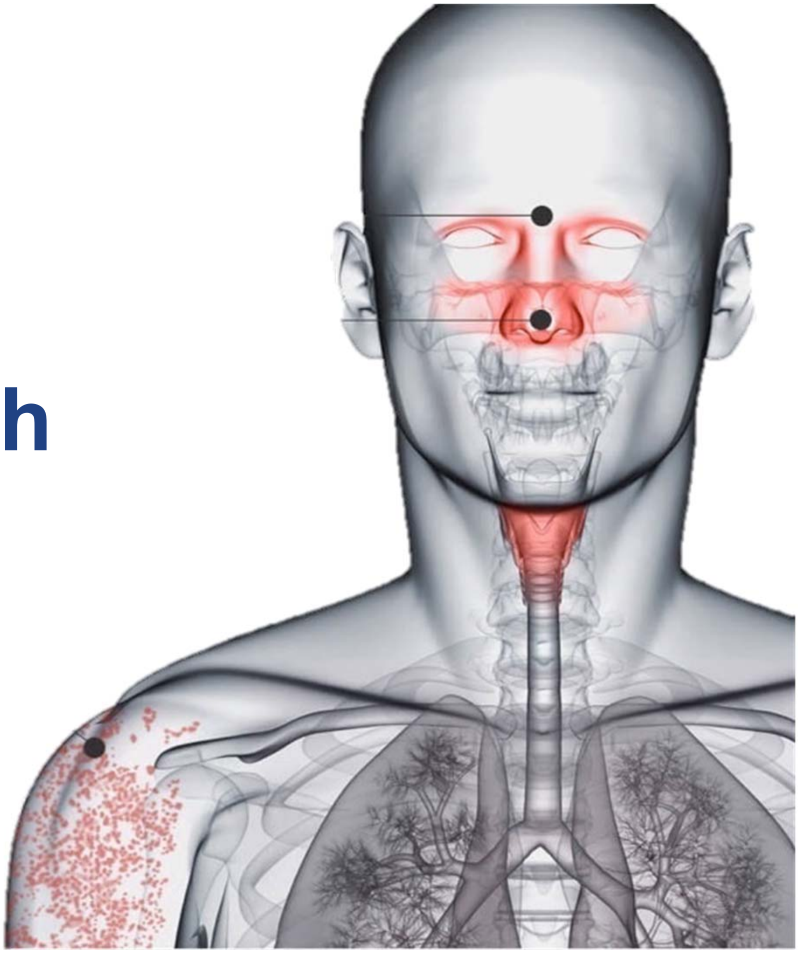
Putting People First!

Managing IAQ for Health



Stephanie Taylor, M.D., M. Arch

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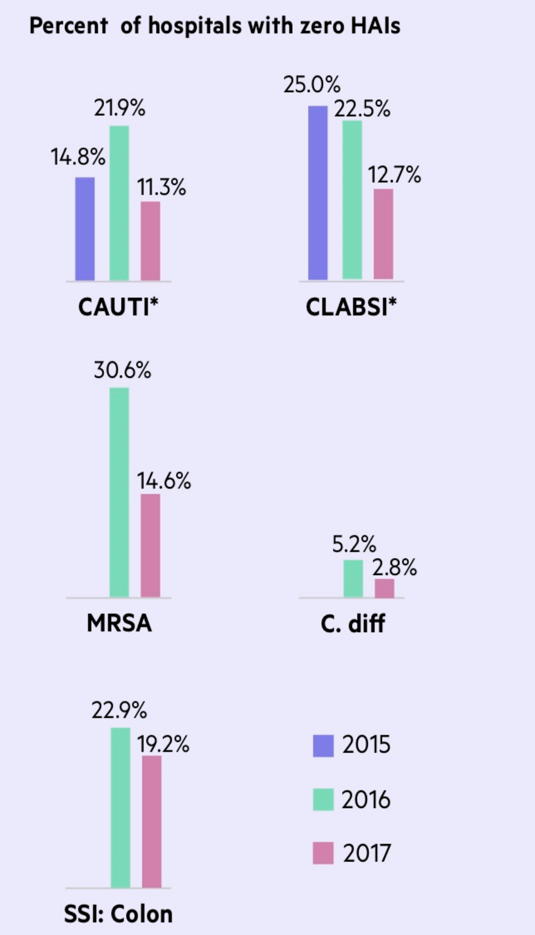
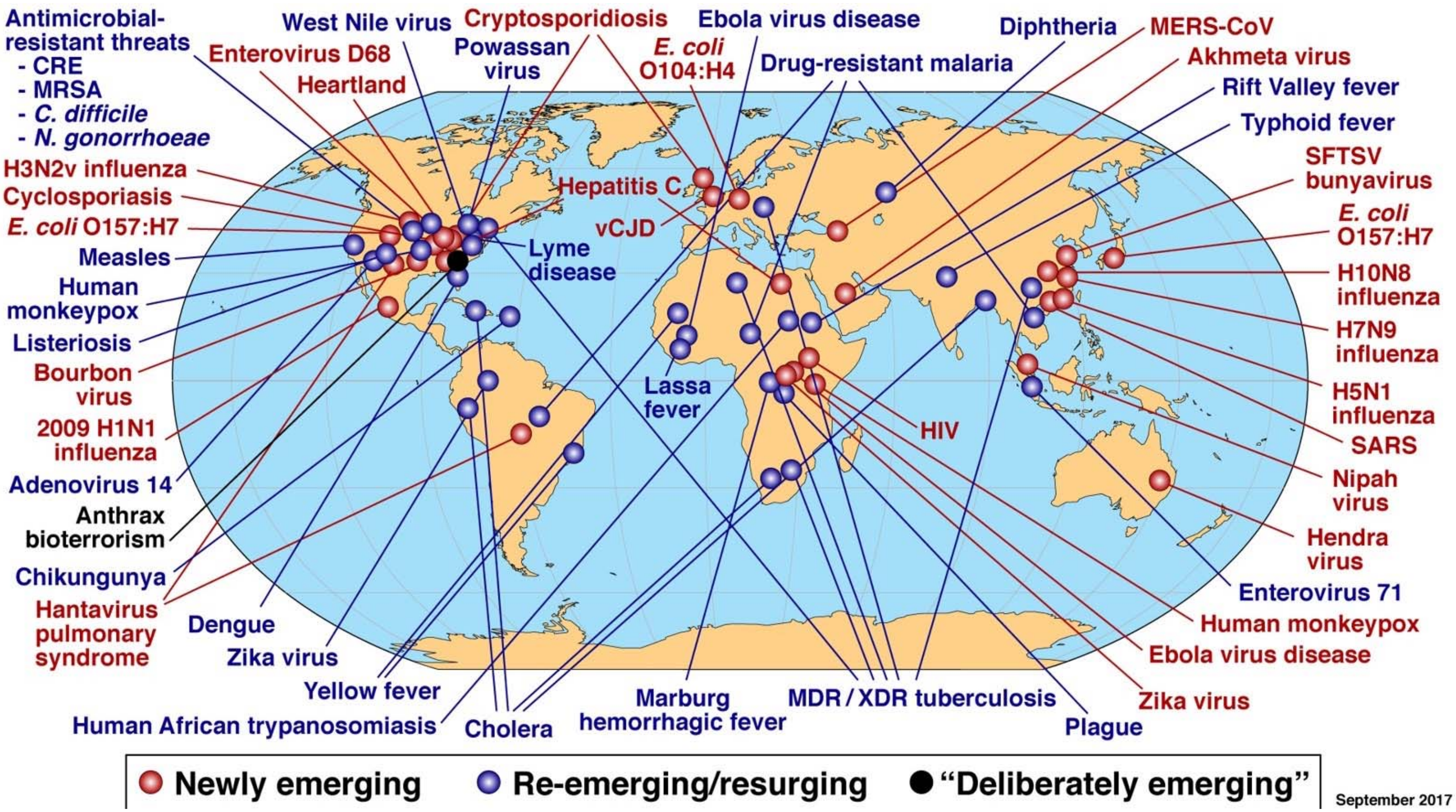
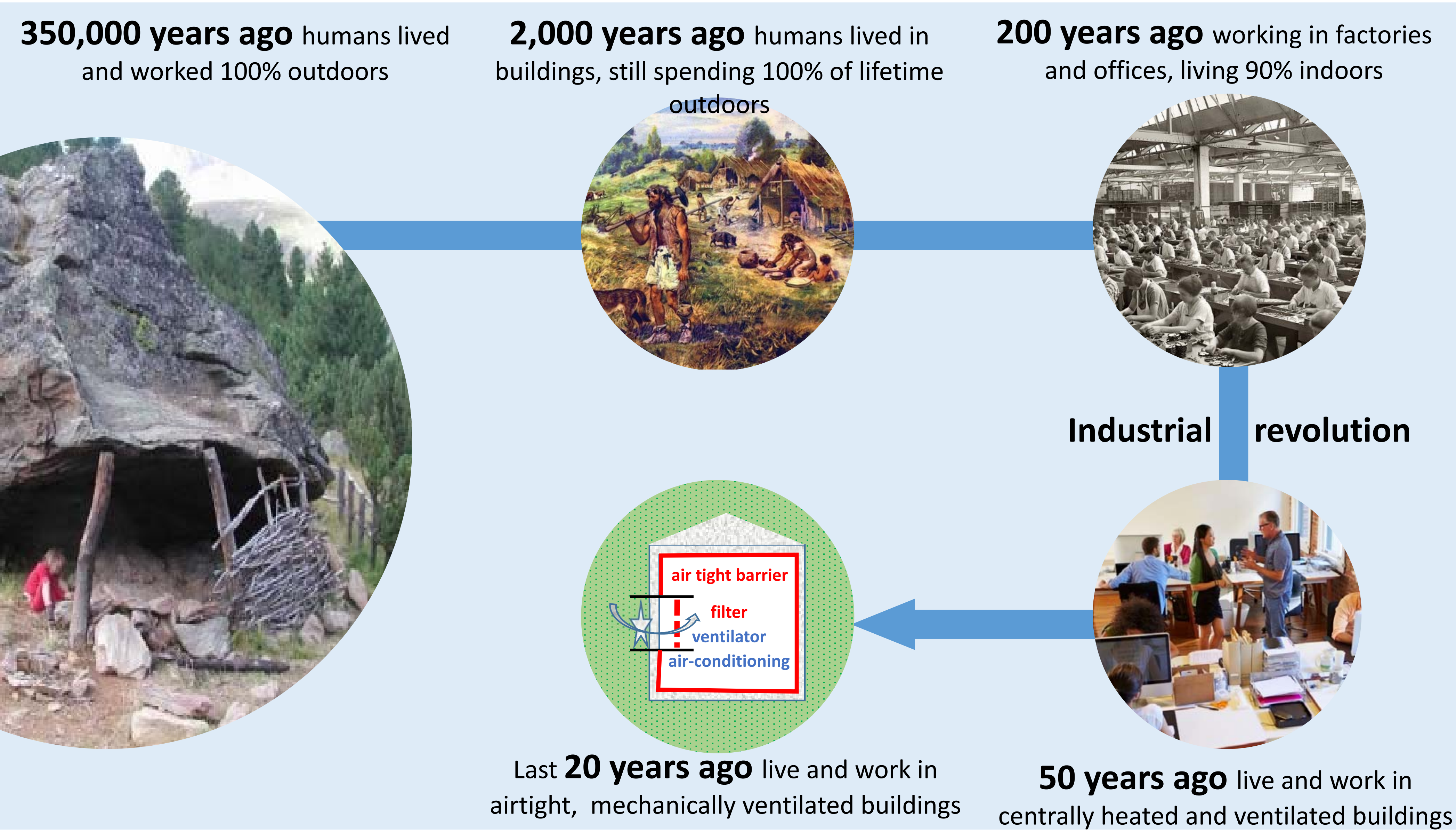
We are trying hard to decrease HAI rates, but these infections are still too common



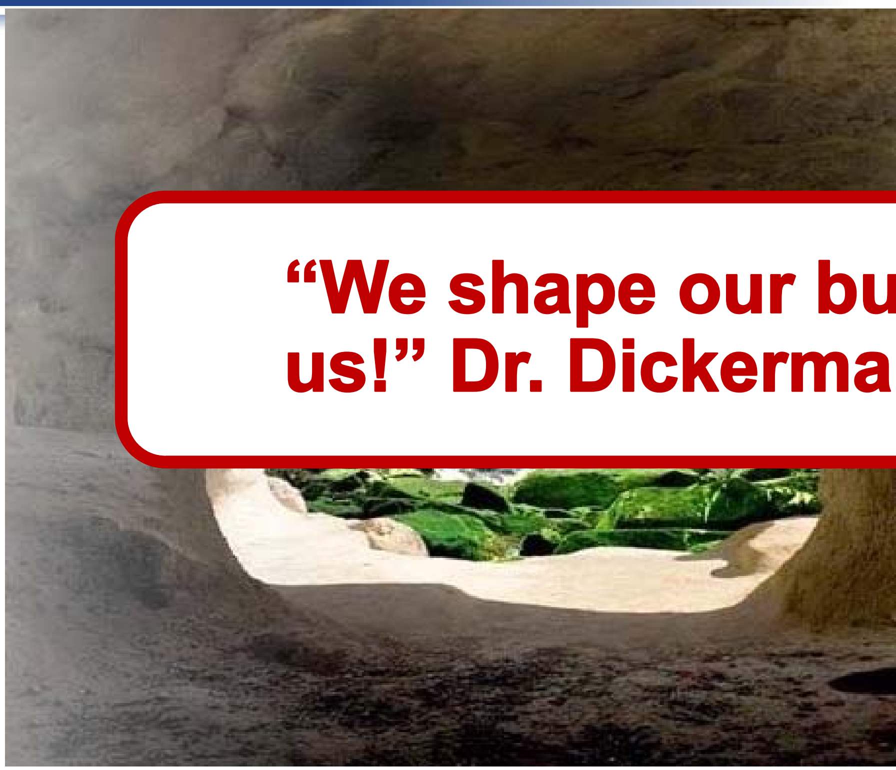
Autoimmune, inflammatory and many infectious diseases are on the rise



Domesticated dogs are now carriers of the quickly evolving influenza virus


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
air tight barrier
filter
ventilator
air-conditioning
Last 20 years ago live and work in airtight, mechanically ventilated buildings
50 years ago live and work in centrally heated and 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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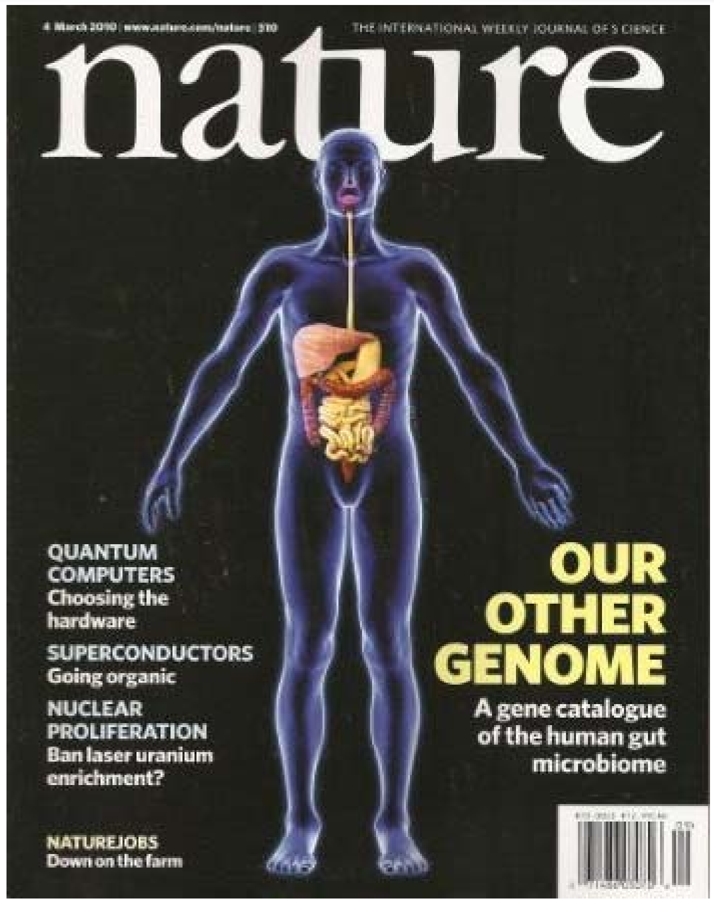
Thankfully, we can now see if this is true

Tissue culture

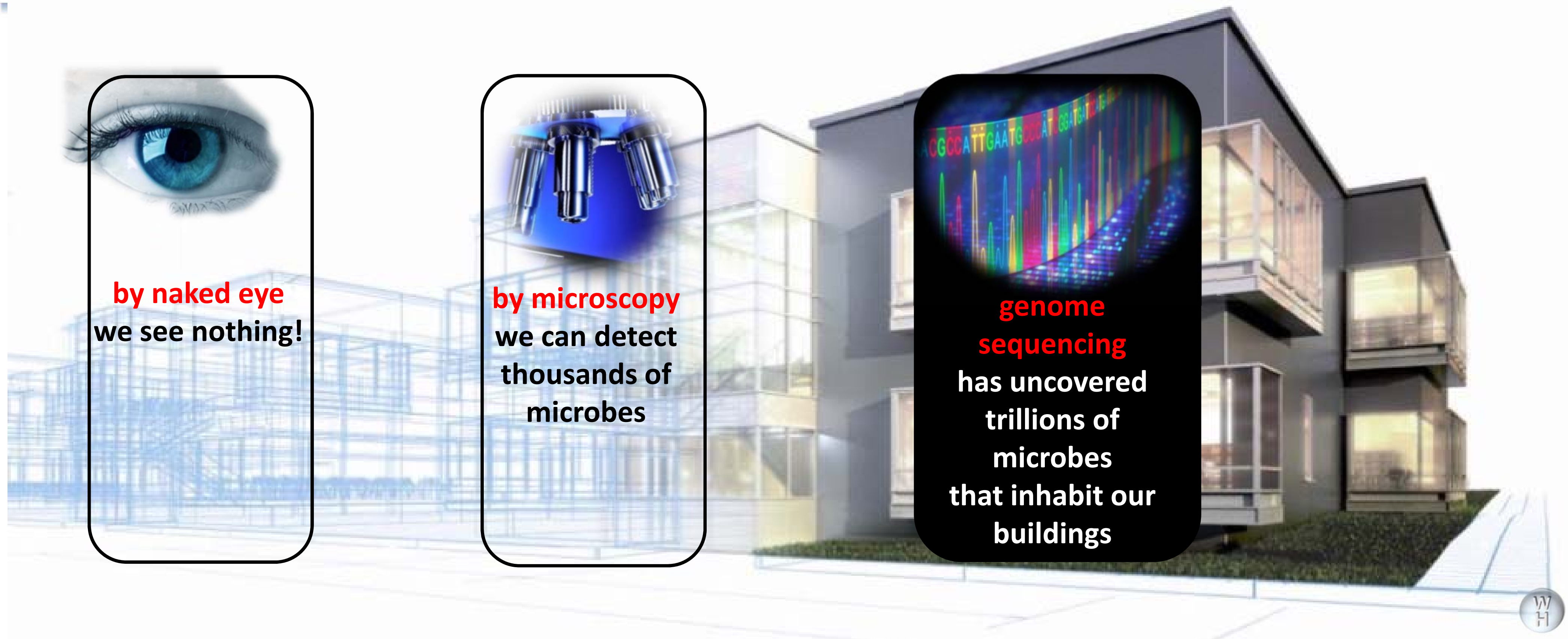
→

Metagenomics 2018

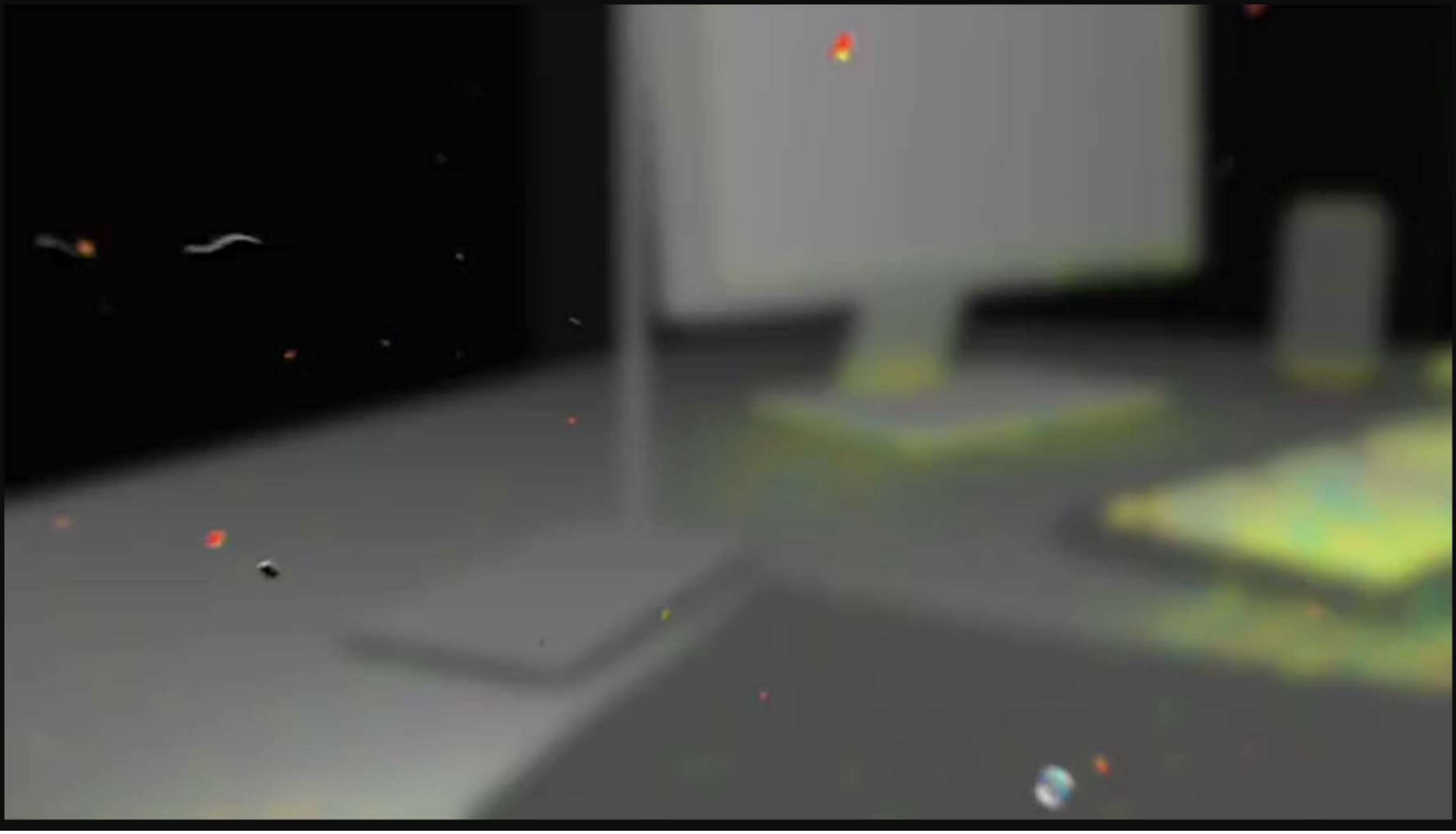
Genetic analysis has shown us that each of us is an entire ecosystem!



Buildings have their own microbiome

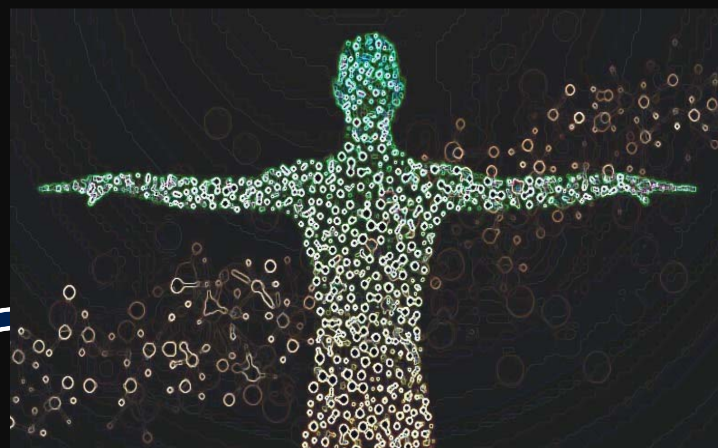


A closer look at our surroundings



The indoor environment now drives natural selection

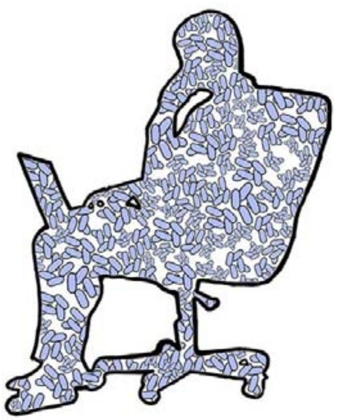
Occupants send microbes into buildings

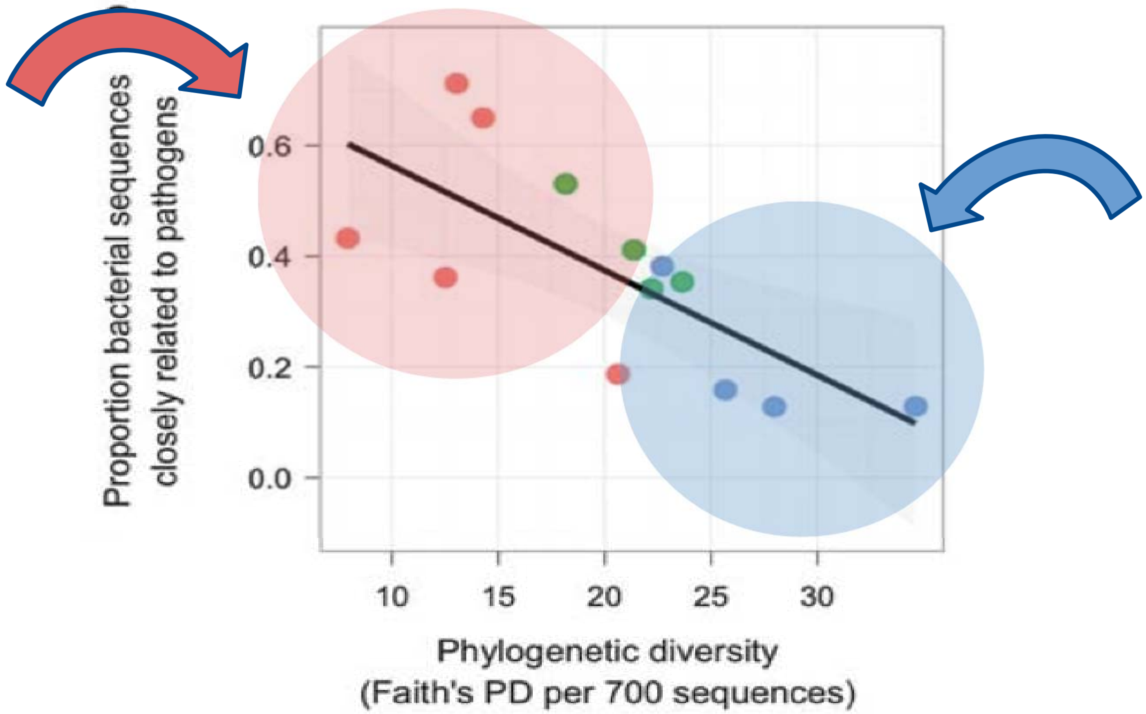


Building design, use and ventilation “select” microbes which survive and interact with occupants

Microbes in mechanically ventilated buildings are more closely related to pathogens

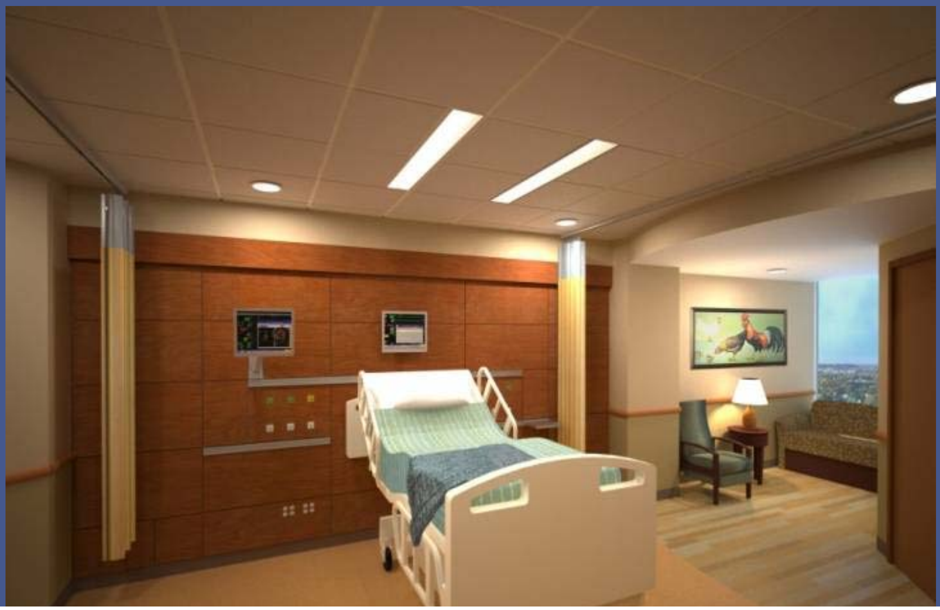
<u>Mechanically ventilated</u>
- ***Low*** bacterial diversity
- ***High*** average pathogenicity



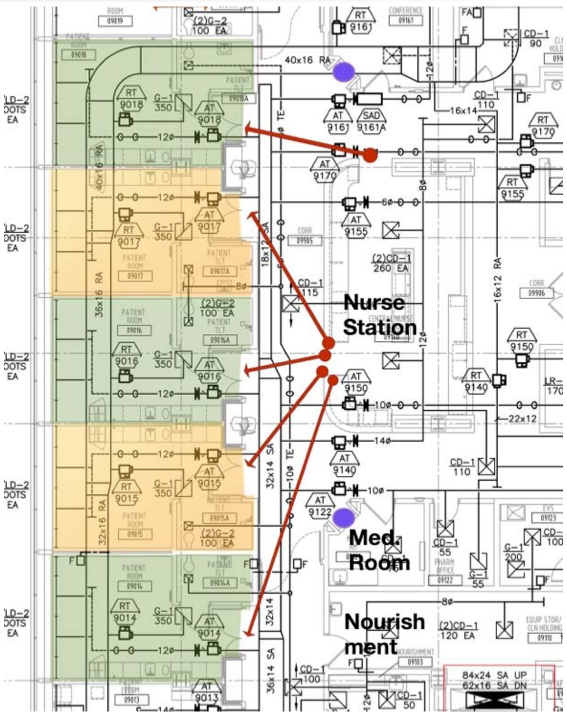


<u>Outdoor Air</u>
- ***High*** bacterial diversity
- ***Low*** average pathogenicity

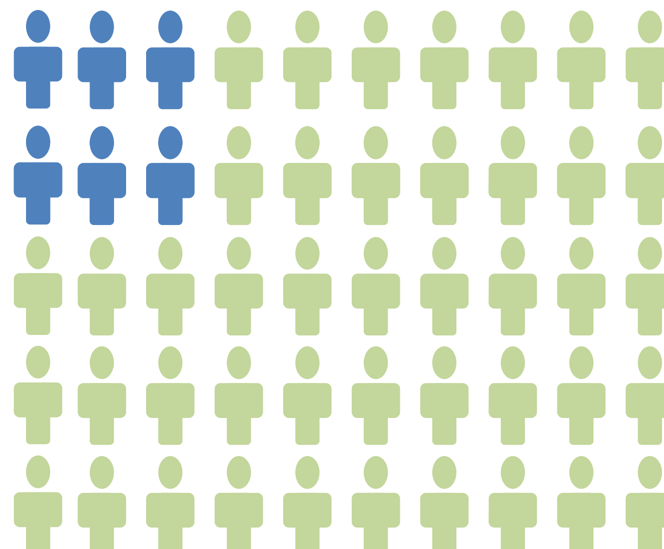
A study to examine the impact of a building on occupant health



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



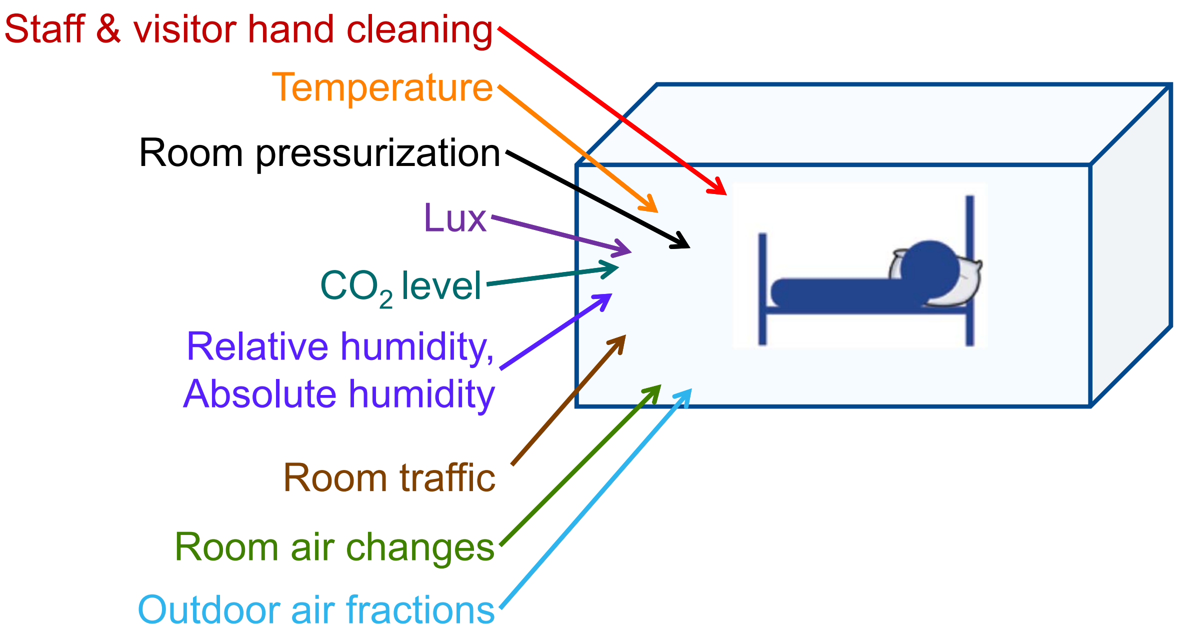
Correlate indoor conditions in 10 patient rooms and 2 nurse stations



With new patient infections

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

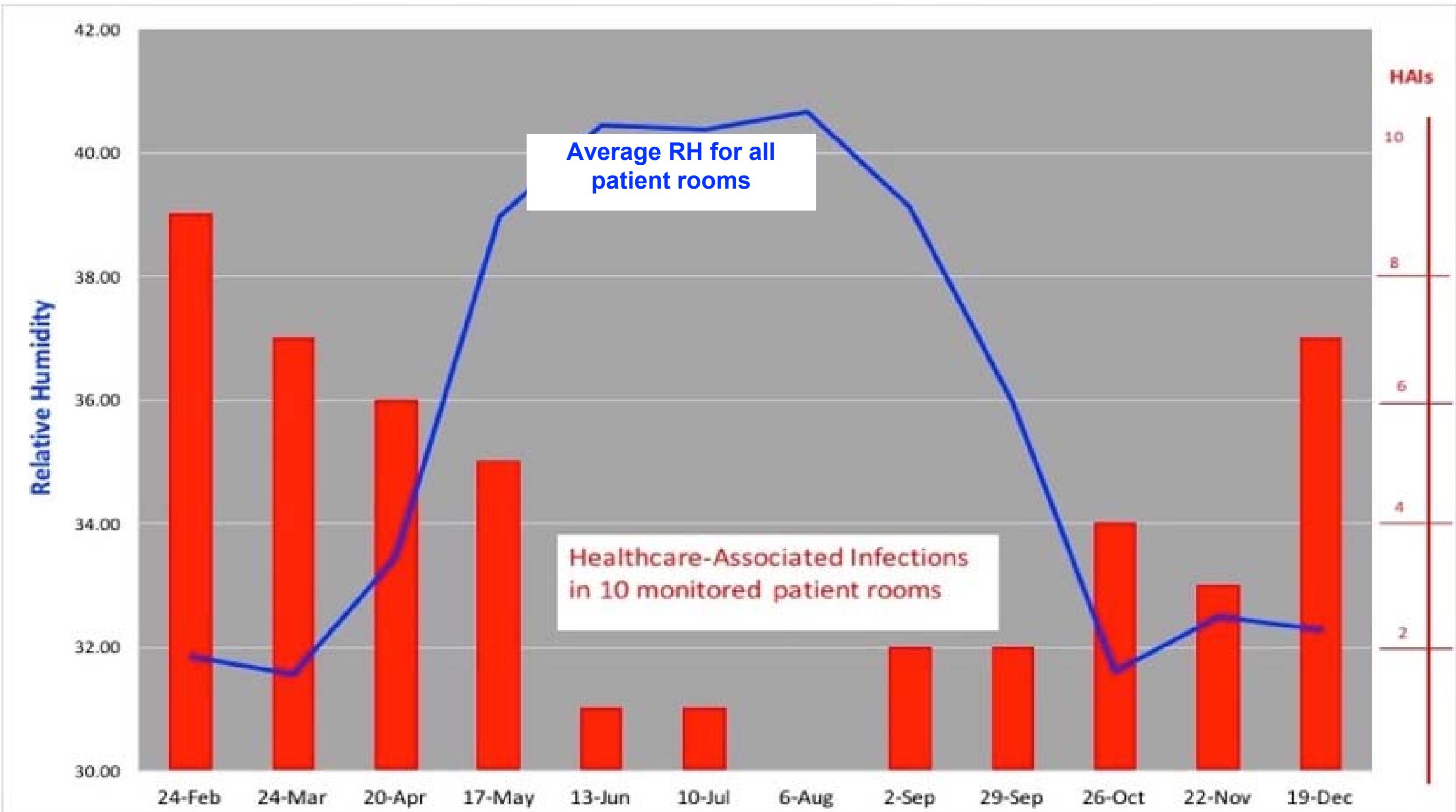
Patient room data ***vs.*** **Patient HAIs**



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**

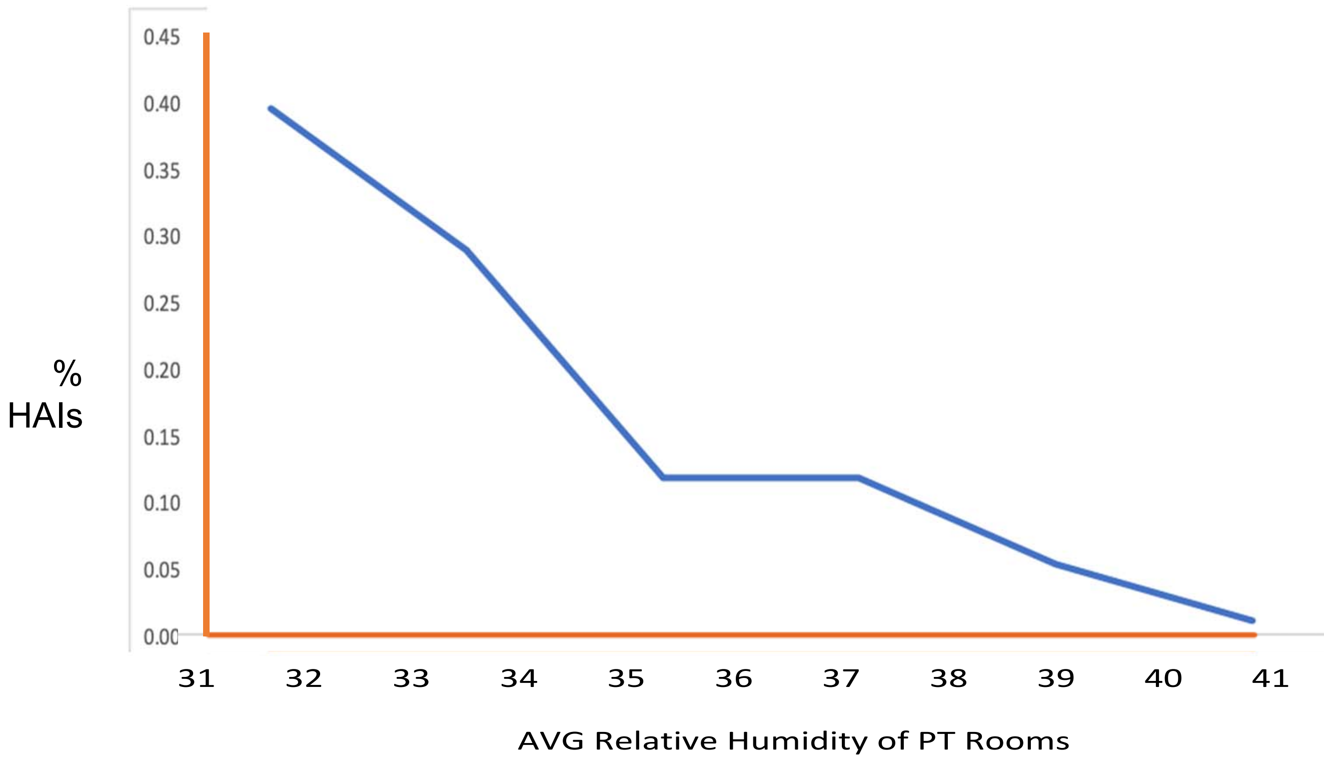
As patient room RH went down, HAIs went up!



Coefficients[a]

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

As patient room RH went up, HAIs went down!



Coefficients[a]

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

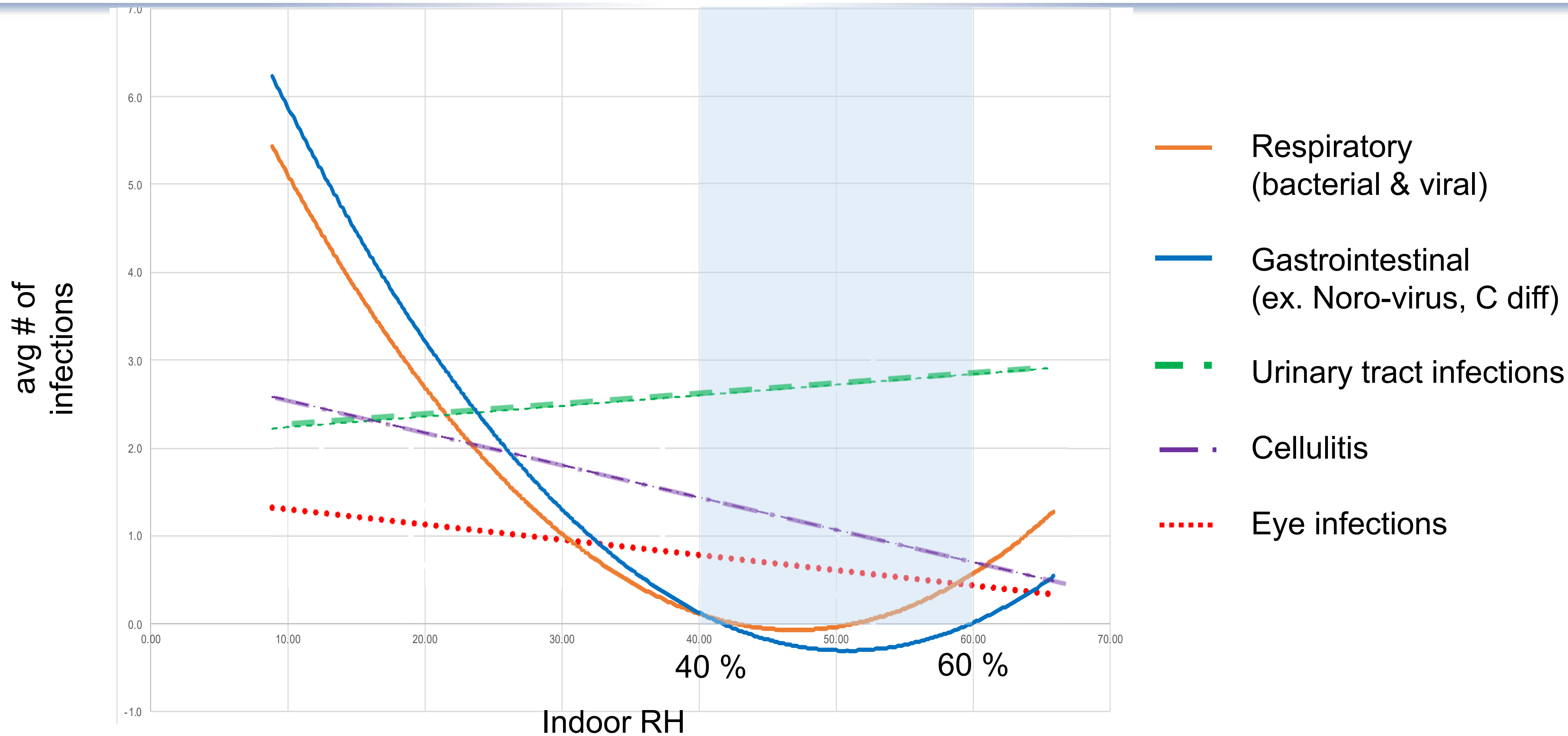
Patient infections VS Environmental data

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

Indoor conditions
- temperature
- relative humidity
- visitors
- staff absenteeism

Outdoor climate
- 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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Please explain!	▪ **Microbes indoors** ▪ **Humans indoors**
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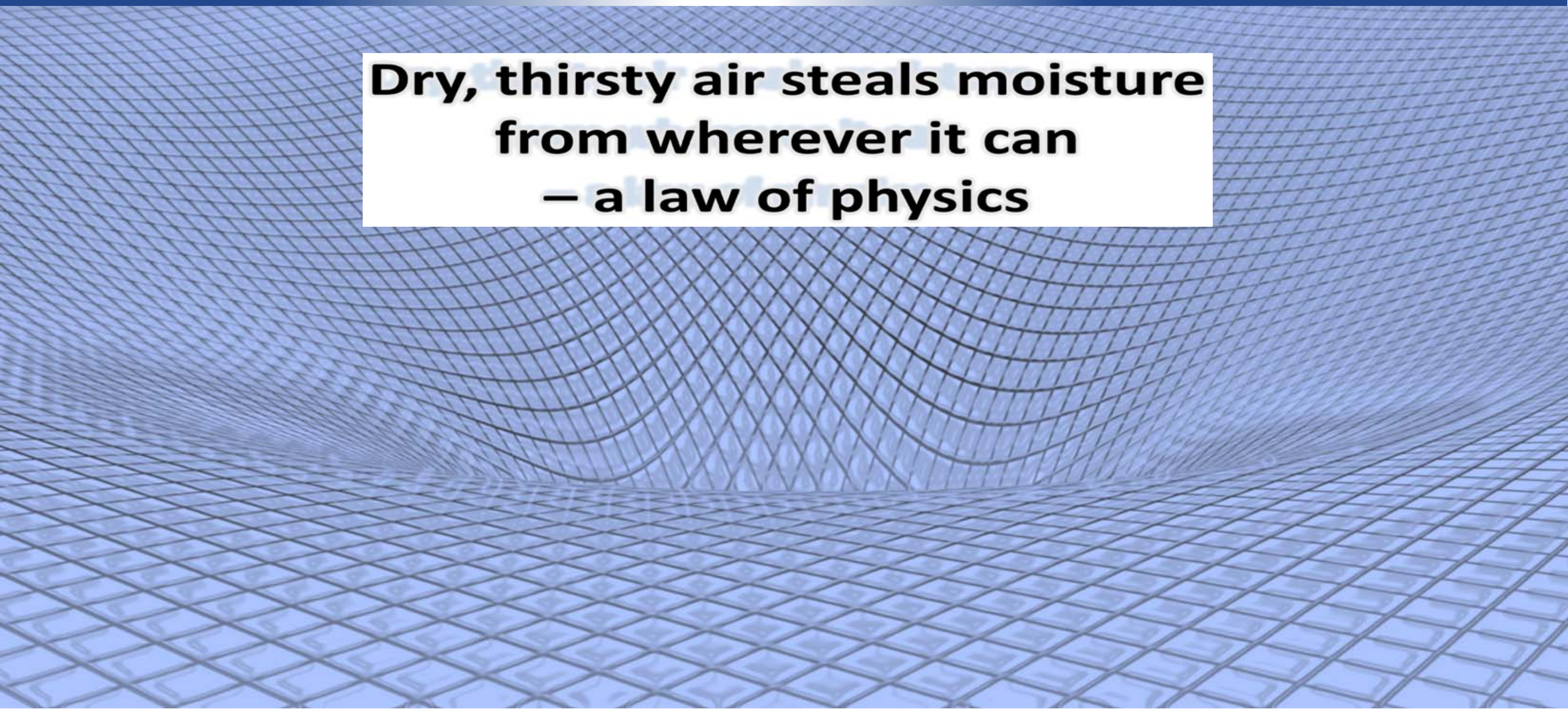
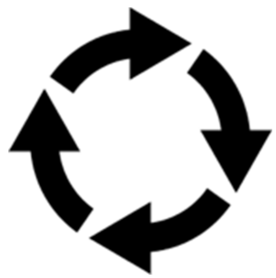
Why is dry air so powerful?



What determines if this cough will infect others?

When RH < 40%, pathogen infectivity is high

Greater airborne transmission



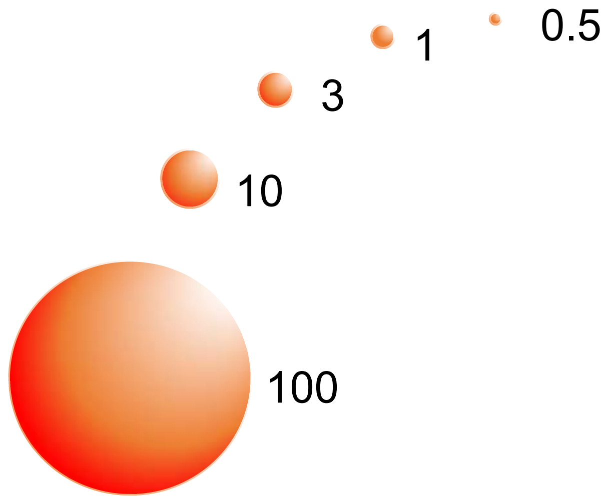
Evasion from surface cleaning through resuspension

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:

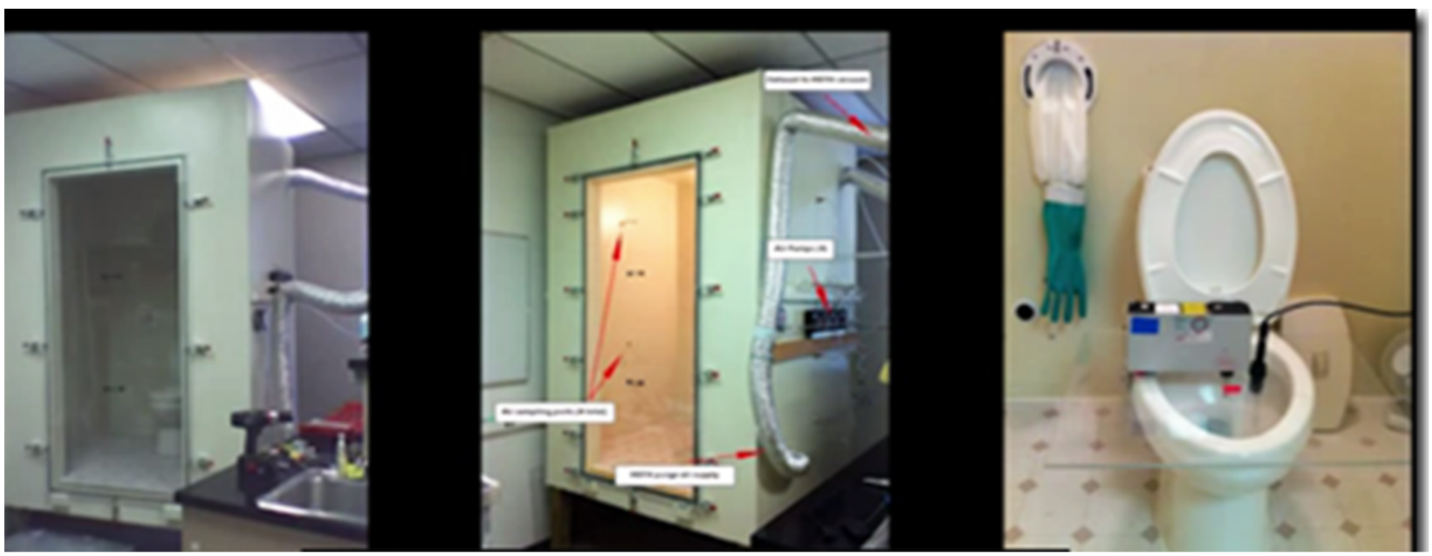
- No significant increase in transmission rates
- The health system saved approx. $643,776 and 45,277 hours per year in healthcare worker time previously spent on donning and doffing personal protective equipment

Pduwlq/#H1/#Lqihfwlrq#Frqwuro#)#Krvslwdo#Hslghplrorj|

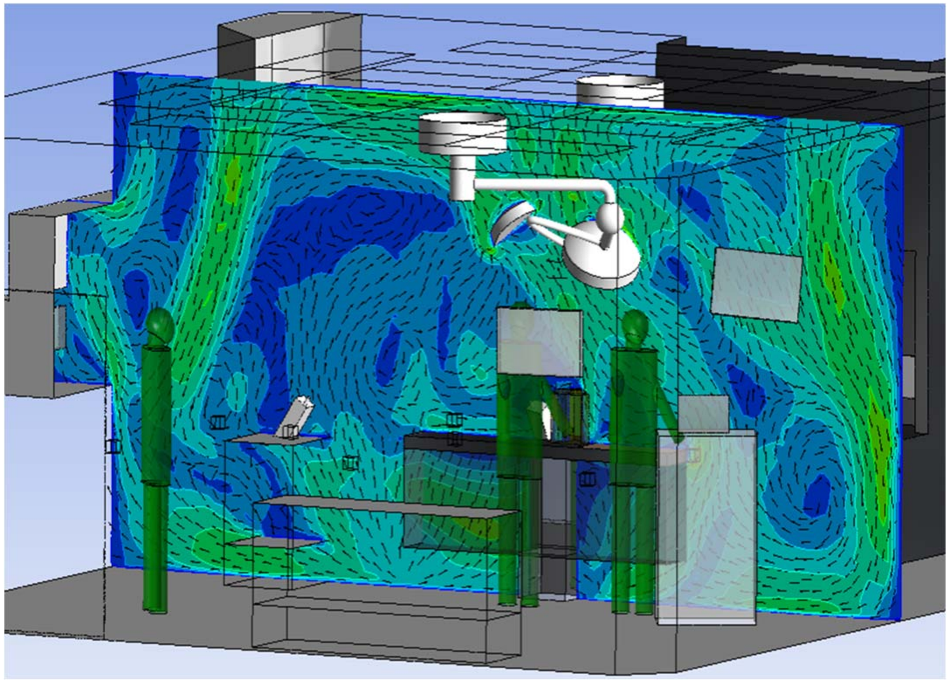
C. diff can travel in infectious aerosols

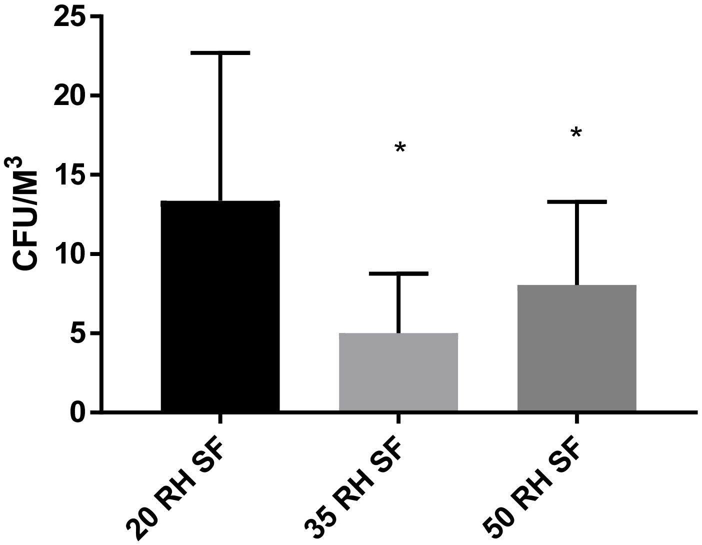
December 2018 – American Journal of Infection Control.

- 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 <u>higher</u> in low RH



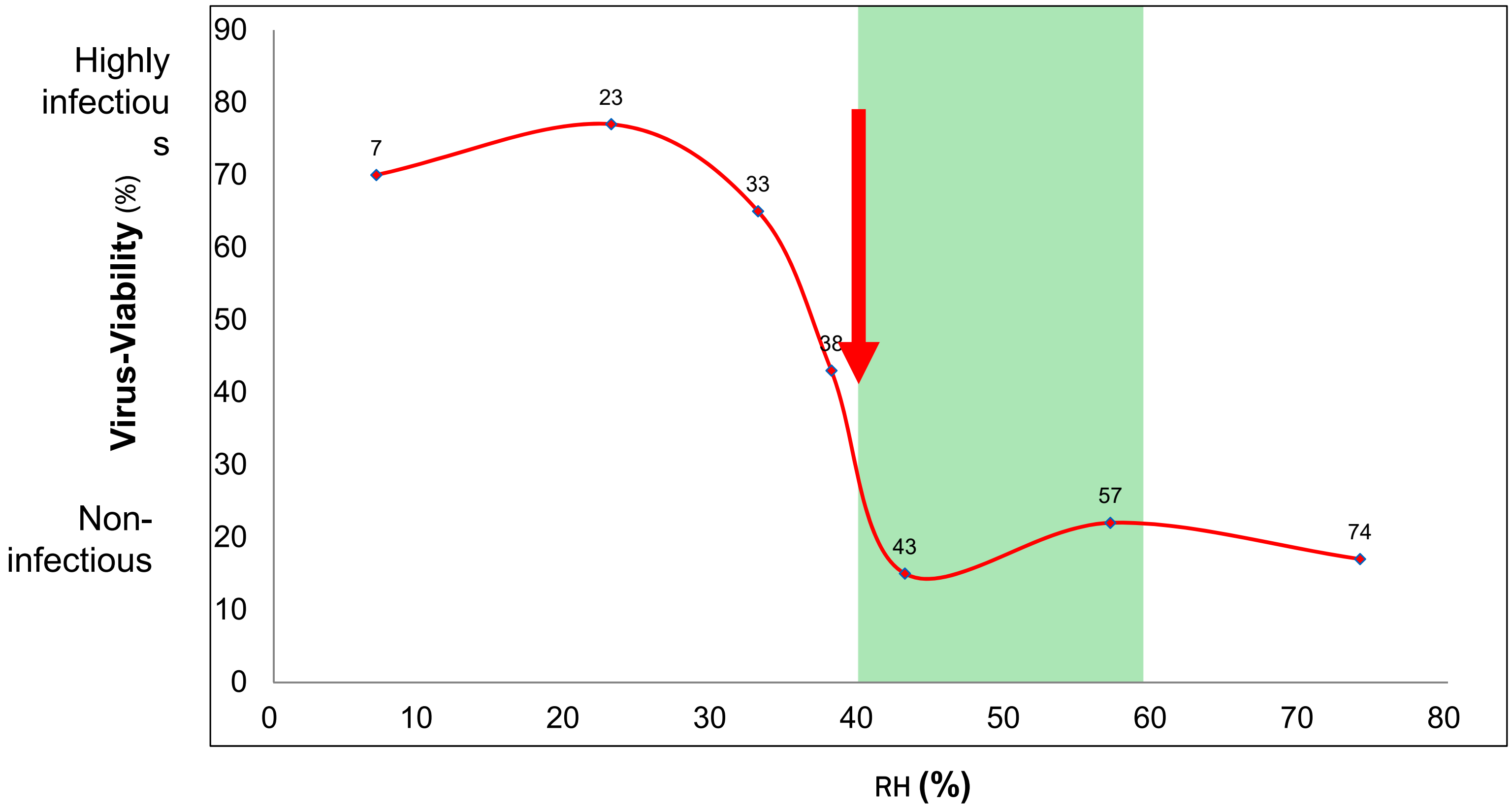


*=p<0.0167 v. 20RH

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

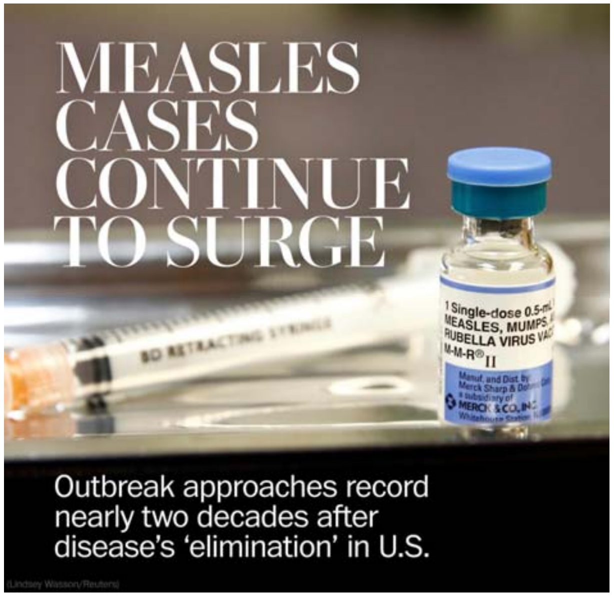
Greeley, D Indiana Medical Center, 2018

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

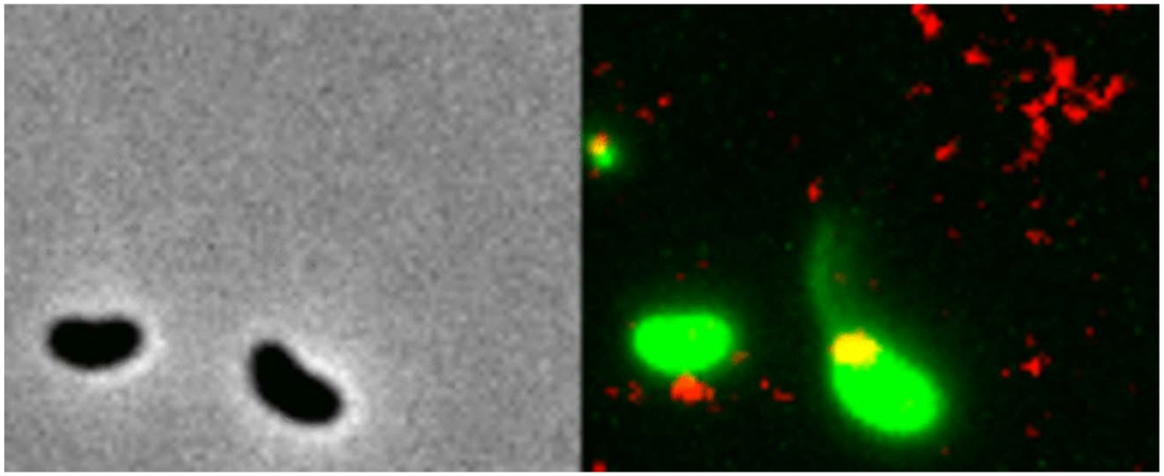
New news

- 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

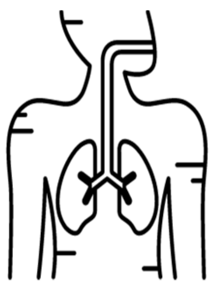


Dry conditions increase horizontal transfer of antibiotic resistance genes

Enough about microbes. How do humans do in dry air?

When RH<40%, humans suffer!

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



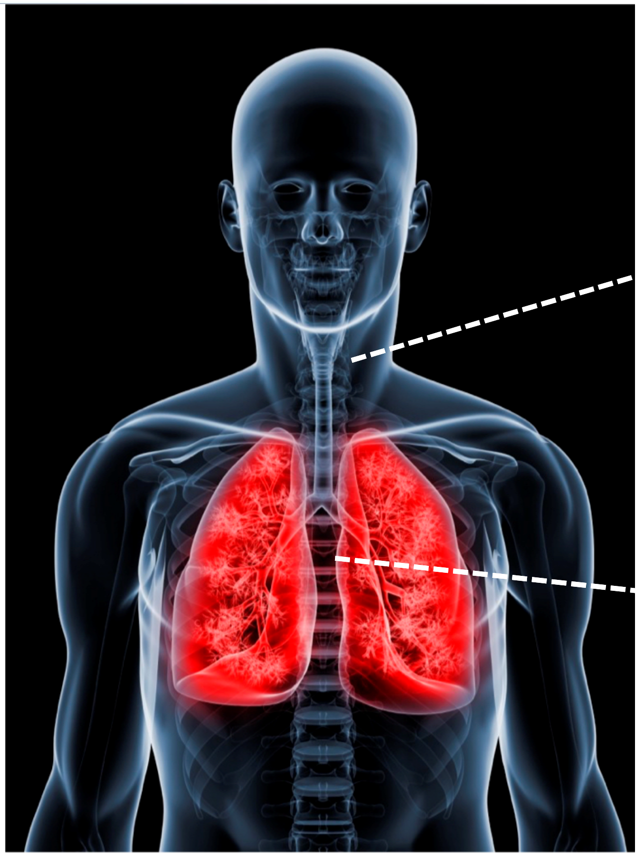
more infections & asthma attacks

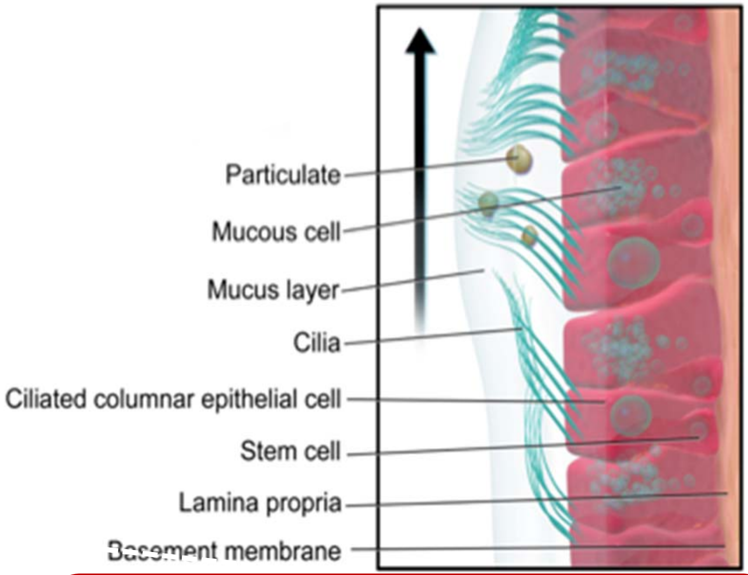
impaired brain function

skin cracking, decreased wound healing

dry eyes, excessive tearing

Dry air impairs our respiratory system defenses





<u>Dry inhaled air causes:</u>

- Increased susceptibility to infections
- Increased wheezing from allergic disease

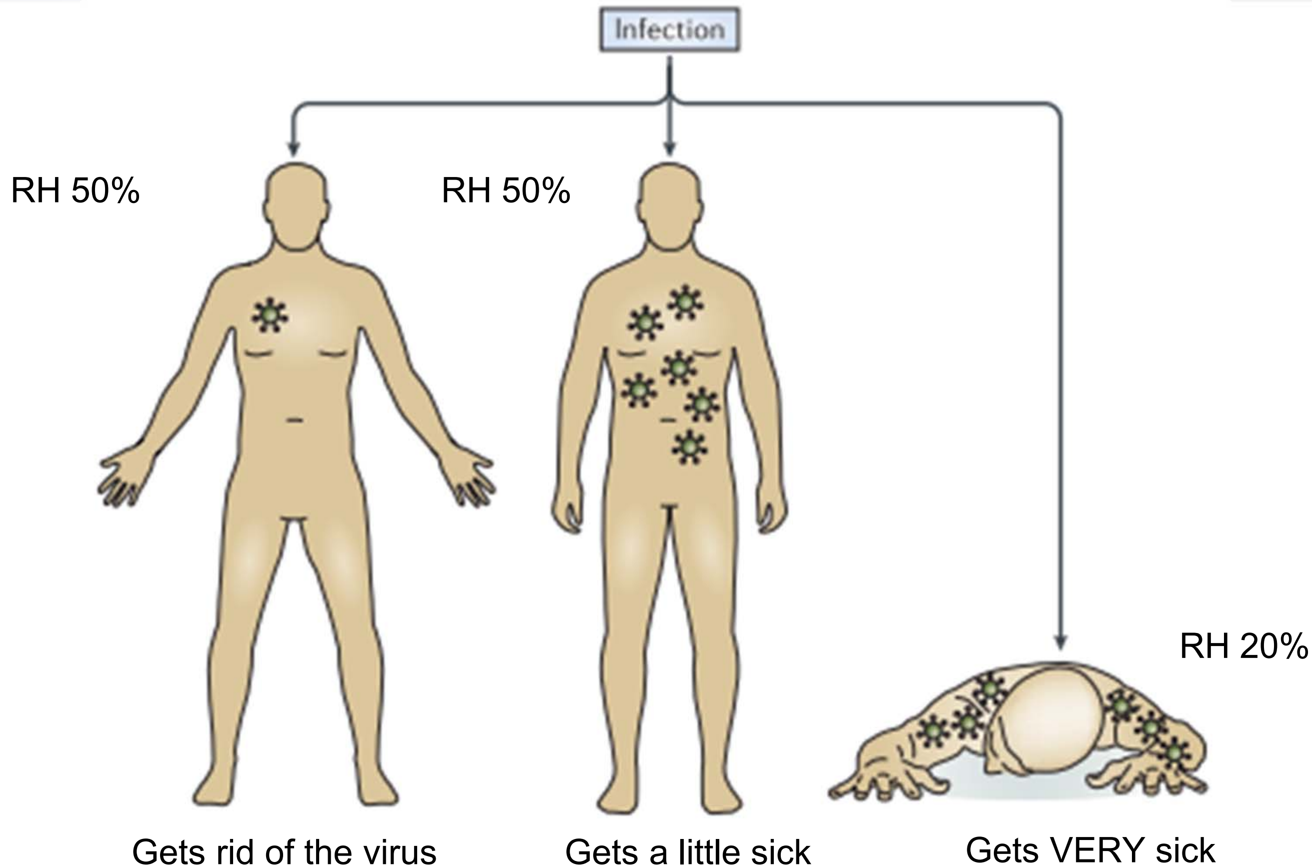
A key study just published in PNAS

“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?



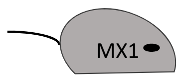
Study setup

Chamber conditions
Temp = 20°C

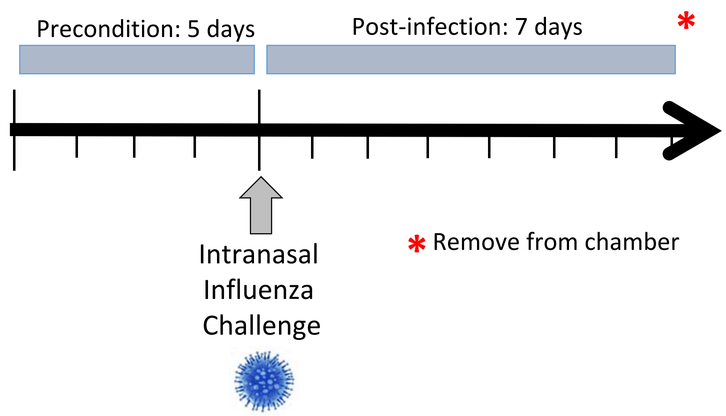
20%RH
$3g/m^3$ AH

or

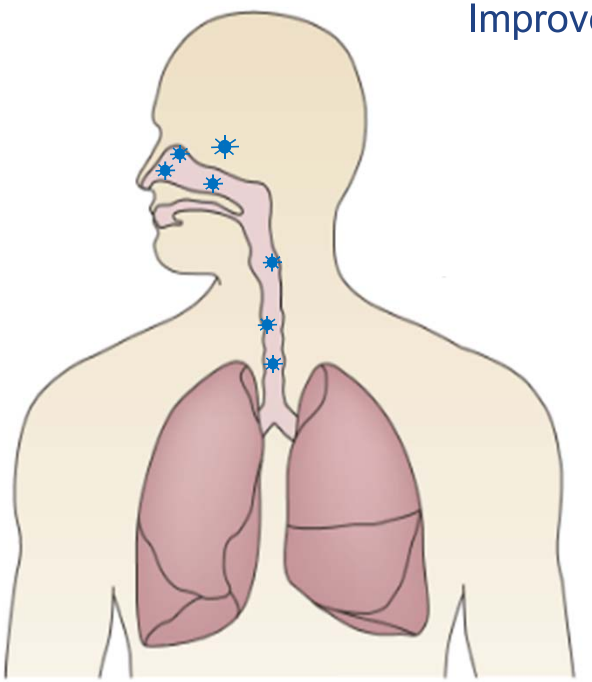
50%RH
$9g/m^3$ AH

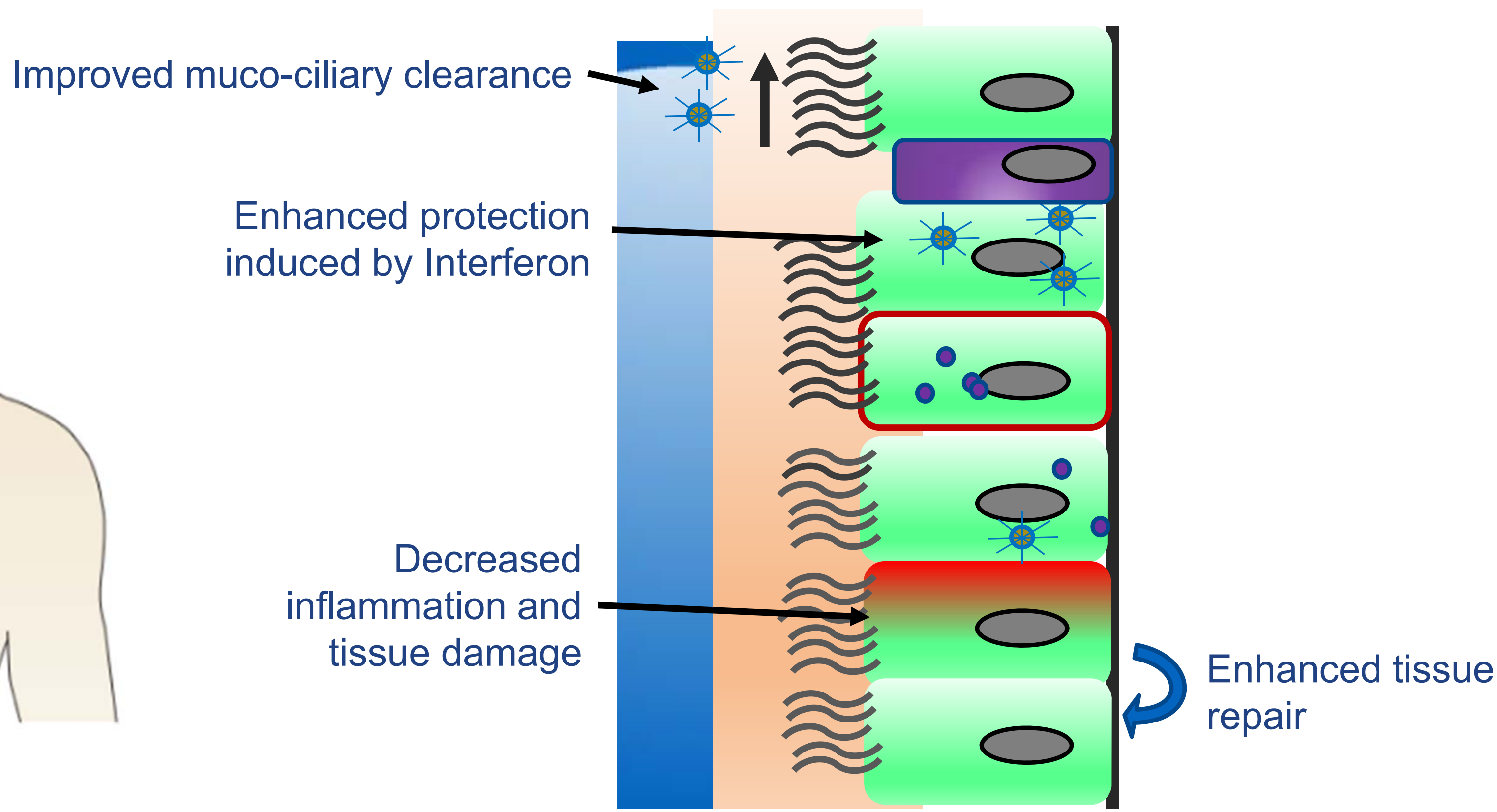


Mx1 mice have functional Type I IFN responses



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





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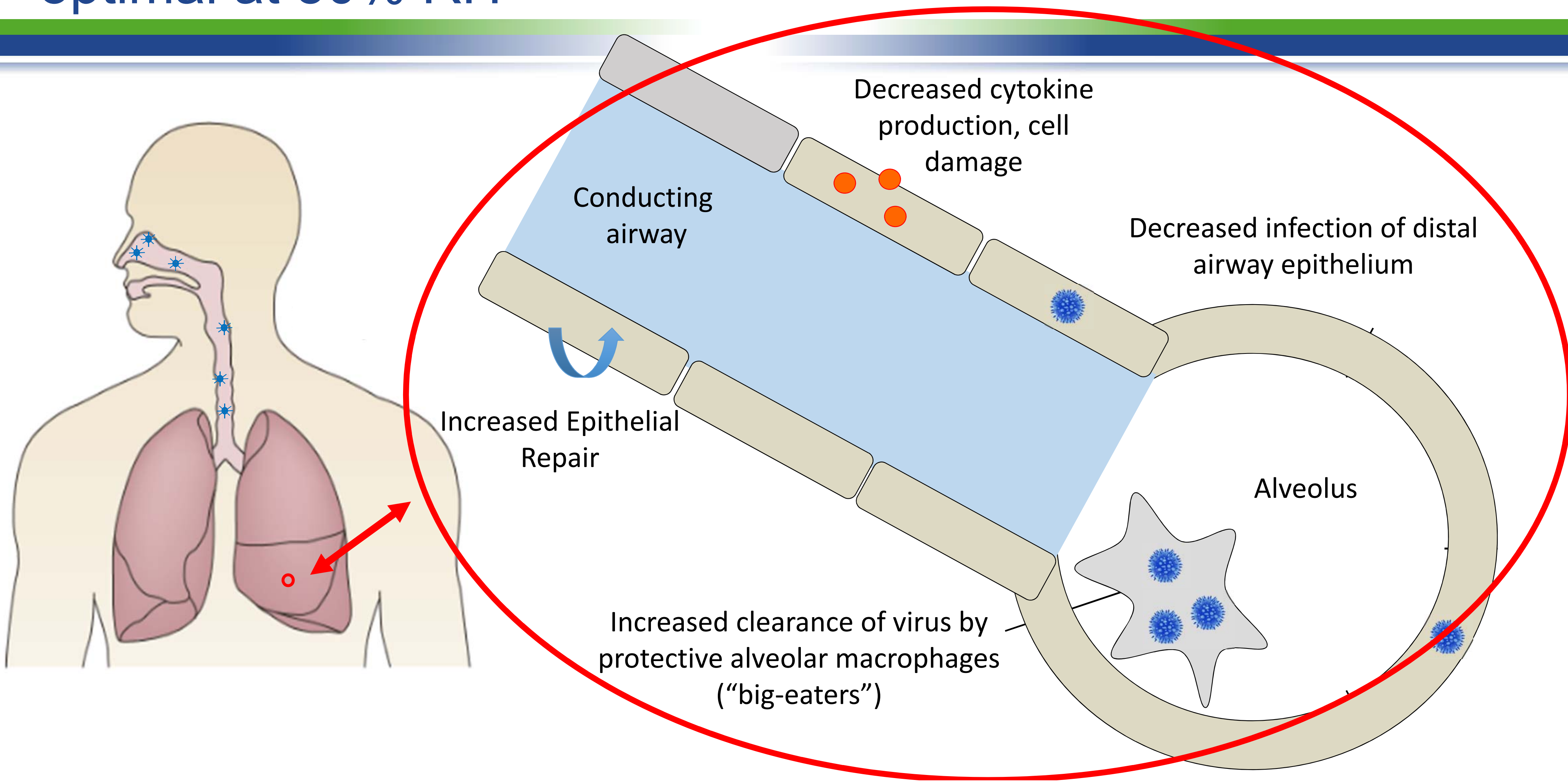
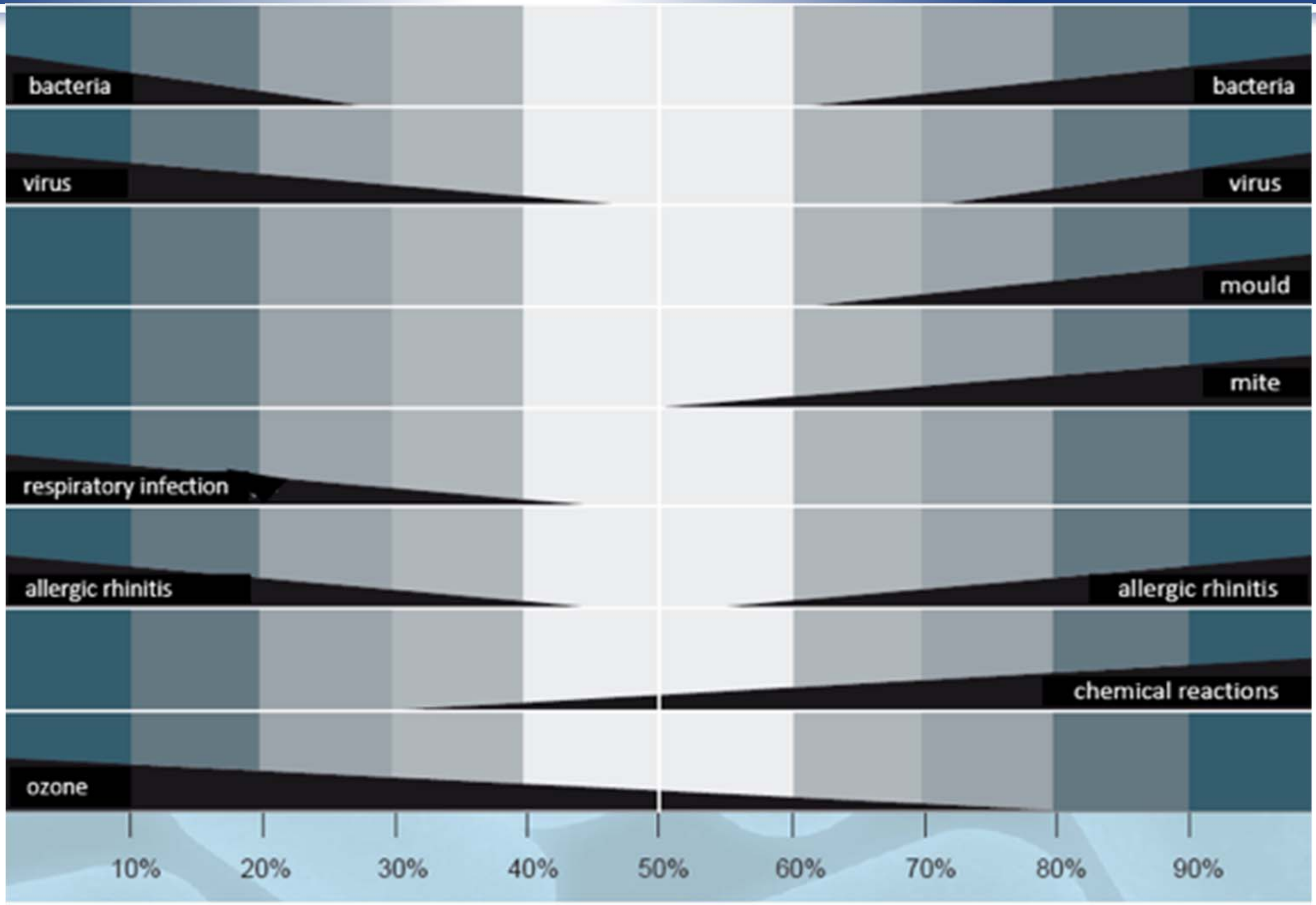
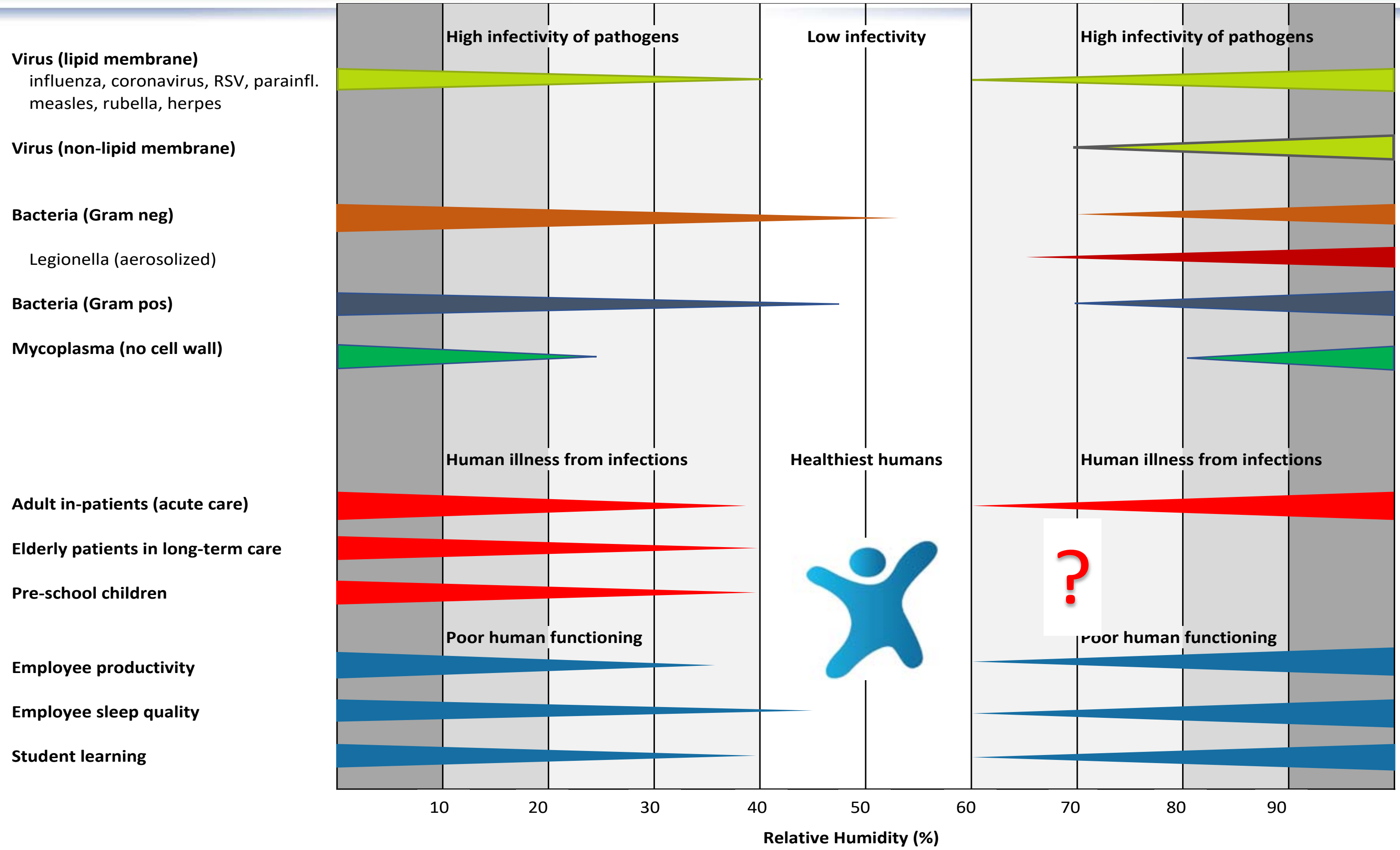


ASHRAE 1985:“Optimal RH Level For Health” = 40%–60%



35 years later….. Taylor Chart 2019



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Why do we still keep our indoor environment so dry?

The great indoor air RH debate!

Protect the building

Protect the occupants

RH: 0% 50% 60% 70% 80% 90% 100%

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

What motivates people to listen?



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%

Do humans have a dollar value?

These humans are worthy of humidification

"Arrrgghh, Why didn't we humidify our air sooner?!?"

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

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 rea		91,787
	CMS Quality Index penal		TBD
	Joint Commission citatior		TBD
	Employee absenteeism		TBD
	HAI litigation by patients		TBD
	Quarterly total		$2,166,803
	Cumulative value		$2,166,803
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			

$899,880

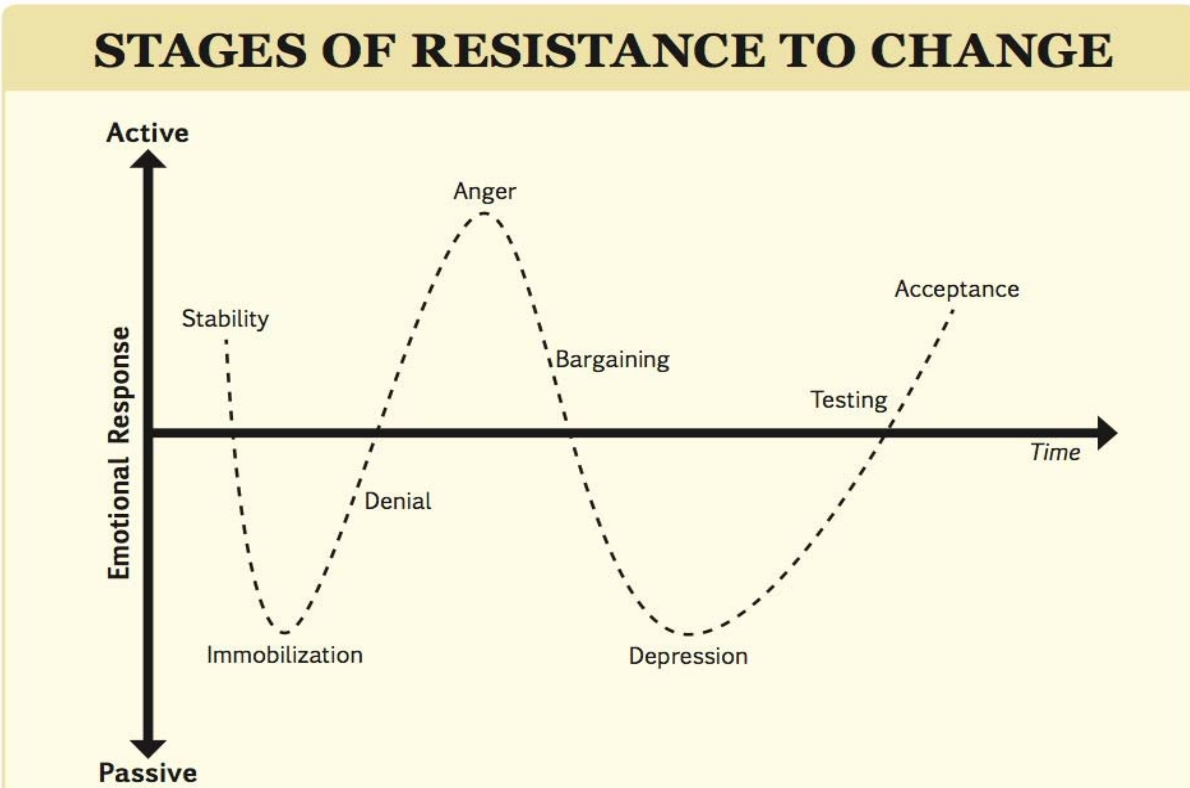
$899,880

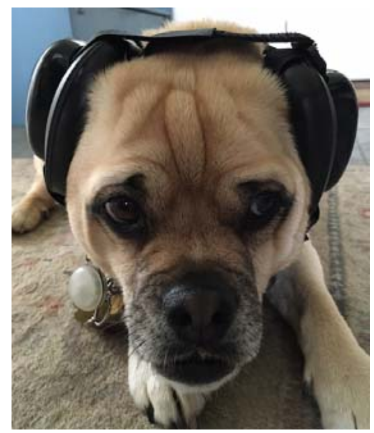
$7,225,018

1st Quarter

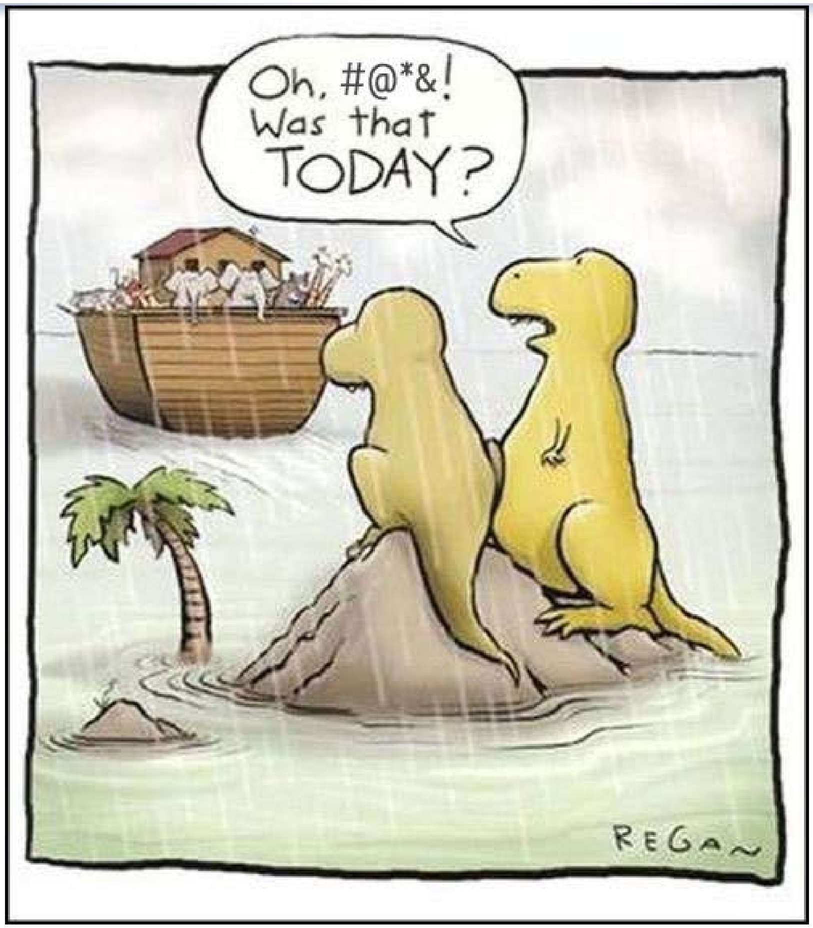
500.97%

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





Do we really want to keep doing the same old thing?



Collaboration is essential

Working alone

Clinicians working alone in their silo of delivering medical and surgical treatments cannot solve problems caused by the indoor environment.

Working together

If clinicians, facility managers and regulators work together, we can soar!

Uniting our goals would benefit everyone

Medical professionals

- Heal patients
- Follow clinical protocols
- Avoid lawsuits

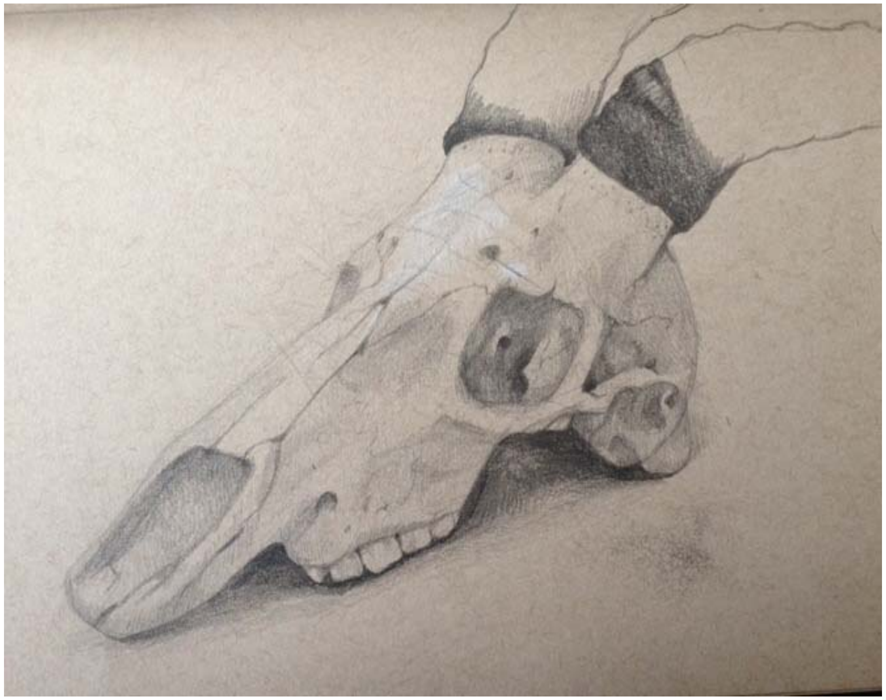
Building professionals

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

IMPROVE OCCUPANT HEALTH

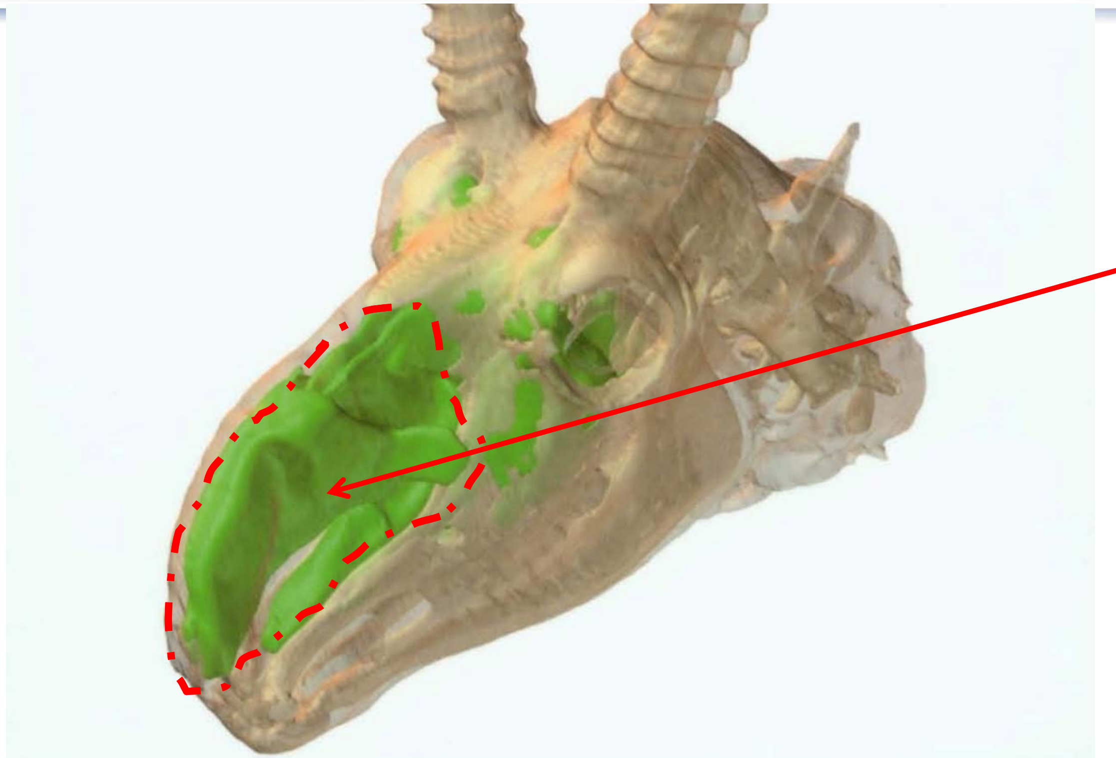
- Better health
- Decrease acute and chronic diseases
- Decrease financial losses from illness

Evolution and RH



skull of the grassland Saiga antelope

Evolution and RH



the African desert first cousin

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

Conclusions

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

Thank you!

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Additional slides on Yale research

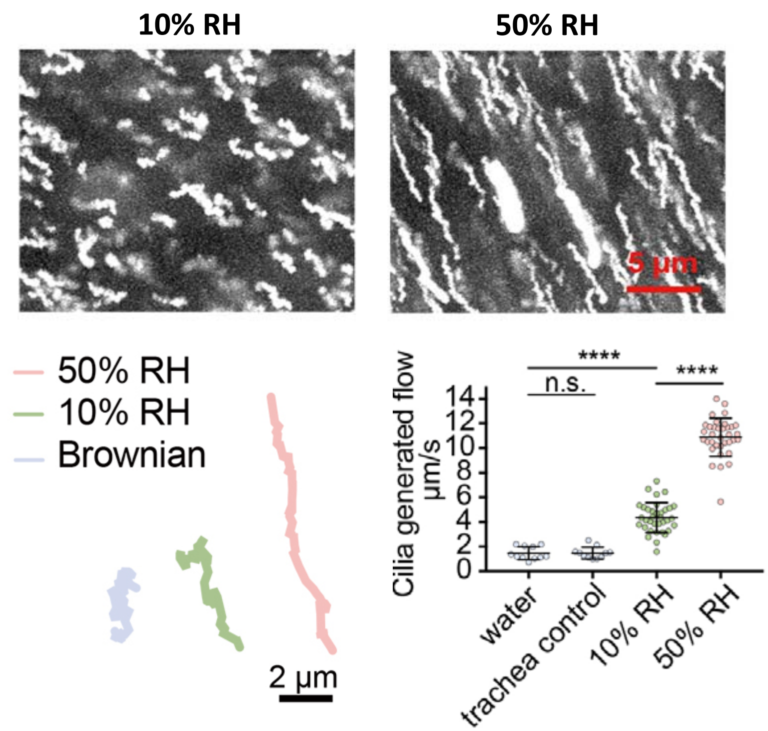
"Low ambient humidity impairs barrier function and innate resistance against influenza infection"

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

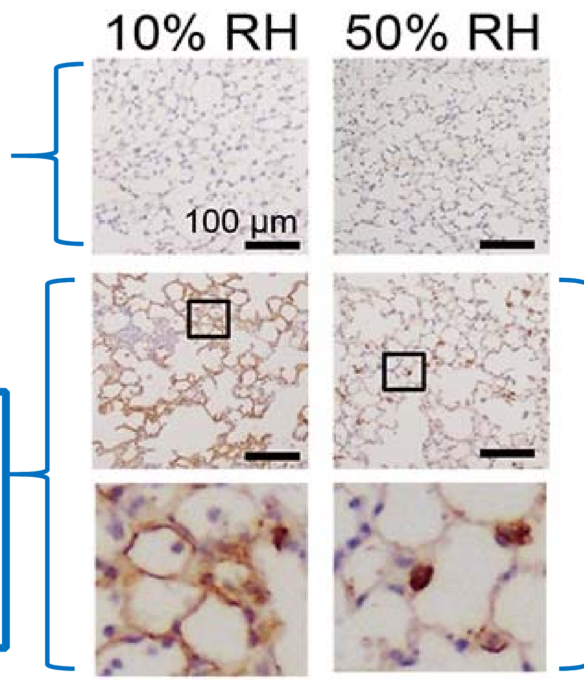
Proceedings of the National Academy of Sciences, USA. May 19, 2019

Findings: 1

Low humidity of RH = 10% decreased muco-ciliary clearance of influenza virus



Findings: 2

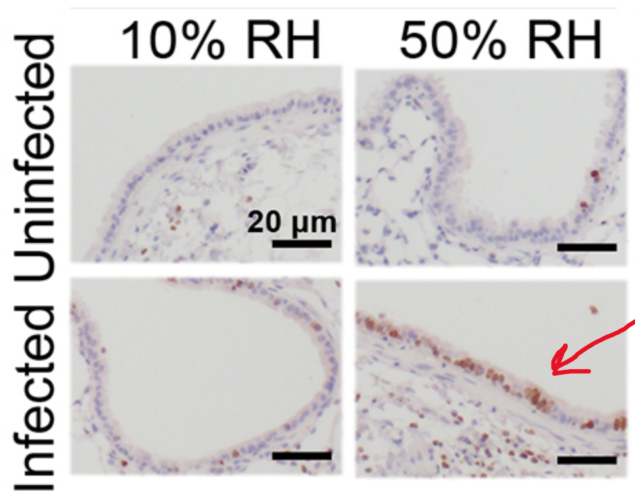


Mice in RH 10% were less able to clear the virus from their lungs, and therefore viral growth was ongoing

Mice in RH 50% were more resistant to the virus and had milder infections

Findings: 3

Low humidity of RH = 10% diminished repair of airways damaged by infection



Active airway repair (dark dots) at RH = 50%