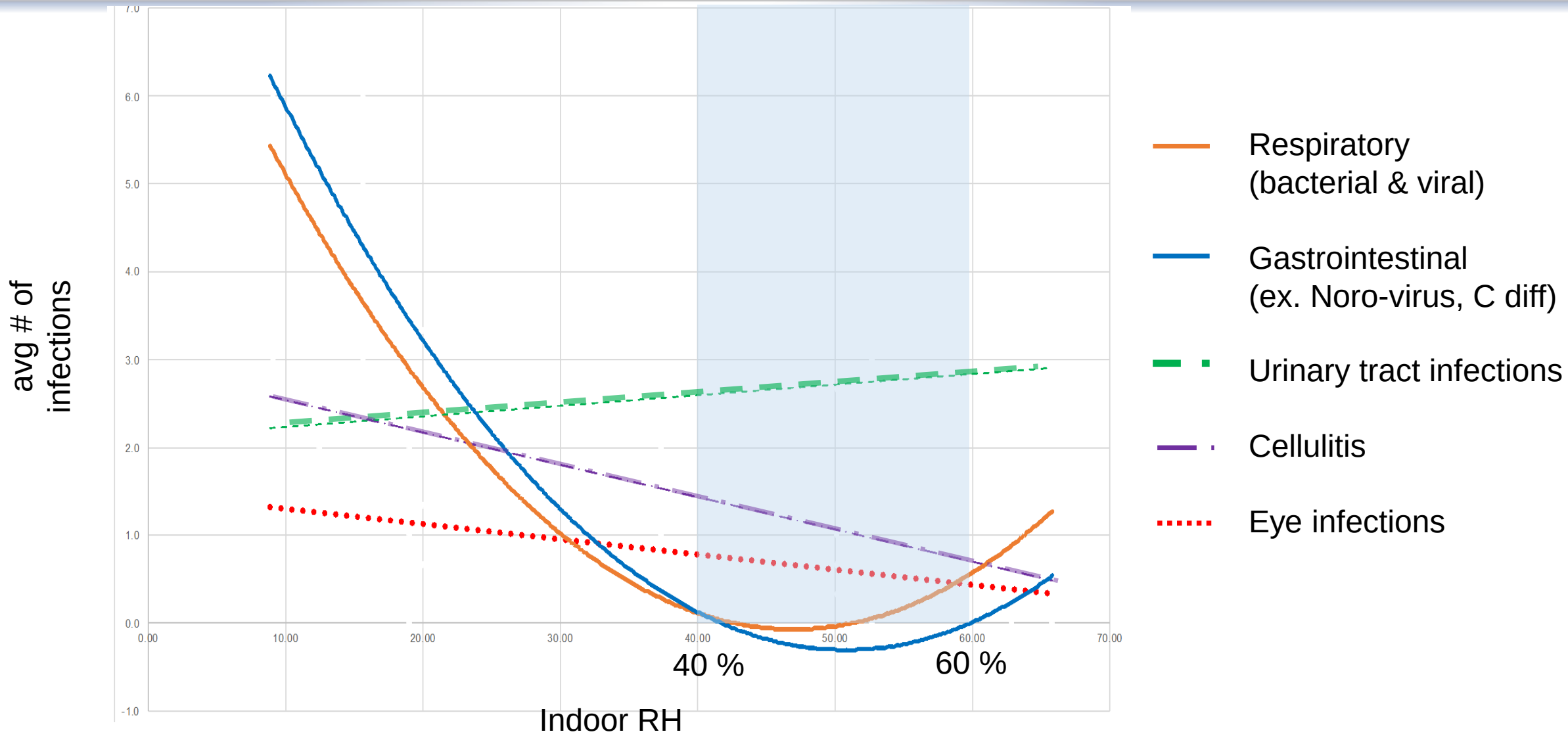
Environmental data

<u>Infections</u>
- respiratory (viral & bacterial)
- GI (Noro. & Notovirus, C. diff)
- urinary tract
- conjunctivitis
- cellulitis

<u>Indoor conditions</u>
- temperature
- relative humidity
- visitors
- staff absenteeism

<u>Outdoor climate</u>
- temperature
- relative humidity
- flu outbreaks

Respiratory & GI infection rates were lowest when indoor RH = 40-60%



2018 study: Humidity decreased Influenza A illness in a pre-school

January 25 – March 11 (32 days)

Half of the classrooms were humidified, the other half were not

RH of classrooms	% Airborne particles carrying virus (PCR)	Virulence of airborne virus (% cells infected)	# children absent due to influenza illness
20%	49%	75%	22
45%	**19%**	**35%**	**9**

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- **Humans indoors**

New directions

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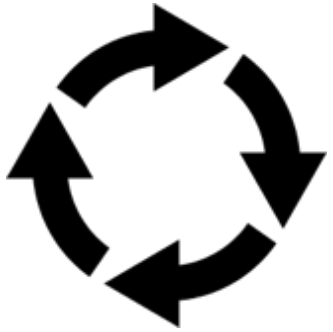
What determines if this cough will infect others?

When RH < 40%, pathogen infectivity is high

Greater airborne transmission



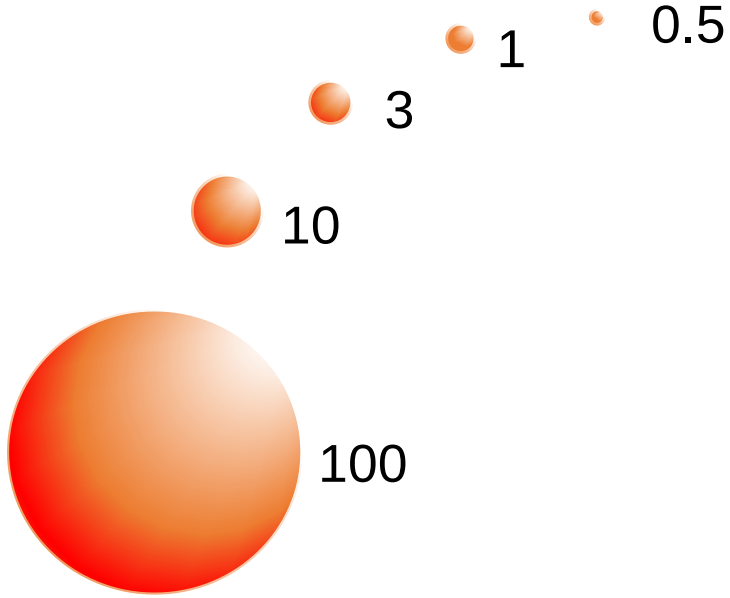
Evasion from surface cleaning through resuspension

Increased survival and infectivity

Infectious droplets shrink, travel far and evade surface cleaning when the air is dry

Droplet diameter in microns (um)

Float time



41 hours – 21 days

1.5 hours

6 seconds

Distance travelled: 1m 10m+

Does recontamination from infectious droplet nuclei settling out of the air explain this?

Contact precautions have ***not*** been shown to effectively reduce transmission in most patients with MRSA and VRE

When full contact precautions were stopped:

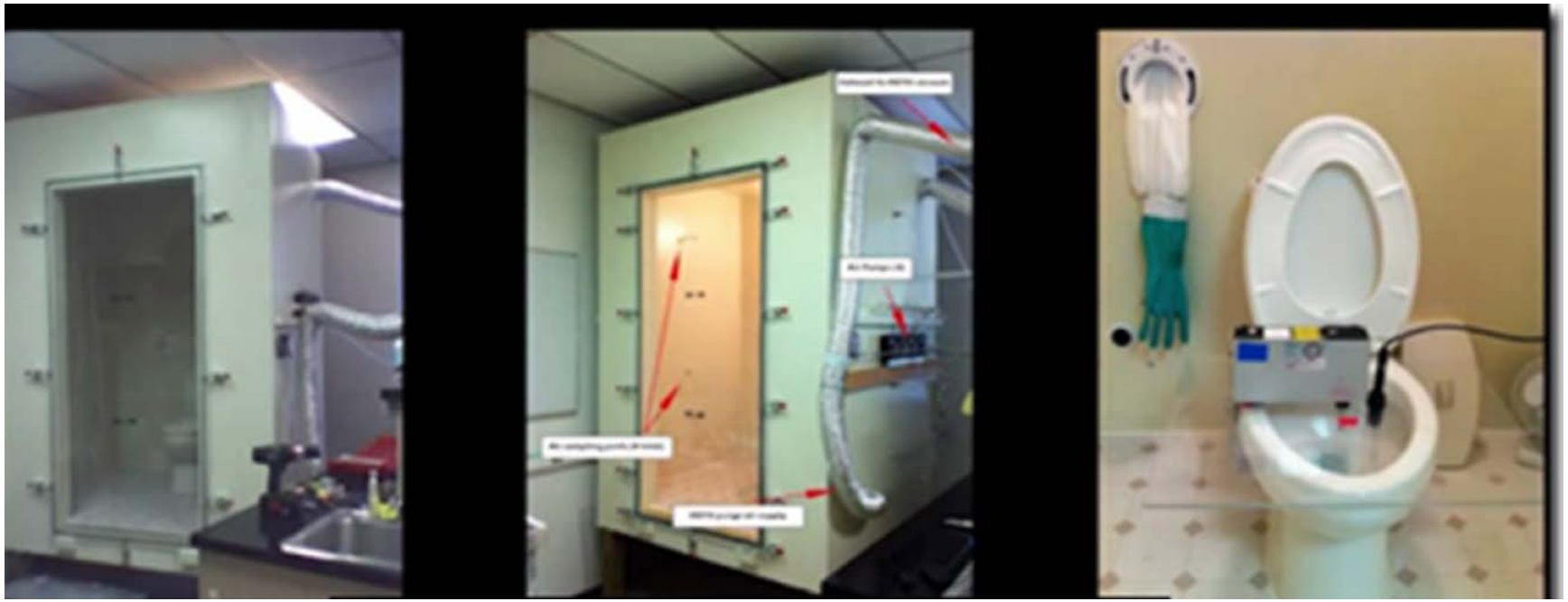
- No significant increase in transmission rates
- The health system saved approx. $643,776 and 45,277 hours per year in healthcare worker time previously spent on donning and doffing personal protective equipment

Martin, E., *Infection Control & Hospital Epidemiology*

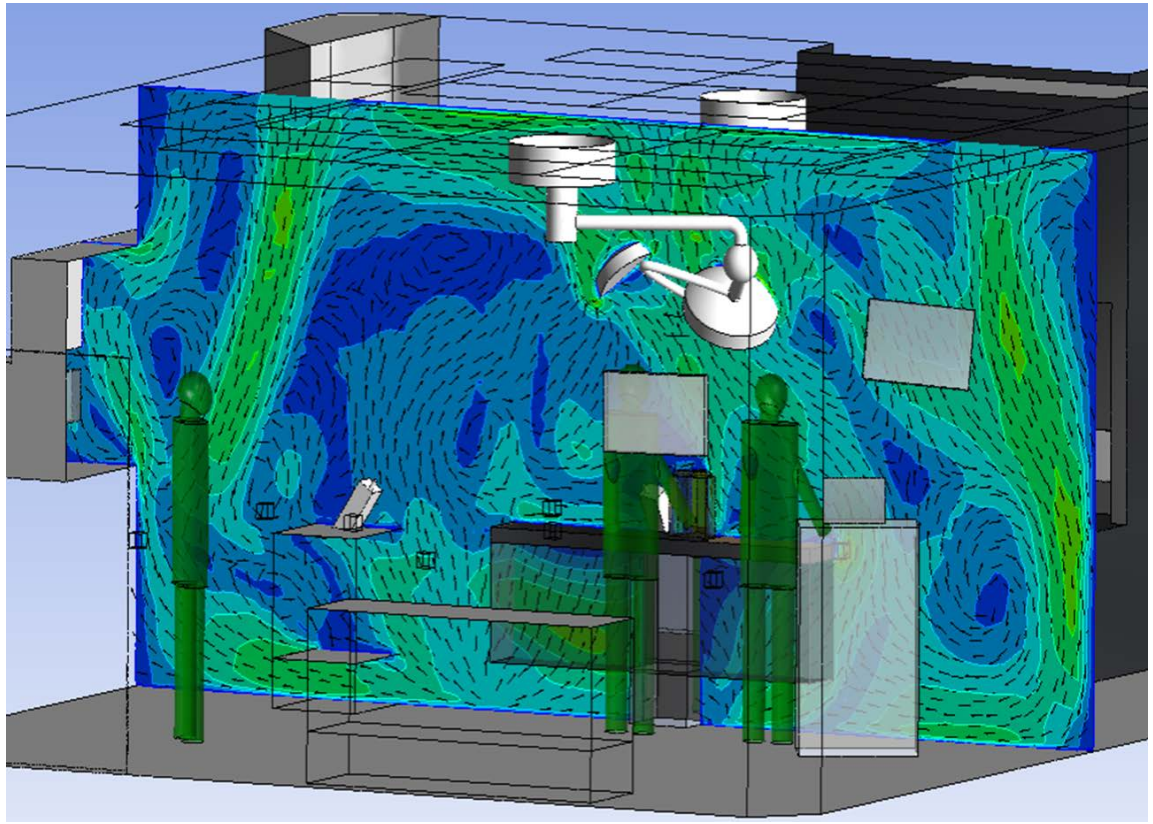
C. diff can travel in infectious aerosols

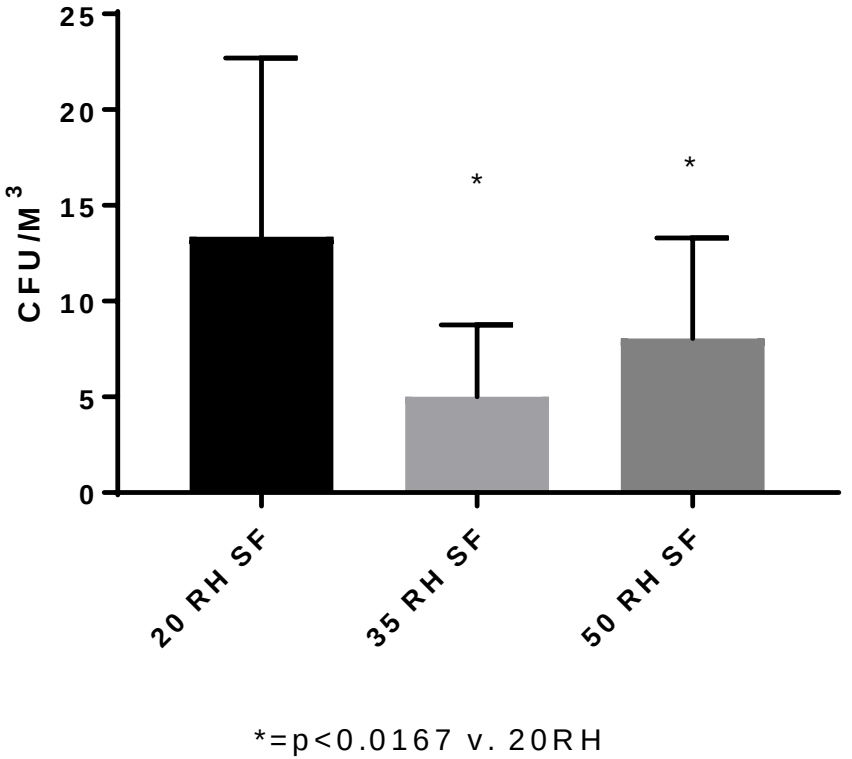
December 2018 – American Journal of Infection Control.

- C-Diff seeded in a toilet
- Water samples, settle plates, and air samples
- Spores present after 24 flushes
- Droplet nuclei spore bioaerosol produced over at least 12 flushes



Transmission of bacteria in the OR is higher in low RH



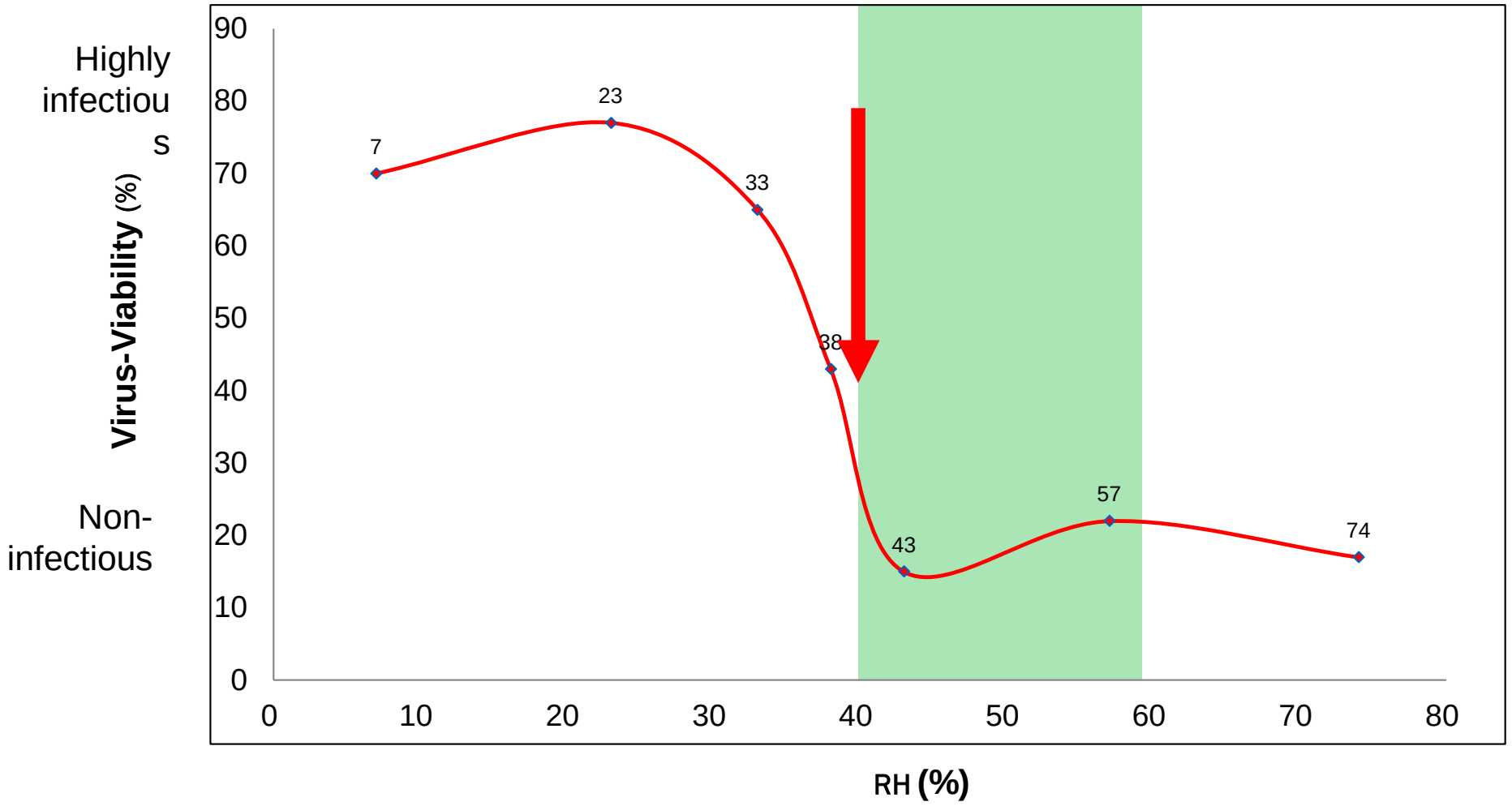


*=p<0.0167 v. 20RH

The sterile field was less contaminated in OR with RH 35% vs 20%

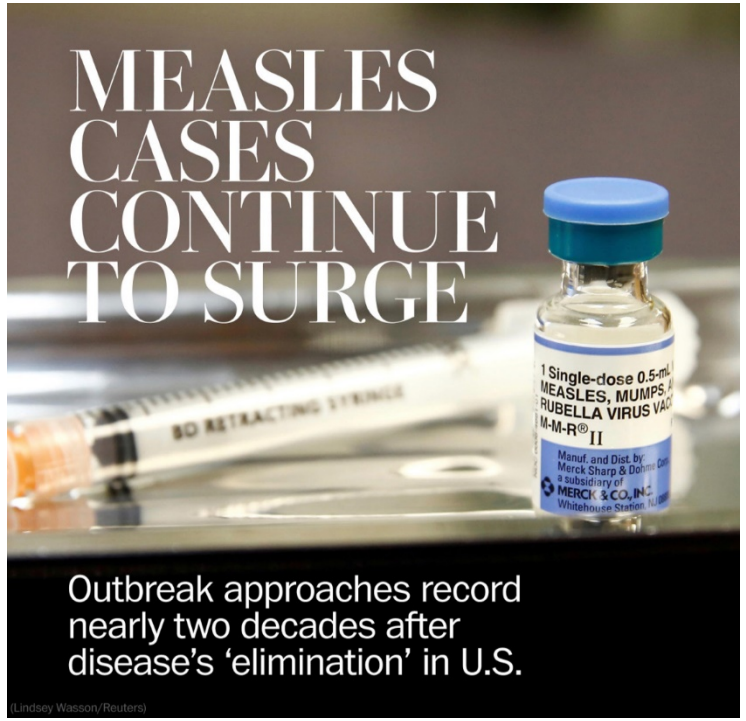
Greeley, D Indiana Medical Center, 2018

Influenza A virus is more infectious when RH is below 40%



Noti 2007

Did the very low RH in the airplane cabin contribute to this?



"Flight attendant in Hospital After Deadly Infection Spreads Onboard" April 7, 2019

✓Yes, she was vaccinated!

Pathogens Requiring Airborne Infection Isolation

Old news

- Anthrax
- Avian influenza
- Varicella disease (chickenpox, shingles
- Measles (rubeola)
- Severe acute respiratory syndrome (SARS)
- Smallpox (variola)/Varioloa virus
- Tuberculosis (TB)

Pathogens Requiring Airborne Infection Isolation

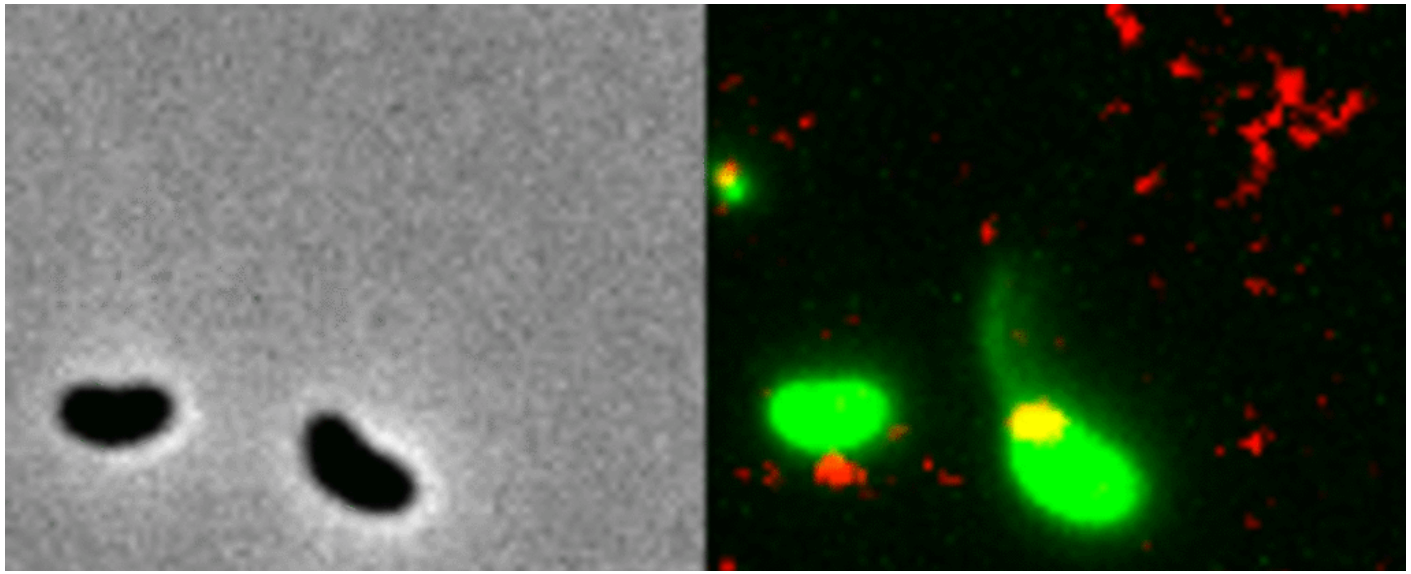
New news

- Clostridium difficile
- Diphtheria
- Epiglottitis, due to Haemophilus influenzae type b
- Haemophilus influenzae Serotype b (Hib) disease
- Influenza, human (typical seasonal variations)
- Meningitis & Meningococcal disease sepsis, pneumonia
- Mumps (infectious parotitis)/Mumps virus
- Mycoplasmal pneumonia
- Parvovirus B19 infection (erythema infectiosum)
- Pertussis (whooping cough)
- Pharyngitis from Adenovirus, Orthomyxoviridae, Epstein-Barr virus, Herpes simplex virus
- Pneumonia (Adenovirus, Haemophilus influenzae Serotype b, Meningococca Mycoplasma)
- Streptococcus Group A
- Pneumonic plague/Yersinia pestis
- Rubella virus infection (German measles)/Rubella virus
- Severe acute respiratory syndrome (SARS)
- Streptococcal disease (group A streptococcus)
- Viral hemorrhagic fevers due to Lassa, Ebola, Marburg, Crimean-Congo fever viruses

Stanford | Environmental Health & Safety

This is the most startling news of all...

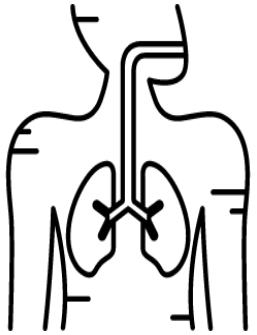
"Antibiotic Resistance Can Spread Through The Air, Scientists Warn, And Yes - You Should Be Terrified"
July 26, 2018



Dry conditions increase horizontal transfer of antibiotic resistance genes

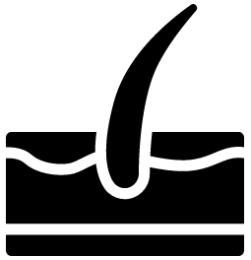
When RH<40%, humans suffer!

Sitting in room air with 20% RH, the average person becomes clinically dehydrated in 8 hours



more infections & asthma attacks

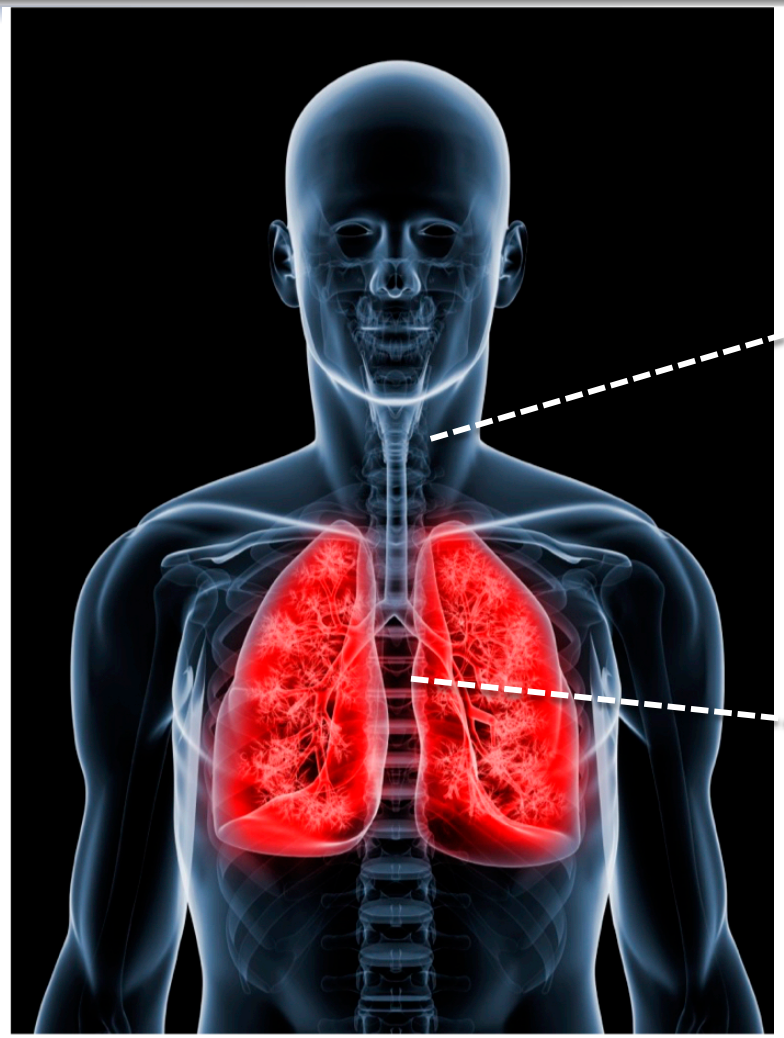
impaired brain function

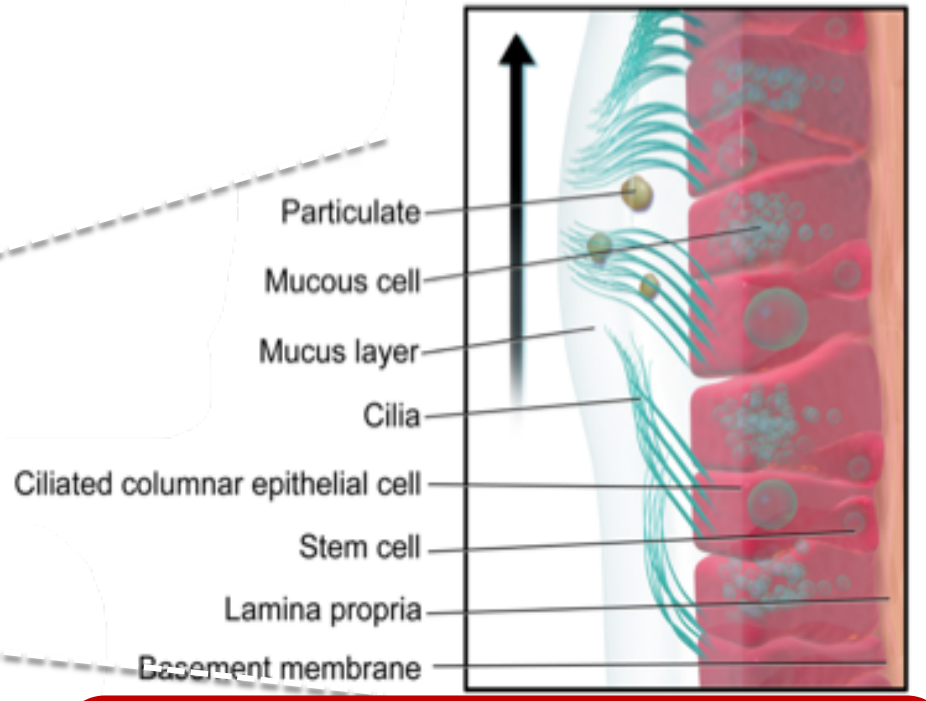


skin cracking, decreased wound healing

dry eyes, excessive tearing

Dry air impairs our respiratory system defenses





Dry inhaled air causes:

- Increased susceptibility to infections
- Increased wheezing from allergic disease

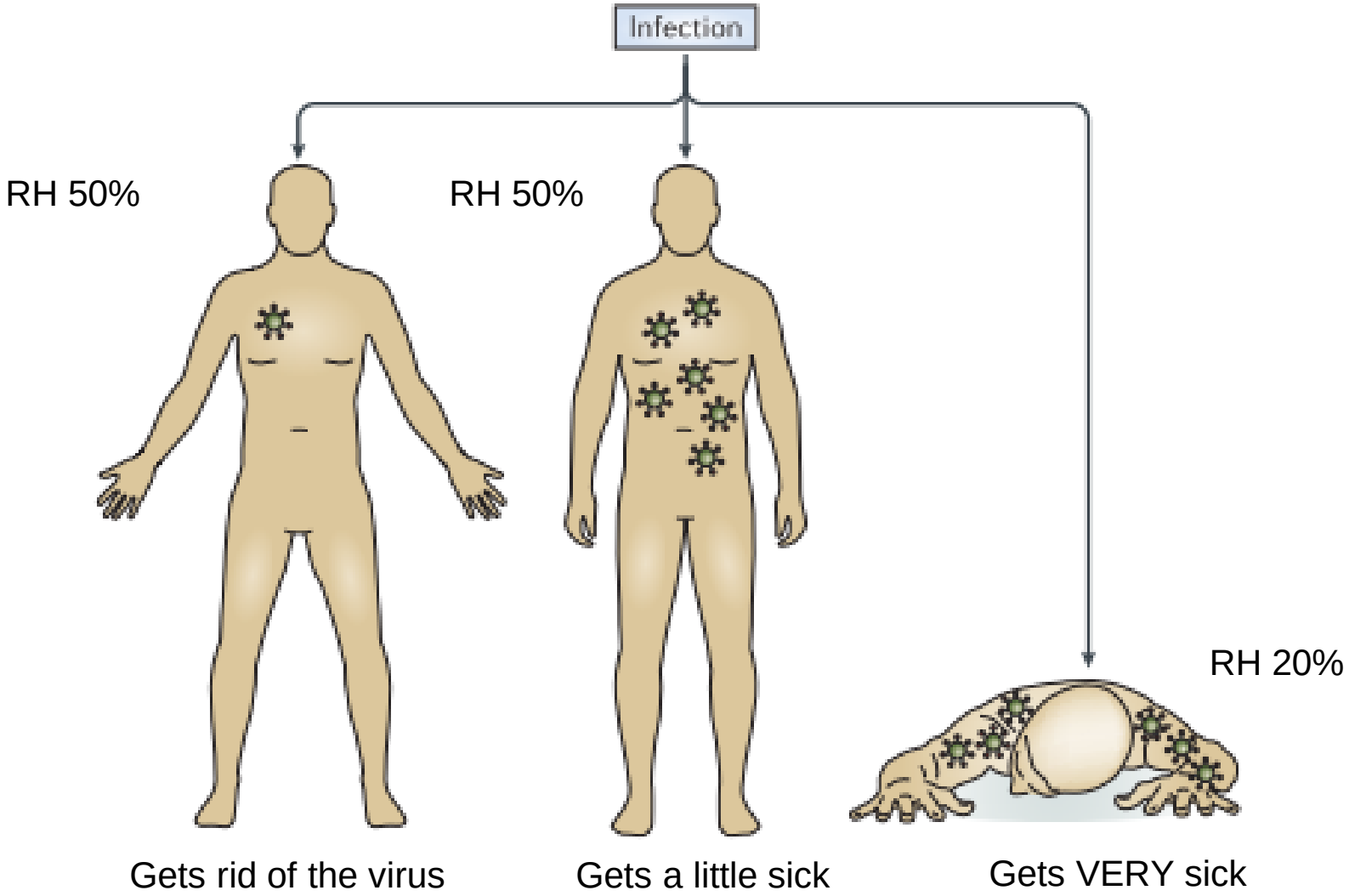
A key study just published in PNAS

“Low ambient humidity impairs barrier function and innate resistance against influenza infection”

Proceedings of the National Academy of Sciences, USA. May 19, 2019

Eriko Kudo, Eric Song, Laura Yockey, Tasfia Rakib, Patrick Wong, Robert Homer, Akiko Iwasaki

Question investigated: Why do these differences exist?



Study setup

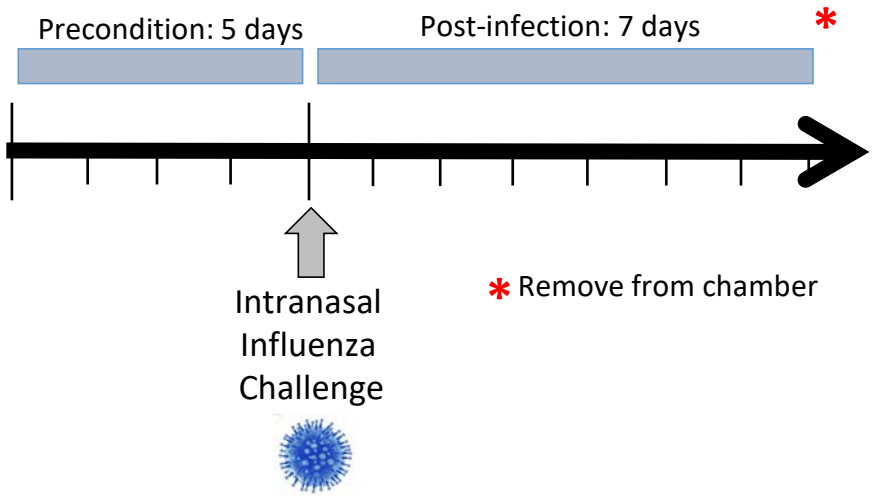
Chamber conditions
Temp = 20°C

20%RH
3g/m³ AH

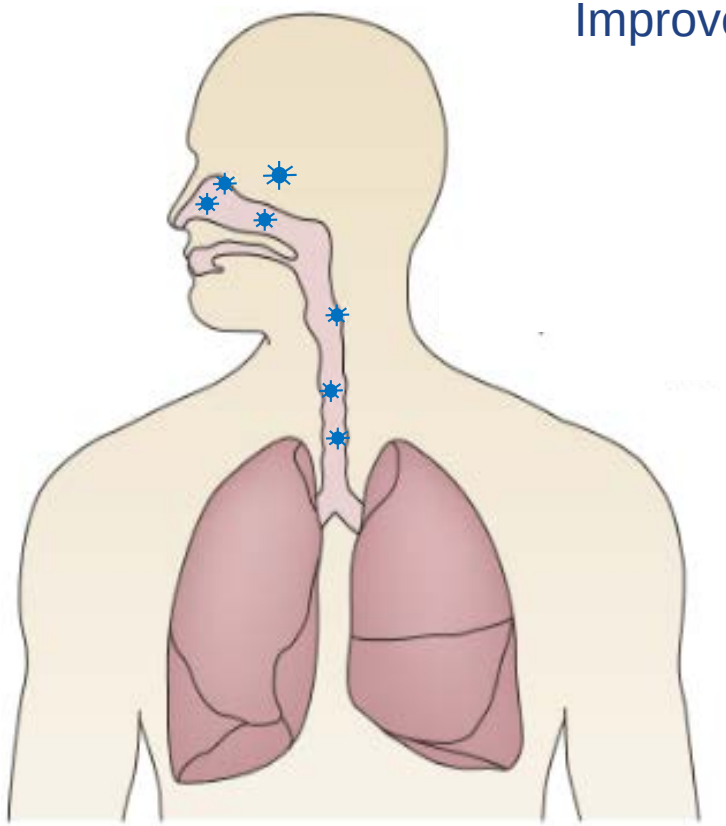
or

50%RH
9g/m³ AH

Mx1 mice have functional Type I IFN responses



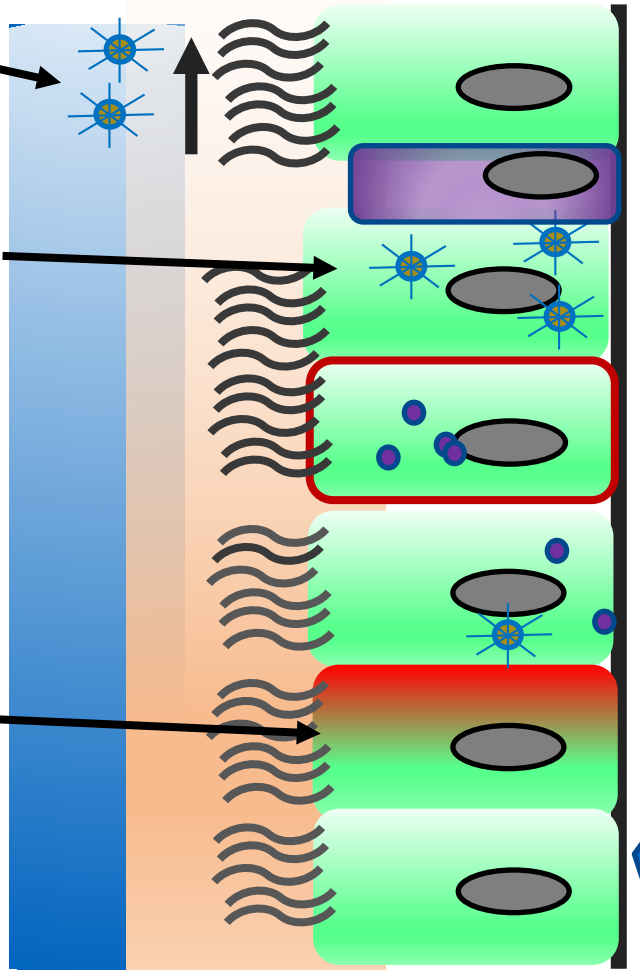
Summary: Innate respiratory protective mechanisms are optimal at 50% RH, and impaired at RH 20%



Improved muco-ciliary clearance

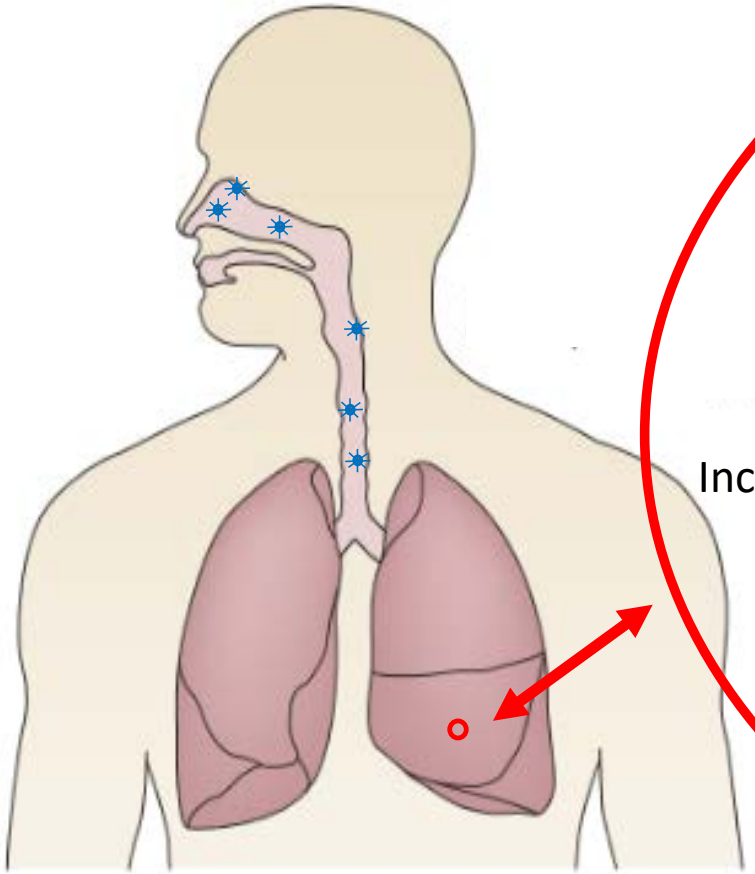
Enhanced protection induced by Interferon

Decreased inflammation and tissue damage



Enhanced tissue repair

Summary: Innate respiratory protective mechanisms are optimal at 50% RH



Decreased cytokine production, cell damage

Conducting airway

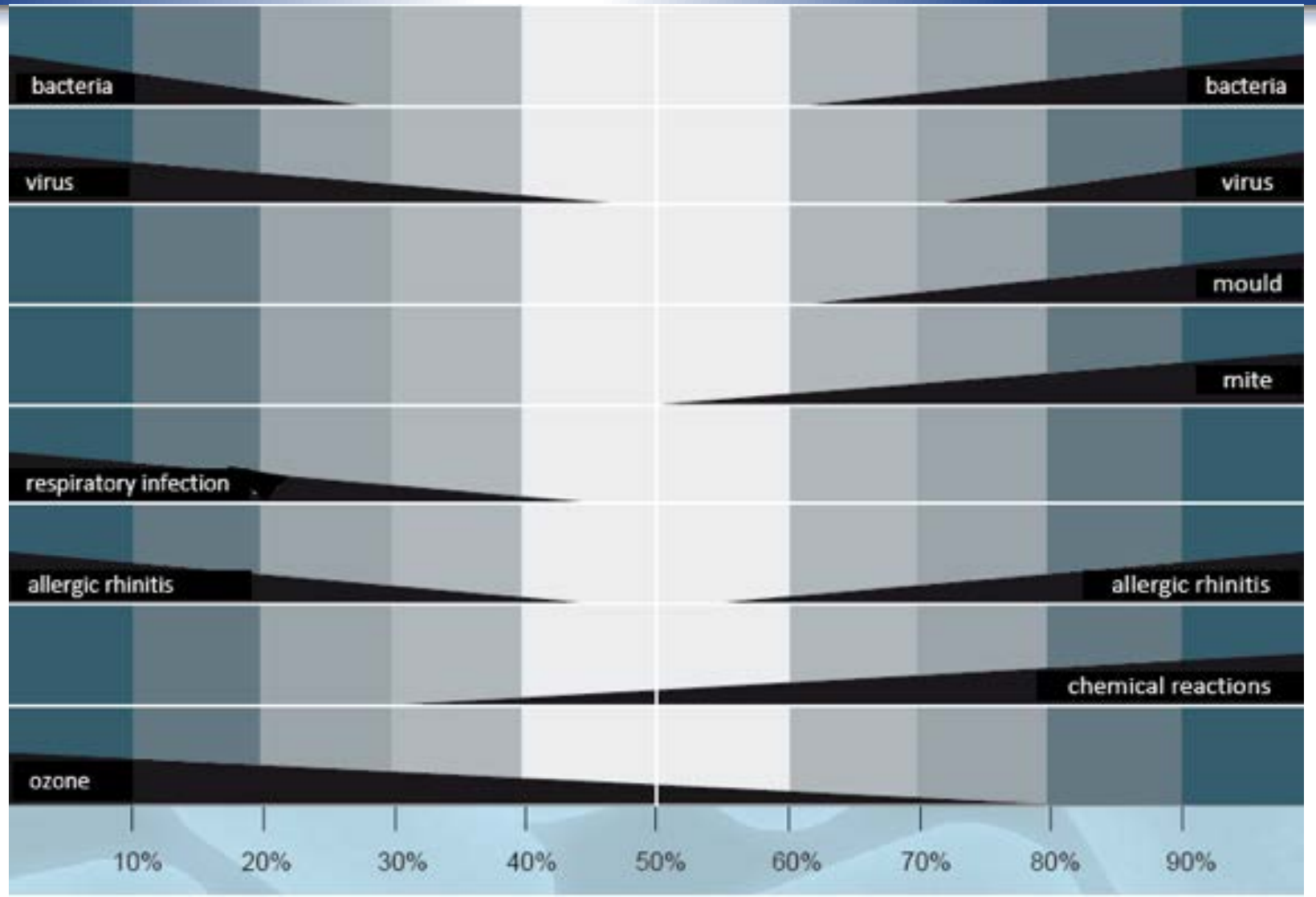
Decreased infection of distal airway epithelium

Increased Epithelial Repair

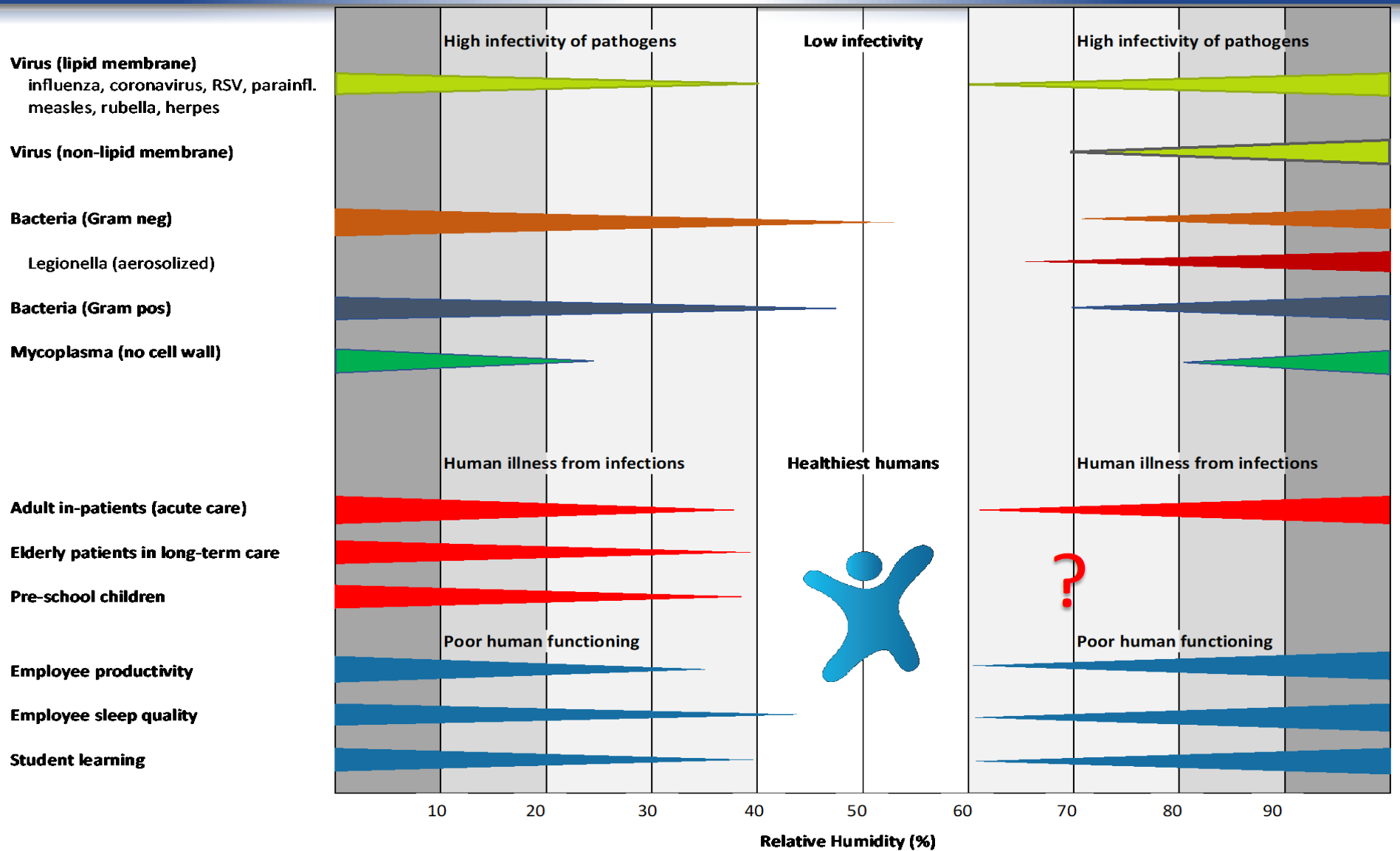
Alveolus

Increased clearance of virus by protective alveolar macrophages ("big-eaters")

ASHRAE 1985:“Optimal RH Level For Health” = 40%–60%



35 years later….. Taylor Chart 2019



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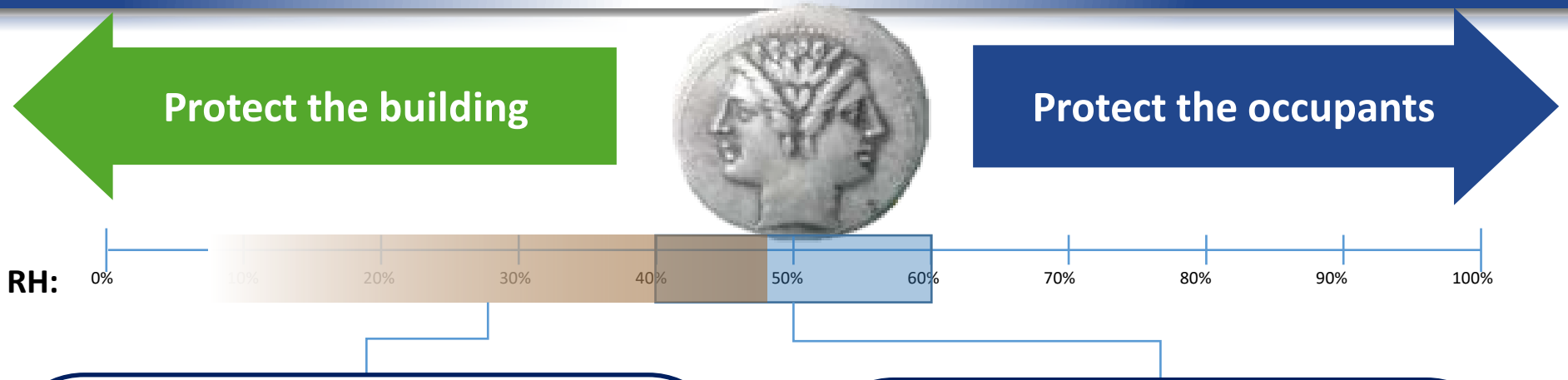
The great indoor air RH debate!



Buildings don't care about humidity

- The drier the air the better
- Easier to dry the air than fix the envelope construction
- Humidification will cost more

Occupants need RH between 40% and 60% for health

- Decreased infections
- Fewer allergies
- Improved hydration
- Improved wound healing
- Increased work performance

Humidification **is** used when the financial impact is quantifiable

National Institute of Health animal facility

Replacement cost of a primate: $22,000

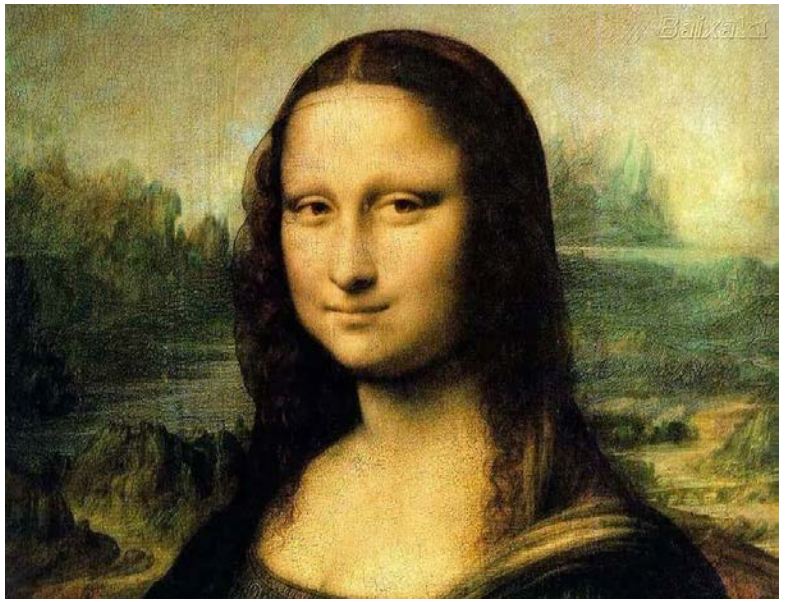
RH 40%–60%

NASA spacecraft

Cost to train an astronaut: $50 million (in 2006)

RH 40%–60%

Louvre



Mona Lisa value: $780 million

RH 40%–60%

HAIs are costly for a 250 bed hospital

Summary of Total Excess Costs and Hospital Days Due to Hospital Acquired Infections

	Total Infections	Total Excess Costs	Total Excess Hospital Days
Urinary Tract Infections	1,296	$1,435,968	2592.0
Surgical Wound Infections	365	$7,042,464	4378.0
CRBSI	148	$4,990,636	2509.0
VAP	15	$401,369	170.0
MRSA	120	$927,162	646.0
CDIFF	122	$500,200	733.0
TOTAL	**2,066**	**$15,297,799**	**11,028.0**

*2015 volume of a selected 250-bed hospital, APIC calculated costs

The majority of bacteria causing HAIs are resistant to dryness and survive in the air

Acinetobacter supp.	3 d	up to	**5 months**	6	references
Clostridium difficile (spores)			**5 months**	3	references
Escherichia coli	1.5 h	up to	**16 months**	10	references
Enterokokkus supp. inkl. VRE und VSE	5 d	up to	**4 months**	4	references
Klebsiella supp.	2 h	up to	**>30 months**	5	references
Pseudomonas aeruginosa	6 h	up to	**16 months**	7	references
Staphylococcus aureus, inkl. MRSA	7 d	up to	**7 month**	6	references

reaction to hospital's dry environment ⟶ increased infectivity

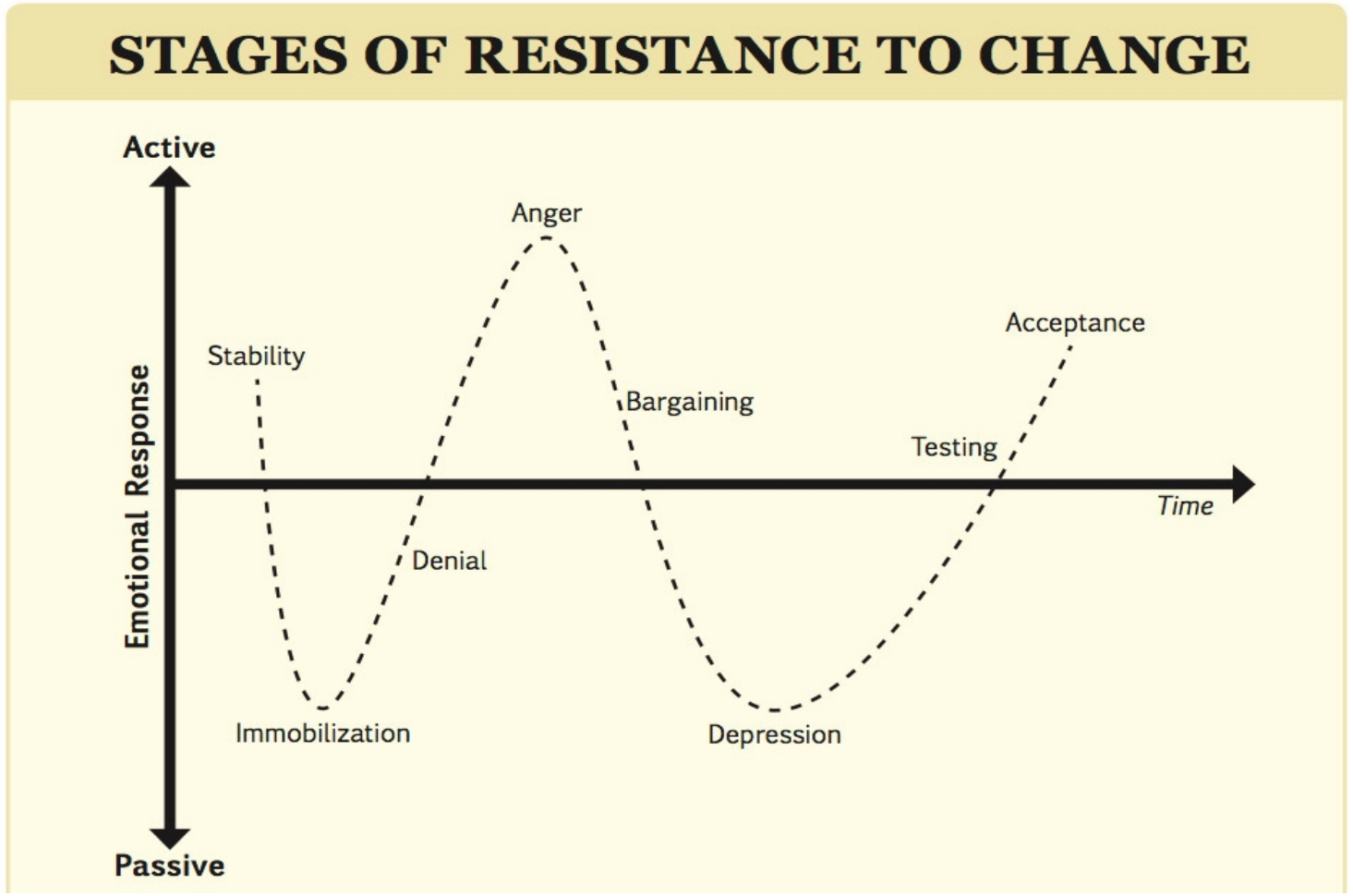
Hospital surfaces are dry and non-porous

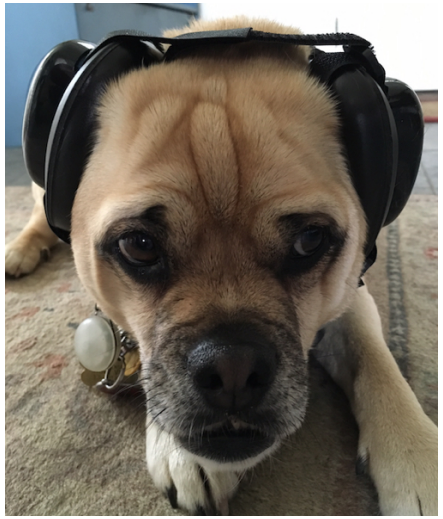
Kramer A et al, How long do nosocomial pathogens persist on inanimate surfaces? a systematic review, BMC Infectious Diseases 2006, 6:130

Value analysis of humidification in 250-bed hospital

BENEFITS - Year One			Dollars
Increased Revenue	Maximize per day bed value by decreasing LOS	$	1,310,126
	Decrease non-reimbursable HAI costs	$	764,890
Cost Avoidance	3% CMS penalty for readmissions	$899,880	91,787
	CMS Quality Index penalty	$899,880	TBD
	Joint Commission citation		TBD
	Employee absenteeism		TBD
	HAI litigation by patients		TBD
	Quarterly total	*$7,225,018*	2,166,803
	Cumulative value	*1st Quarter*	$2,166,803
		500.97%	
INVESTMENTS			
	Gas		
	Installation & Integration of New System	$	(1,198,500)
	Maintenance	$	(23,850)
	Operating Cost	$	(34,573)
	OR & PT Room Down Time	$	(10,000)
	Quarterly total		($1,266,923)
	Cumulative investment		($1,266,923)
NET VALUE			

Change is hard! We resist and often do not even listen





Uniting our goals would benefit everyone

Medical professionals

- Heal patients
- Follow clinical protocols
- Avoid lawsuits

Building professionals

- Reduce energy use
- Stay within budget
- Follow building codes

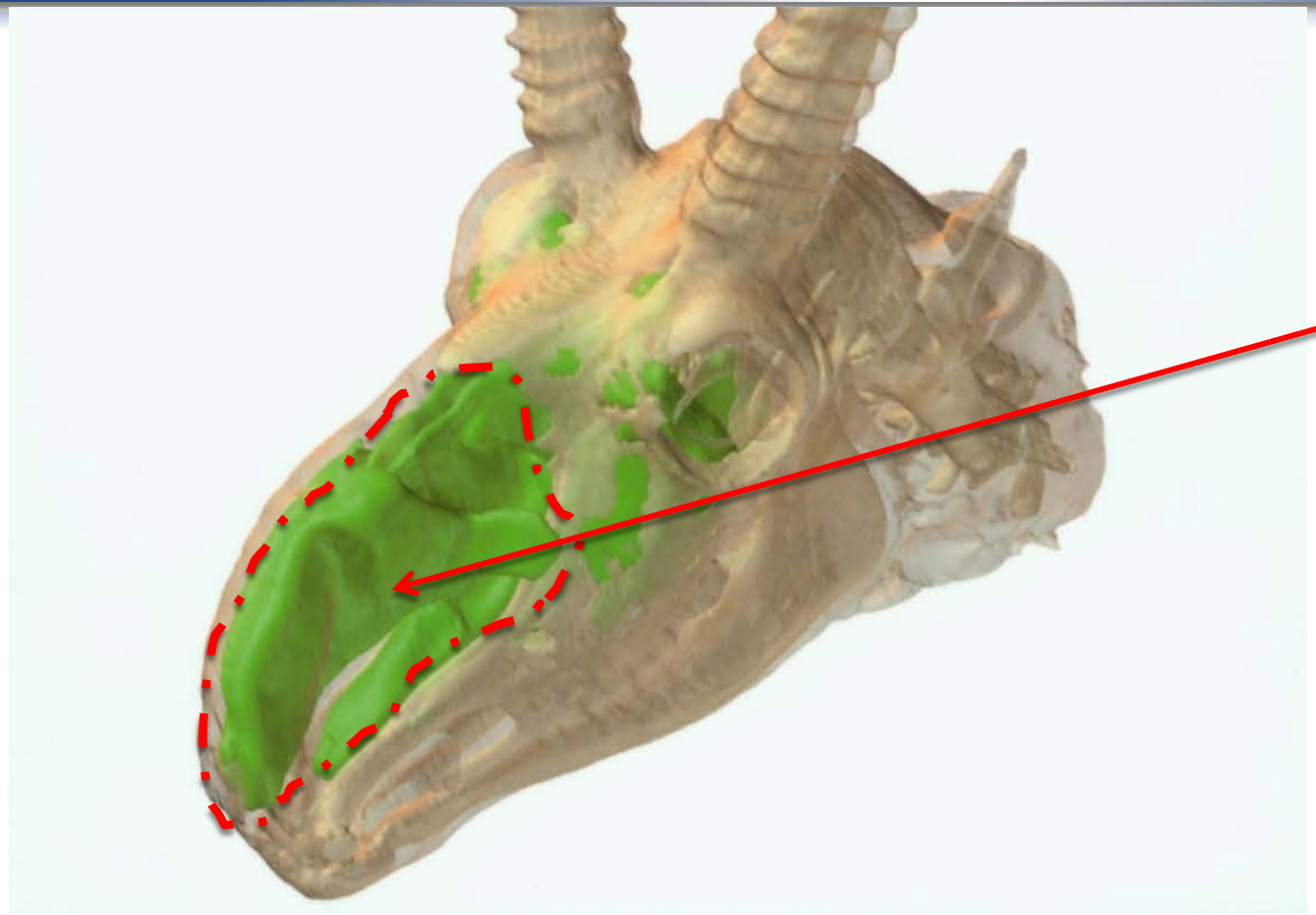
IMPROVE OCCUPANT HEALTH

- Better health
- Decrease acute and chronic diseases
- Decrease financial losses from illness

Evolution and RH

skull of the grassland Saiga antelope

Evolution and RH



A large cranial air cavity increases ambient RH, preventing dust particles and parasites from entering delicate lung tissue

the African desert first cousin

Conclusions

- The indoor environment is critical for our health
- Humans need water vapor
- Humidification can present significant challenges
- We cannot ignore this!

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Thank you!

MD@taylorcx.com
(860) 501-8950

Stephanie Taylor, MD,
M Arch, FRSPH(UK), M CABE

Questions Please