

# Engineers Are The Physicians of the Future

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**Boston ASHRAE Chapter**  
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# Hi, I am honored to be speaking with you today



Massachusetts General Hospital Infection Control  
Harvard Medical InCite Health Fellow



Distinguished Lecturer  
Environmental Health Committee  
Standards Committee



USGBC Technical Advisory Committee




CEO and Founder



# I thank my colleagues

- **M. Colin Tasi, MD, MBA:** Massachusetts General Hospital, Brigham & Women's Hospital, Harvard Emergency Medicine Program
- **Stan Finkelstein, MD:** Harvard Medical School, MIT
- **Lisa Robinson, MPH:** Harvard T.C. Chan School of Public Health, Center for Health Decision Science
- **John Levy , PhD:** Boston University School of Public Health, Department of Environmental Health
- **Peter Taylor, Olivia Saber, Yaron Yaniv, Francis Caruccio, Gene Lochart, Oliver Zimmermann:** Building4Health

# Presentation Summary

- 
- 1. Indoor environments drive human health**
  - 2. IAQ management guided by health metrics**
  - 3. Why it Matters: Unlocking the value of health-based data**

# The beginning of my journey to you



Me as a medical student, working in Papua New Guinea

# Conditions appeared dirty, yet there were few new infections



Wewack General Hospital, Papua New Guinea



# Meanwhile, in “clean” US hospitals over 1,700,000 patients/year get a Healthcare-Associated Infection



*“Never under-estimate the role of the environment!”*

Harvard Medical School Chief-of-Surgery,  
M. Judah Folkman, M.D. working with  
medical student Stephanie Taylor

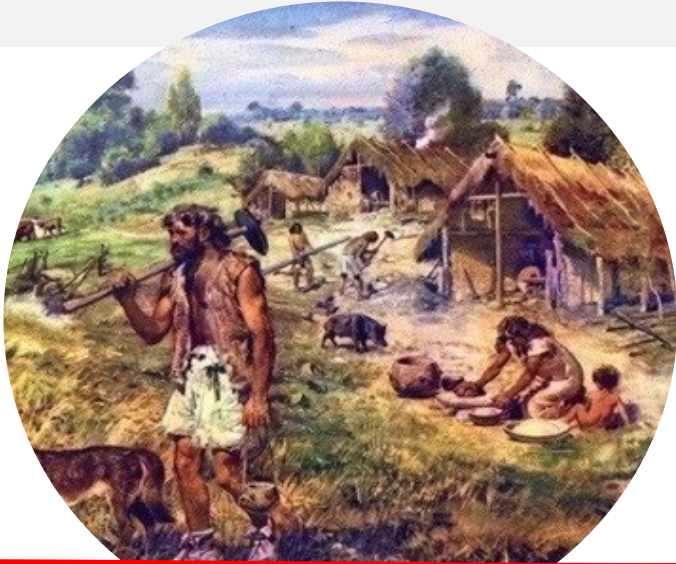


# Let's look at the relationship between buildings and human health

**800 BC - 500 AC**

**Housing:**

simple sanitation,  
in rural villages



**1900 AC**

central sewage & water systems,  
heating, electricity,  
antibiotics & vaccines



**2022**

post-industrial  
cities, tighter buildings, dryer and  
warmer indoor air



## Infectious, allergic and inflammatory diseases

**Infectious  
diseases:**

Parasites,  
zoonotic infections

Small pox, measles,  
1<sup>st</sup> pandemic  
"Spanish flu"

Increasing infections,  
anti-resistant bacteria,  
COVID-19

# Are aspects of modern buildings a root cause of some illnesses?

We are indoors 90% of our time!!

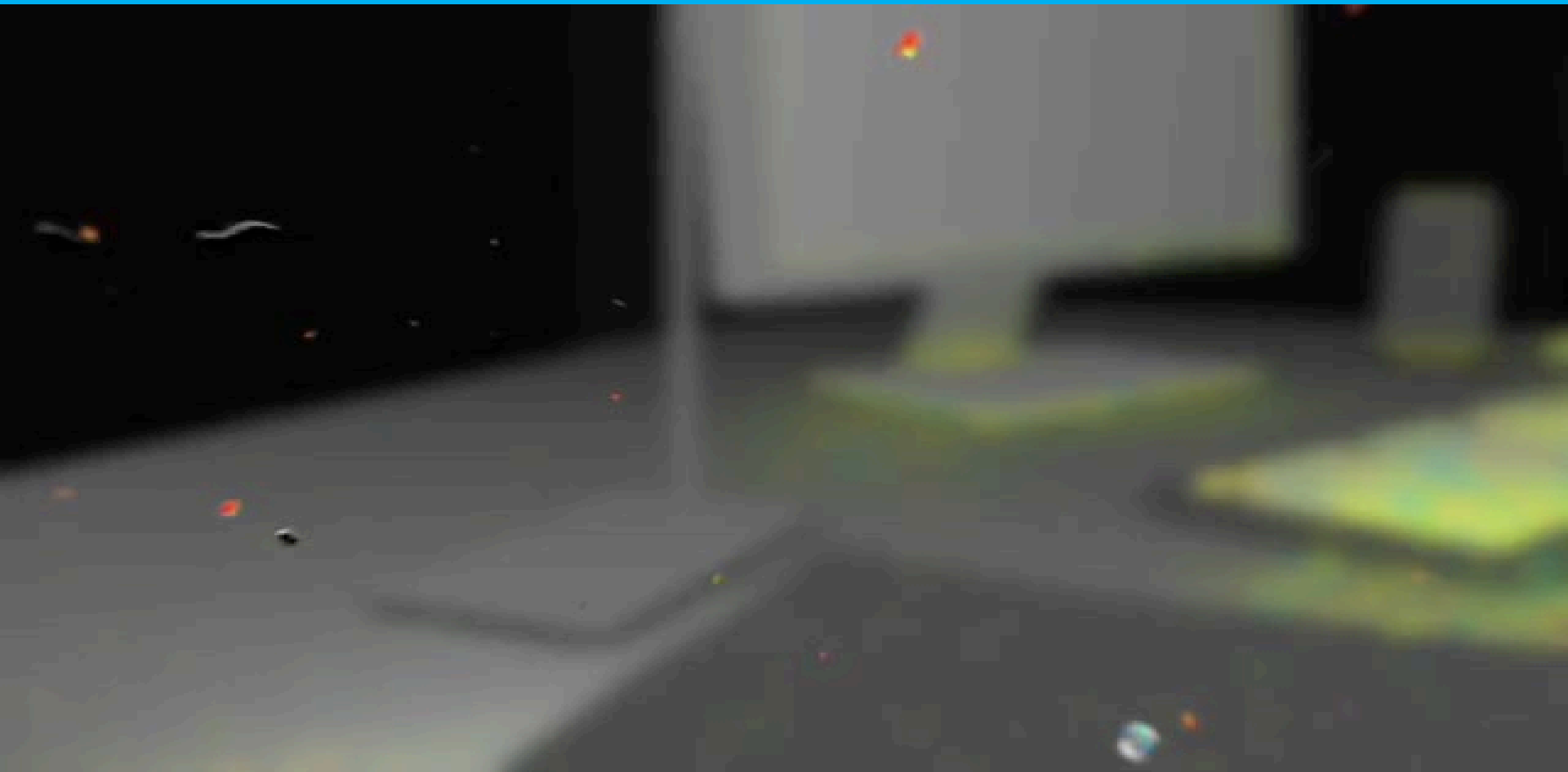
- Tight building envelopes
- Mechanical ventilation systems
- Completely different indoor air conditions from the outside

**“We shape our buildings,  
then they kill us!”**

Ken Dickerman, AIA



# A closer look at humans and microbes indoors



**We are more than 60% microbes by cell number (2 gallons by volume)**



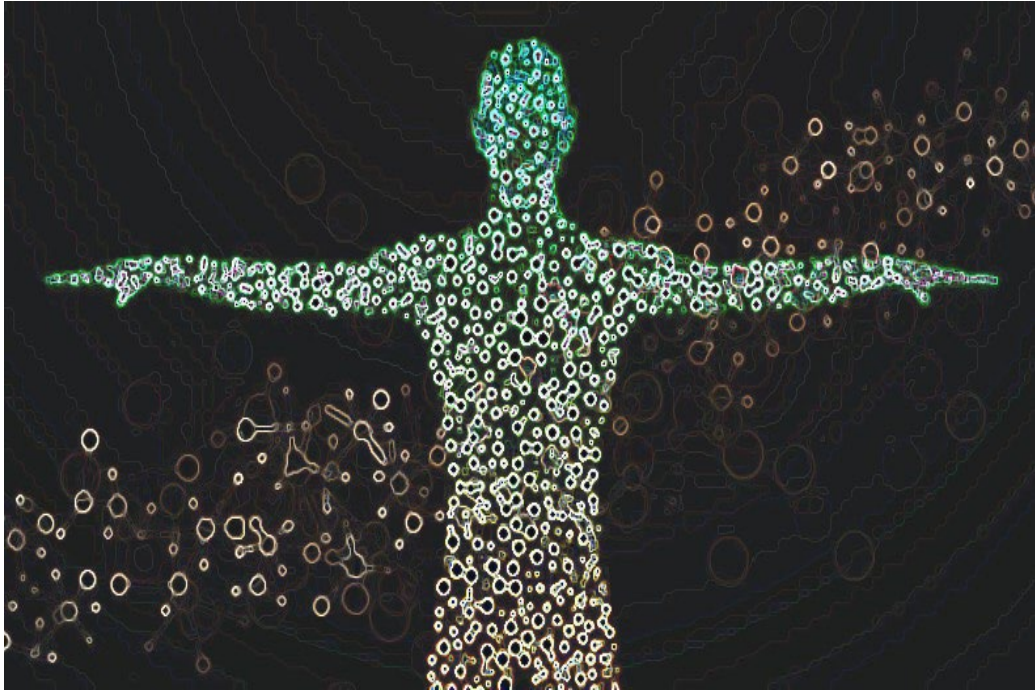
**Microbes live in and on us, influencing all aspects of our health, including:**

- autoimmune diseases, allergies
- immune system protection
- heart attacks
- obesity
- anxiety
- Parkinson's disease
- Alzheimer's
- and more

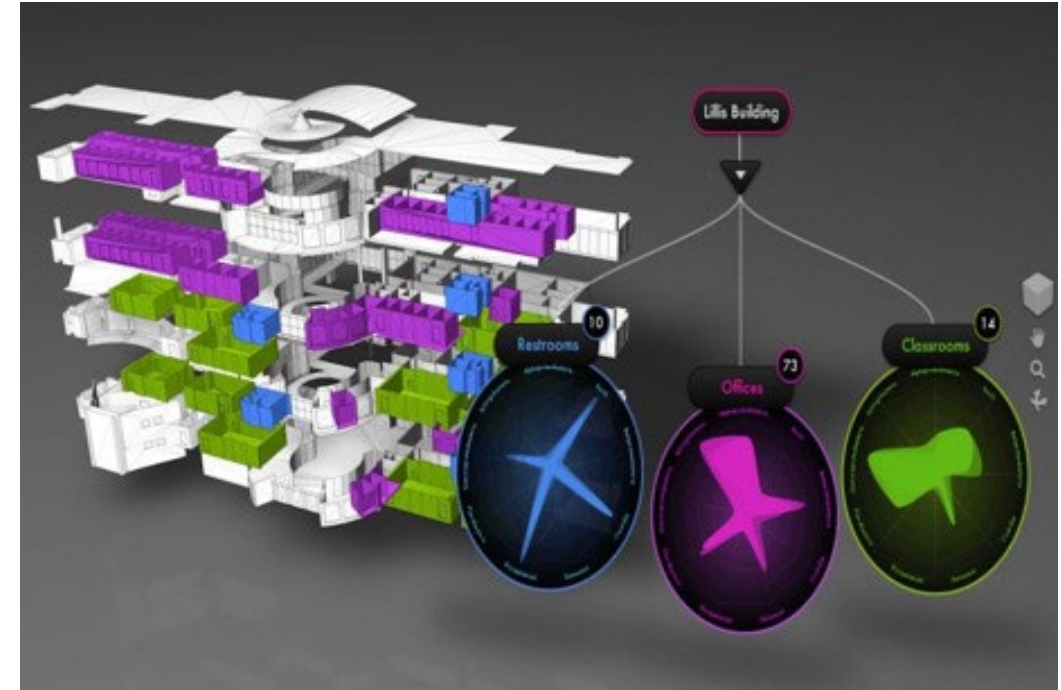
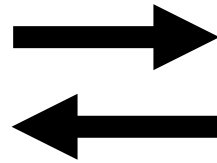
**A healthy microbiome is a diverse microbiome**

# Indoor conditions shape humans and microbes

“survival of the fittest”



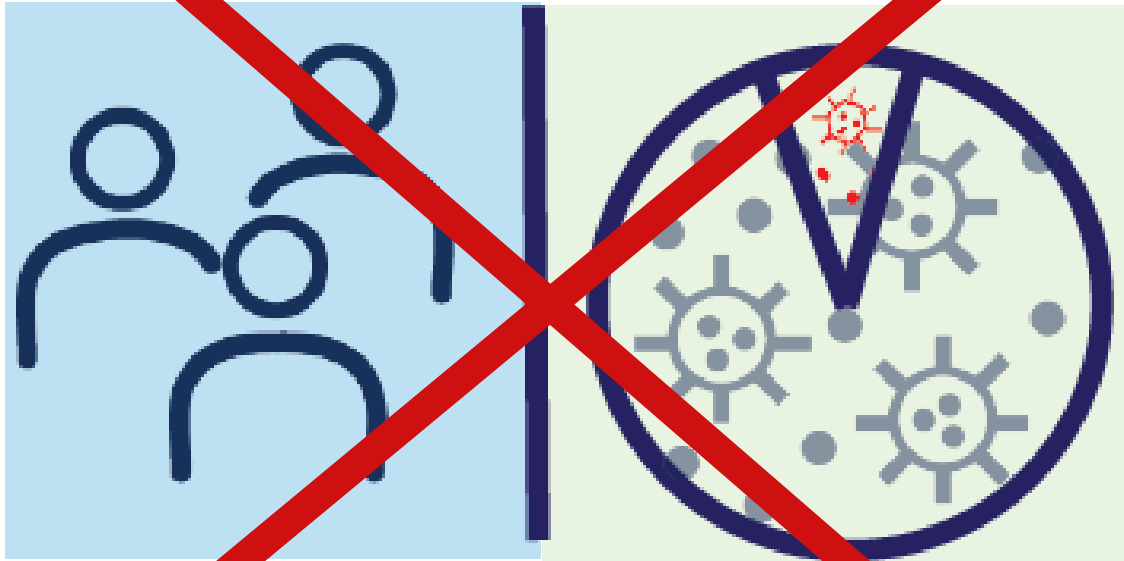
Each of us sheds 37 million microbes per person per hour into our spaces



IAQ shapes bacterial, viral and fungal communities in buildings

# Do not be alarmed, humans and microbes need each other

Historical (and Incorrect)  
Approach to Hygiene



"All microbes are bad germs that require total eradication."

In fact, only a small percentage of microbes are disease causing pathogens.

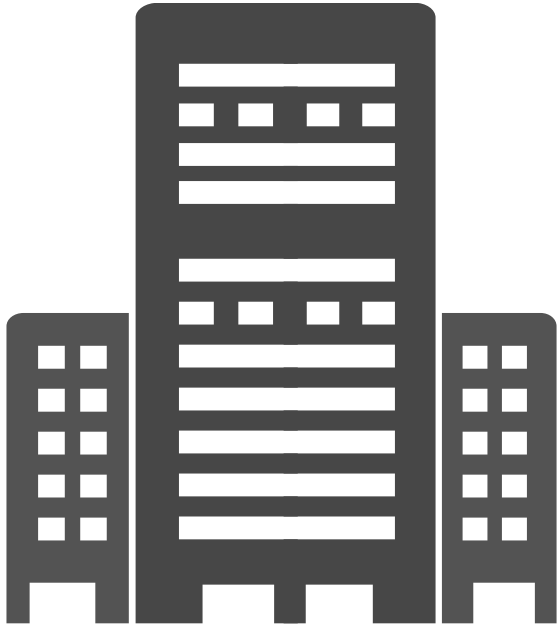


**Good microbes actually help prevent disease!**

Exposure to airborne viruses  $\neq$  disease. IAQ influences our immunity

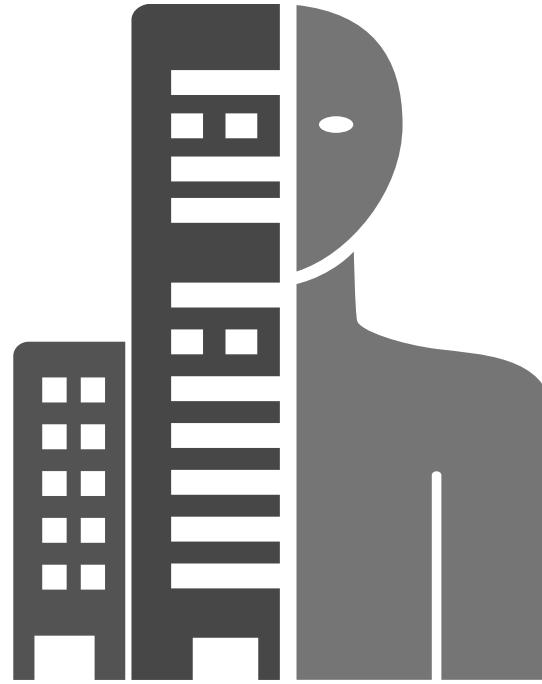


# We need to unite building management and medicine

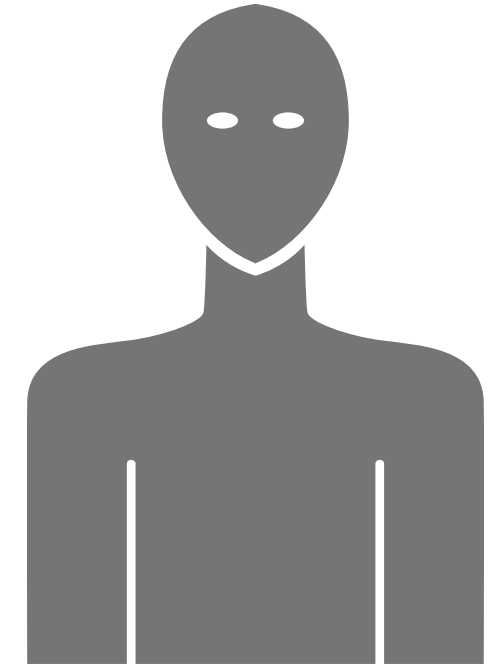


## Building Management

- Reduce energy use
- Avoid disasters
- Follow best practices and coc



## Occupant Health should guide building management



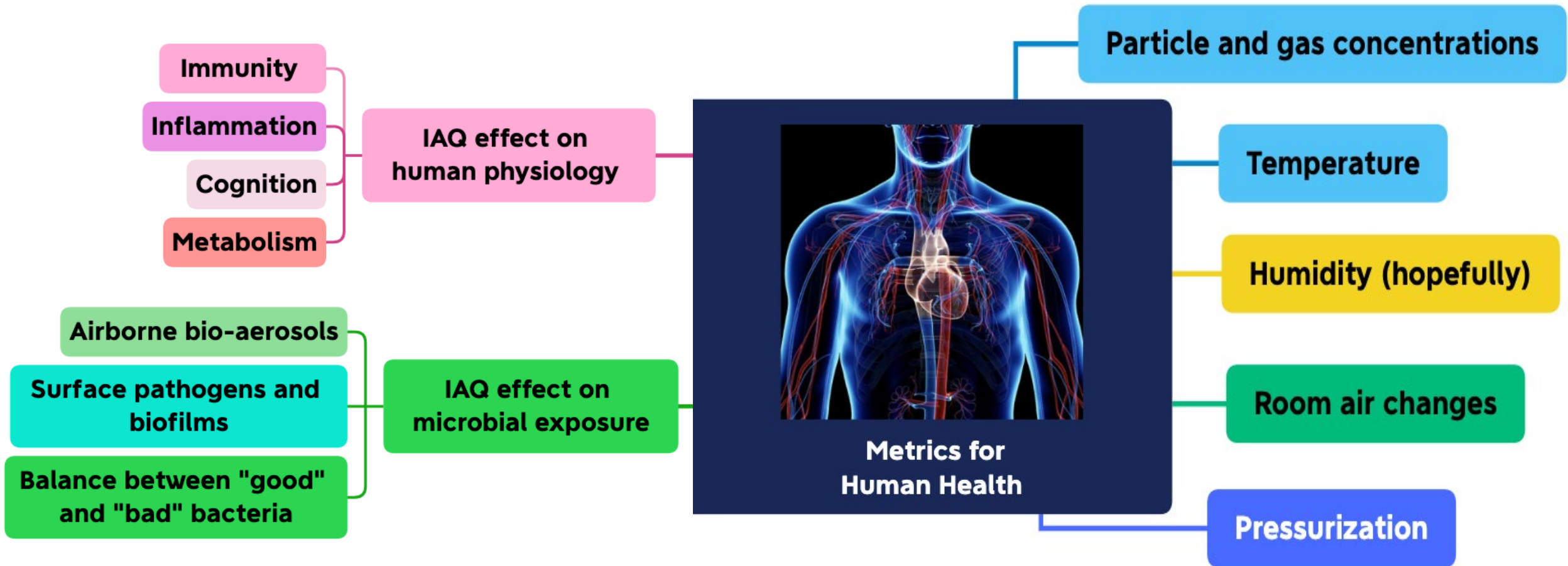
## Medical Care

- Heal patients
- Follow clinical protocols
- Avoid lawsuits

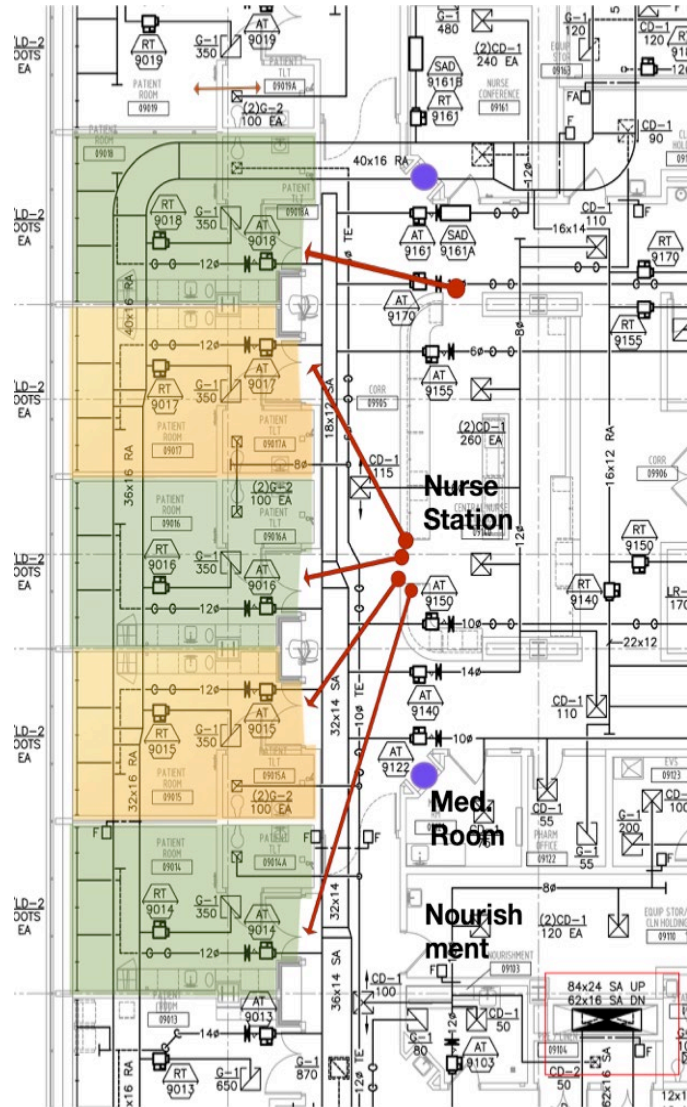
# Data needed to manage IAQ for both energy and occupant health

## Optimize occupant health

## Optimize energy savings



# 2014 study: Does IAQ contribute to infections in hospitalized patients?



Patient room data

vs.

Patient HAIs

Temperature

Staff & visitor hand cleaning

Room pressurization

Lux

CO<sub>2</sub> level

Relative humidity,  
Absolute humidity

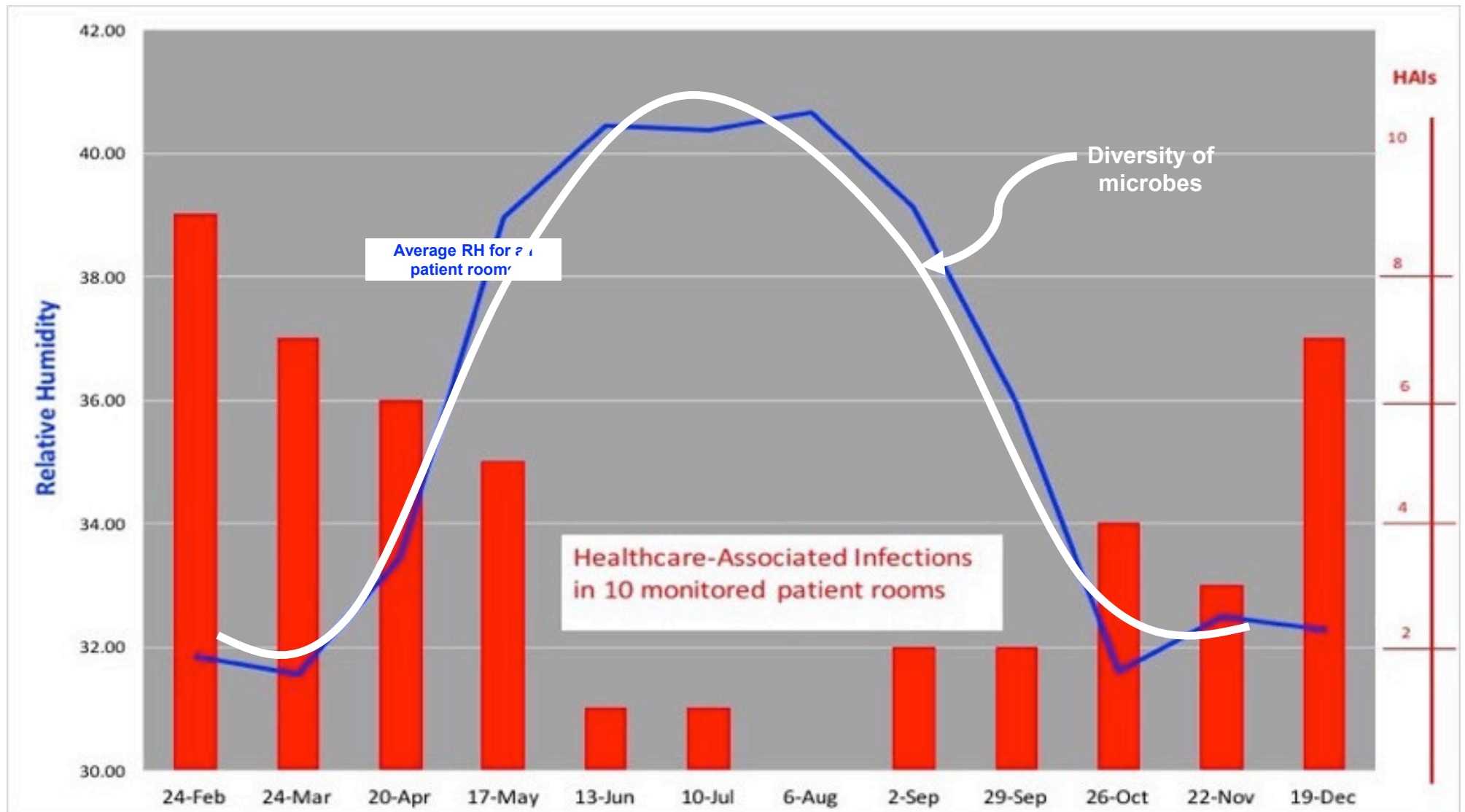
Room traffic

Room air changes

Outdoor air fractions

8 million room data points ~ 300 patient outcomes

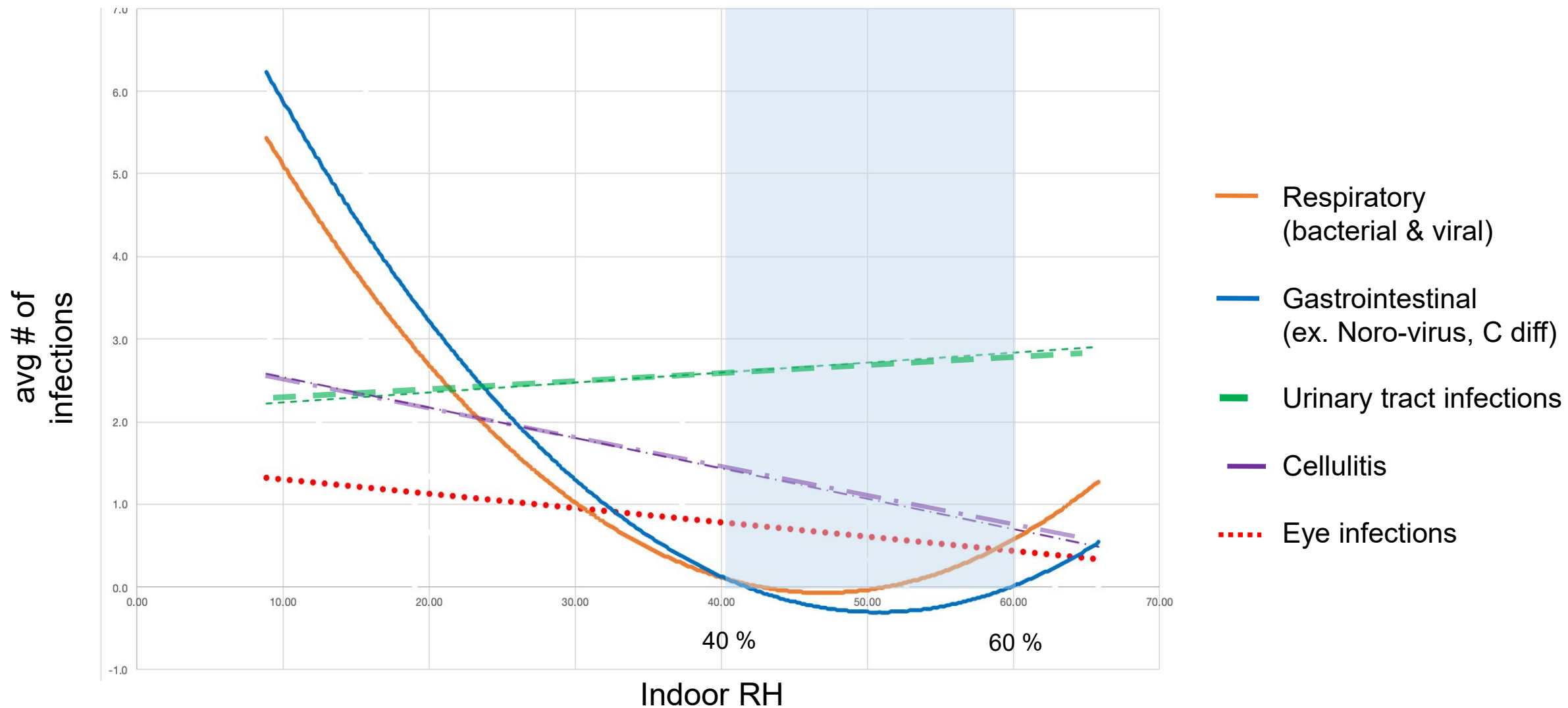
# As patient room RH went down, infections went up!



Coefficients<sup>a</sup>

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

# 4-yr study in senior residence: infection rates were lowest when indoor RH = 40-60%



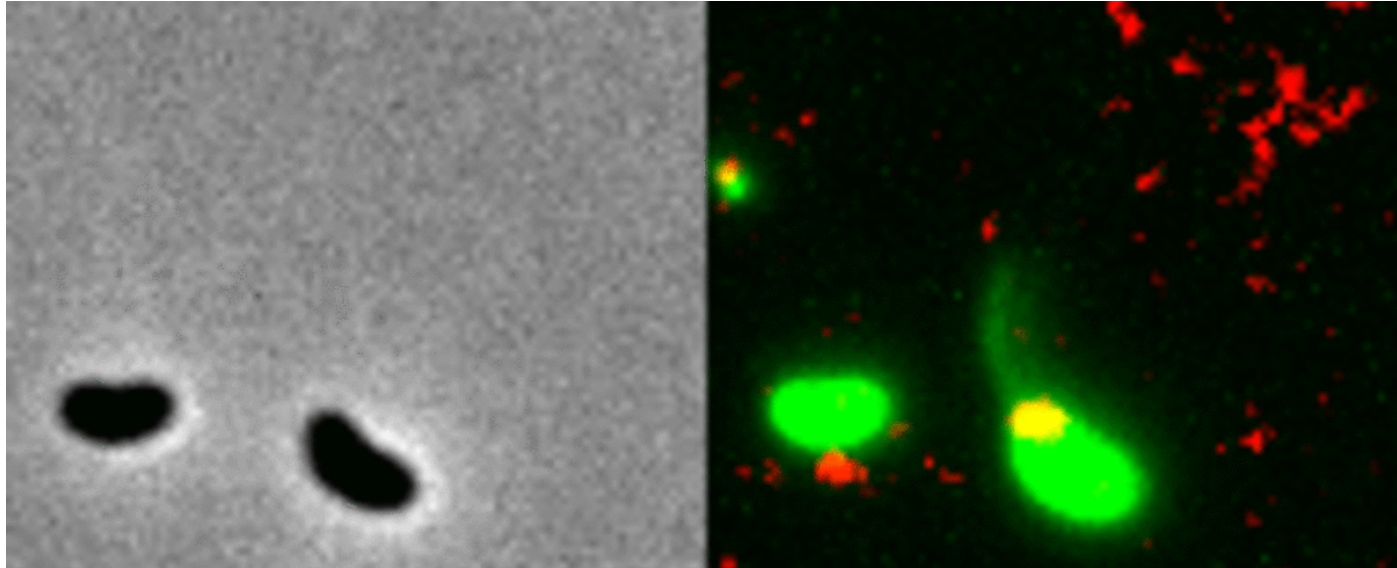
# Low relative humidity worsens diseases in at least four ways

1. Increased infectivity of pathogens in exhaled droplets
2. Airborne droplets shrink, allowing travel over greater distances and remaining in the breathing zone for longer
3. Tiny, dry droplets penetrate deeply into vulnerable tissues
4. Protective human immune functioning is impaired

# This was a startling and very important finding

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

*July 26, 2018*



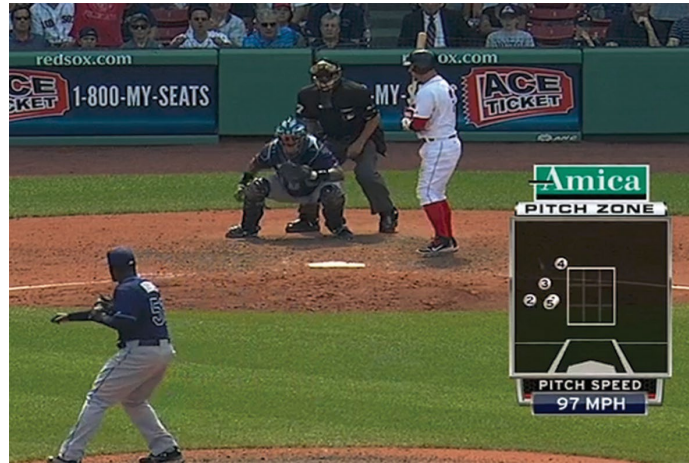
Poor air quality increases the airborne transfer of antibiotic resistance genes

# The evidence is clear: IAQ holistically affects human health

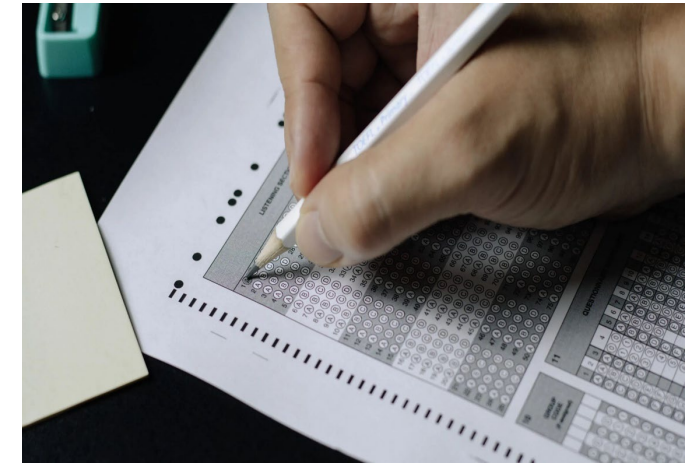
## IAQ IMPACTS PRODUCTIVITY, COGNITIVE PERFORMANCE, AND DECISION-MAKING – AND MORE



Chess players made 26% more mistakes when PM<sub>2.5</sub> was increased by 10 $\mu$ g/m<sup>3</sup>

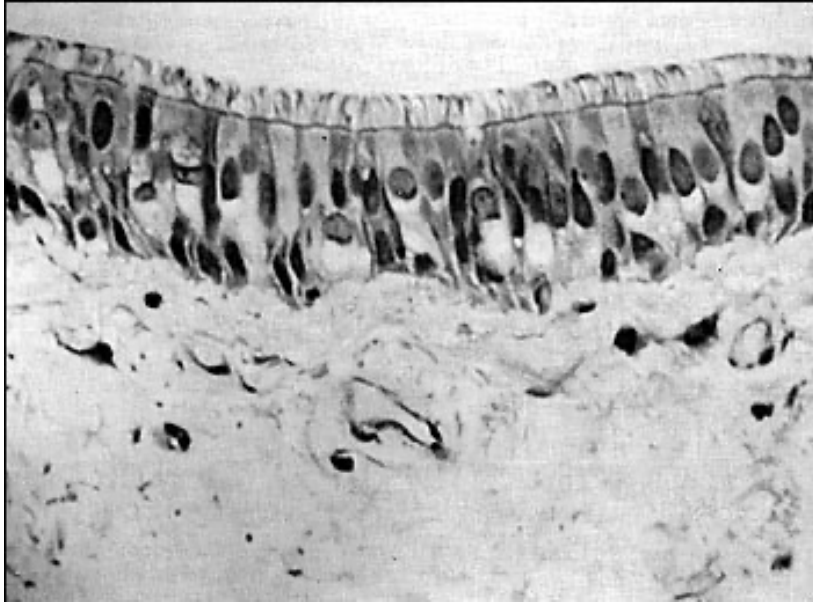


Incorrect calls by umpires increased 11.5% when CO was increased by 1ppm and by 2.6% when PM<sub>2.5</sub> was increased by 10  $\mu$ g/m<sup>3</sup>

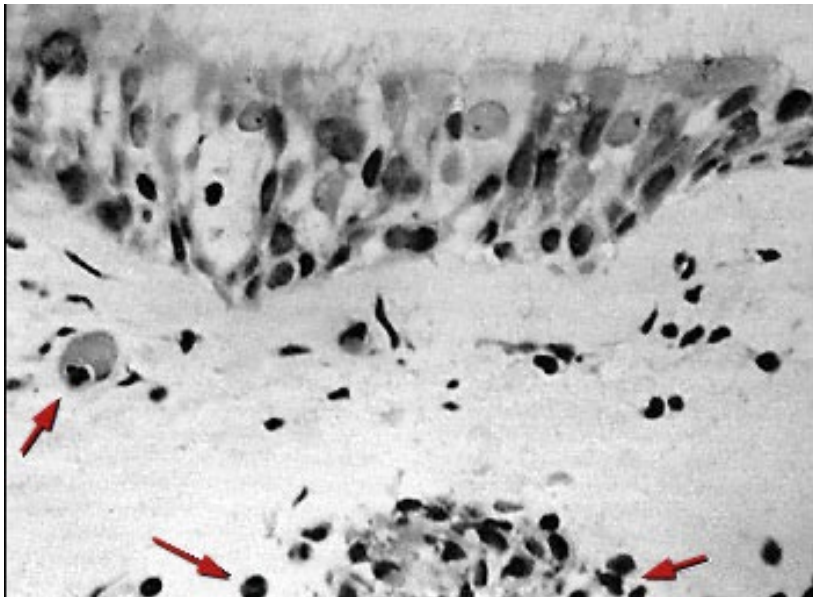


The probability of failing a high-stakes exam was increased by 2% when PM<sub>2.5</sub> was increased by 10 $\mu$ g/m<sup>3</sup>

# Microscopic views of human lung tissue exposed to ozone



Healthy lung of a person exposed only to air, the tiny cilia that clear the lungs of mucus appear along the top of the image in a neat and regular row

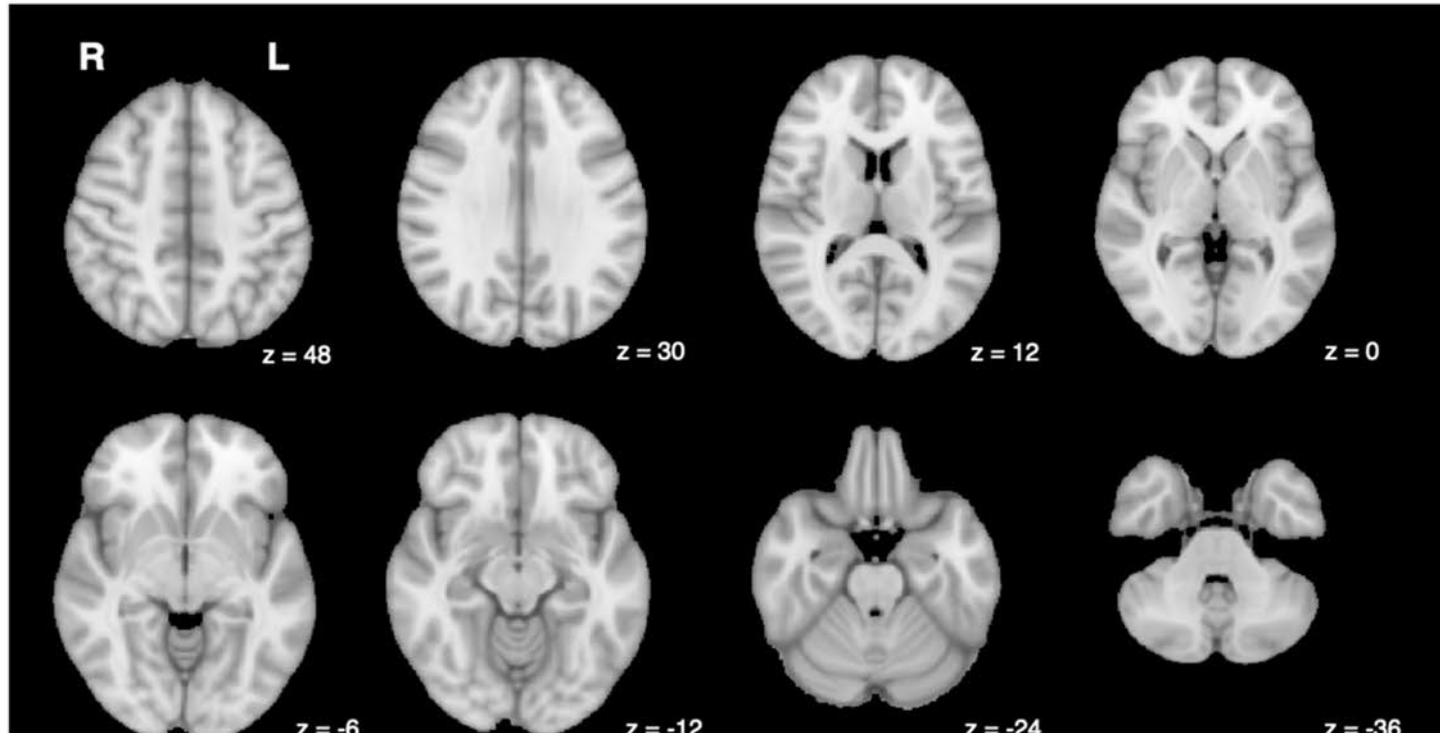


Damage from inflammation from exposure to relatively low level (20 ppb) of ozone

*American Review of Respiratory Diseases*, Vol. 148, 1993,  
Robert Aris et al., pp. 1368-1369.

Magnification: x400.

# Poor IAQ causes acute neurocognitive damage

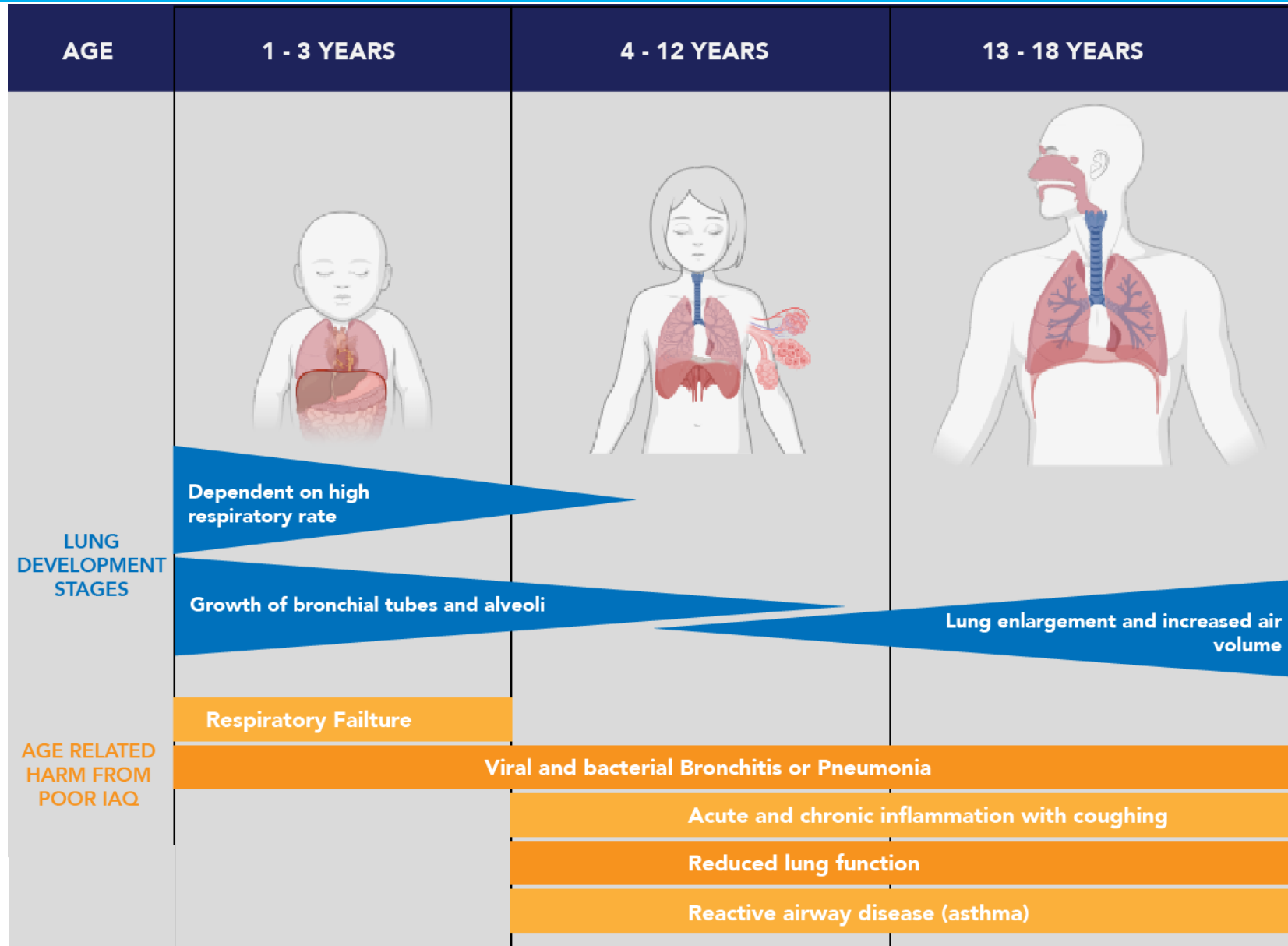


Healthy adults – MRI revealed immediate declines after pollution exposure to commonly found levels

- decreased working memory
- increased behavioral impulsivity
- deterioration in productivity

The changes in cognition put individuals at risk for impaired vocational performance.

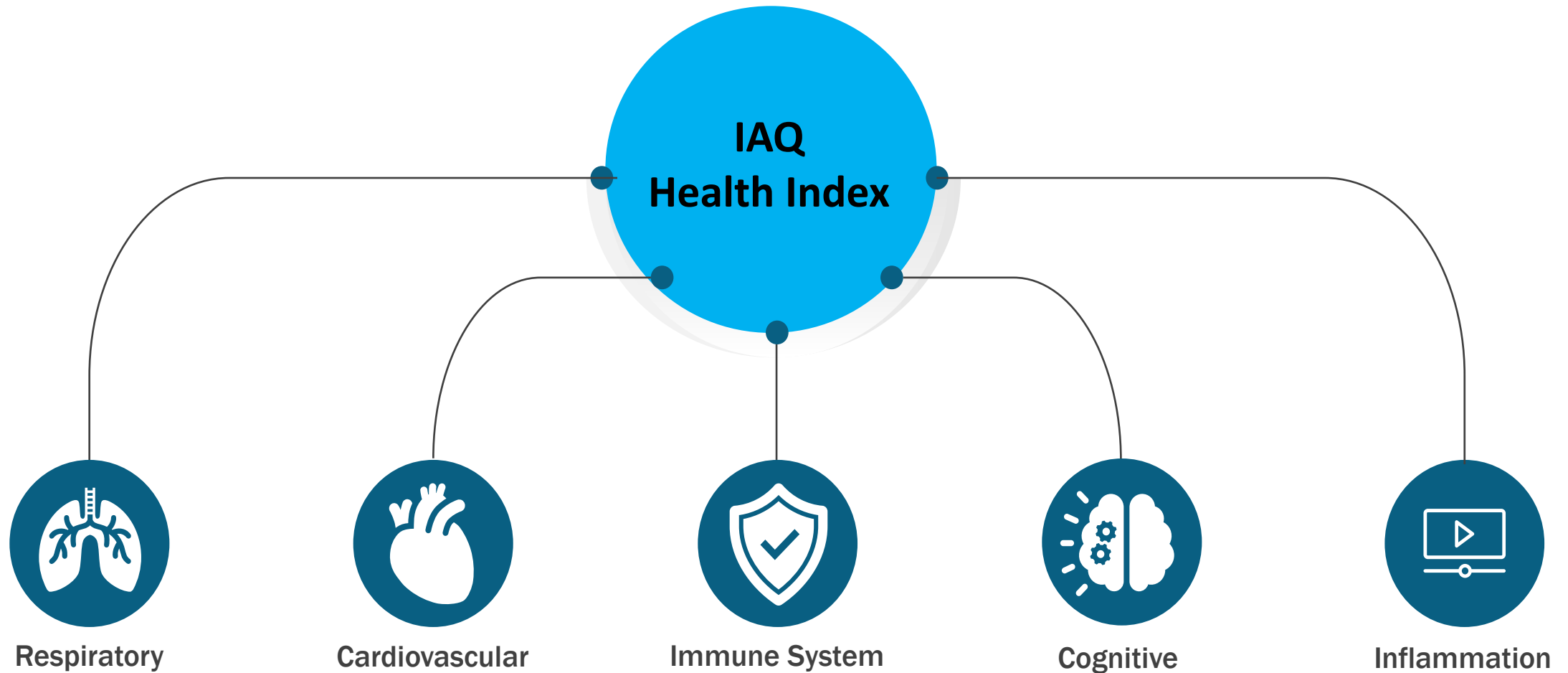
# Children are extraordinarily sensitive to IAQ



# Presentation Summary

- 1. Indoor environments drive human health**
- ➔ 2. IAQ management guided by health metrics**
- 3. Why it Matters: Unlocking the value of health-based data**

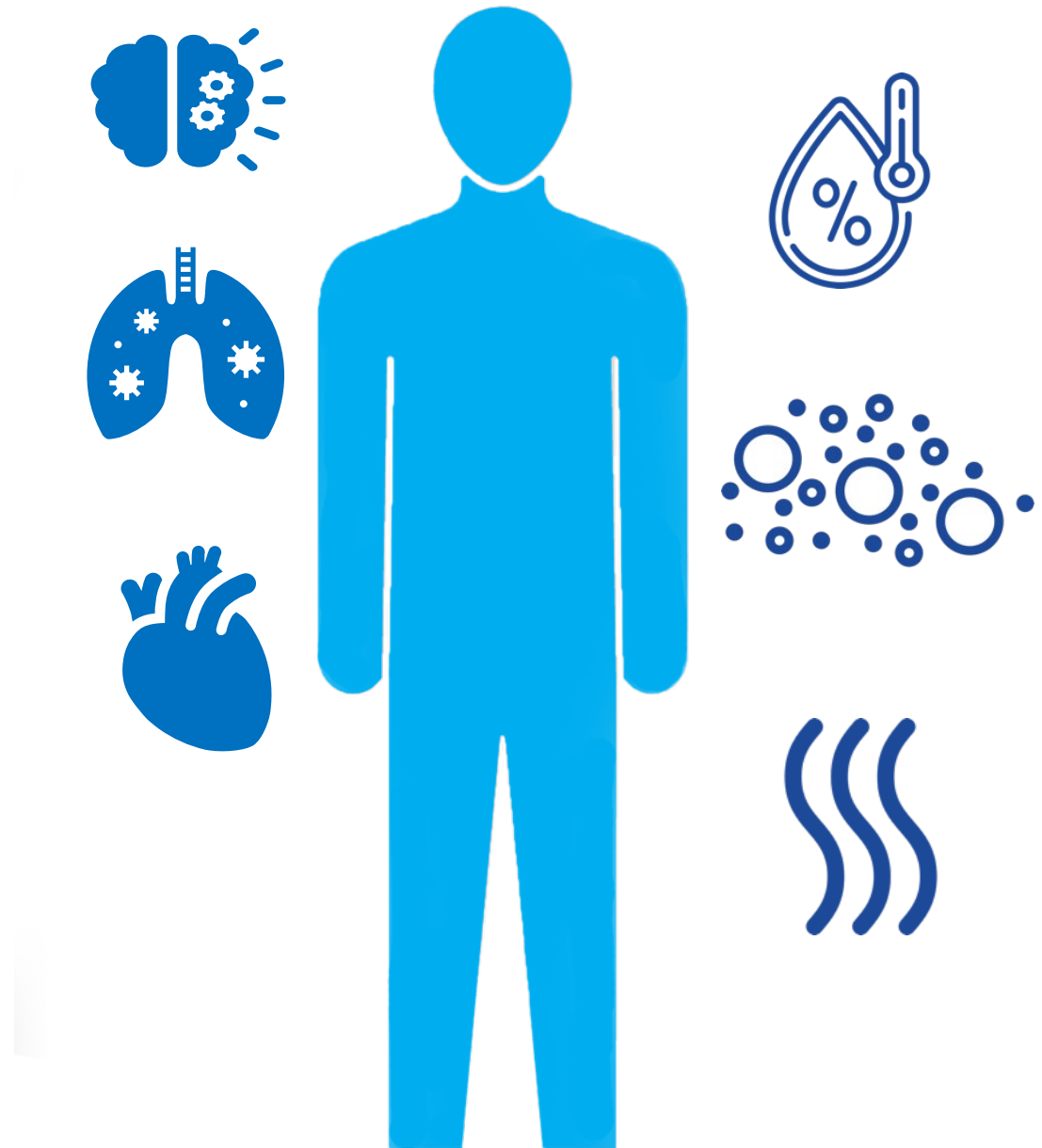
# Structure of a Human-Centered IAQ assessment



# Identify the IAQ constituents that impact health

Gases, particles, temperature and humidity have quantifiable impacts on:

- Brain function and productivity
- Infections and inflammation
- Heart function and blood clotting
- Metabolism and hormones

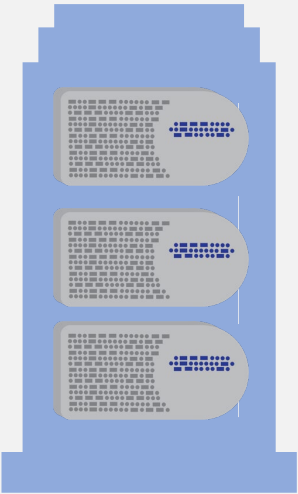


# Take Action: from measurement to management

## MEASURE

1

CONTINUOUSLY  
MONITOR INDOOR &  
OUTDOOR AIR



Indoor Sensors



Outdoor  
Sensor

## ANALYZE

2

CALCULATE IAQ  
HEALTH SCORE

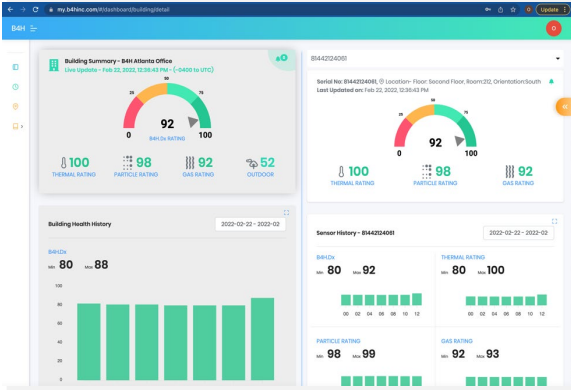


**IAQ Health  
Score**  
Health Score  
1-100

## REPORT

3

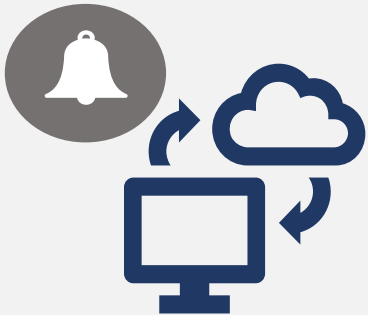
REPORT INDOOR &  
OUTDOOR SCORES



## REMEDiate

4

VENTILATE, FILTER,  
HUMIDIFY or "CLEAN"  
the AIR



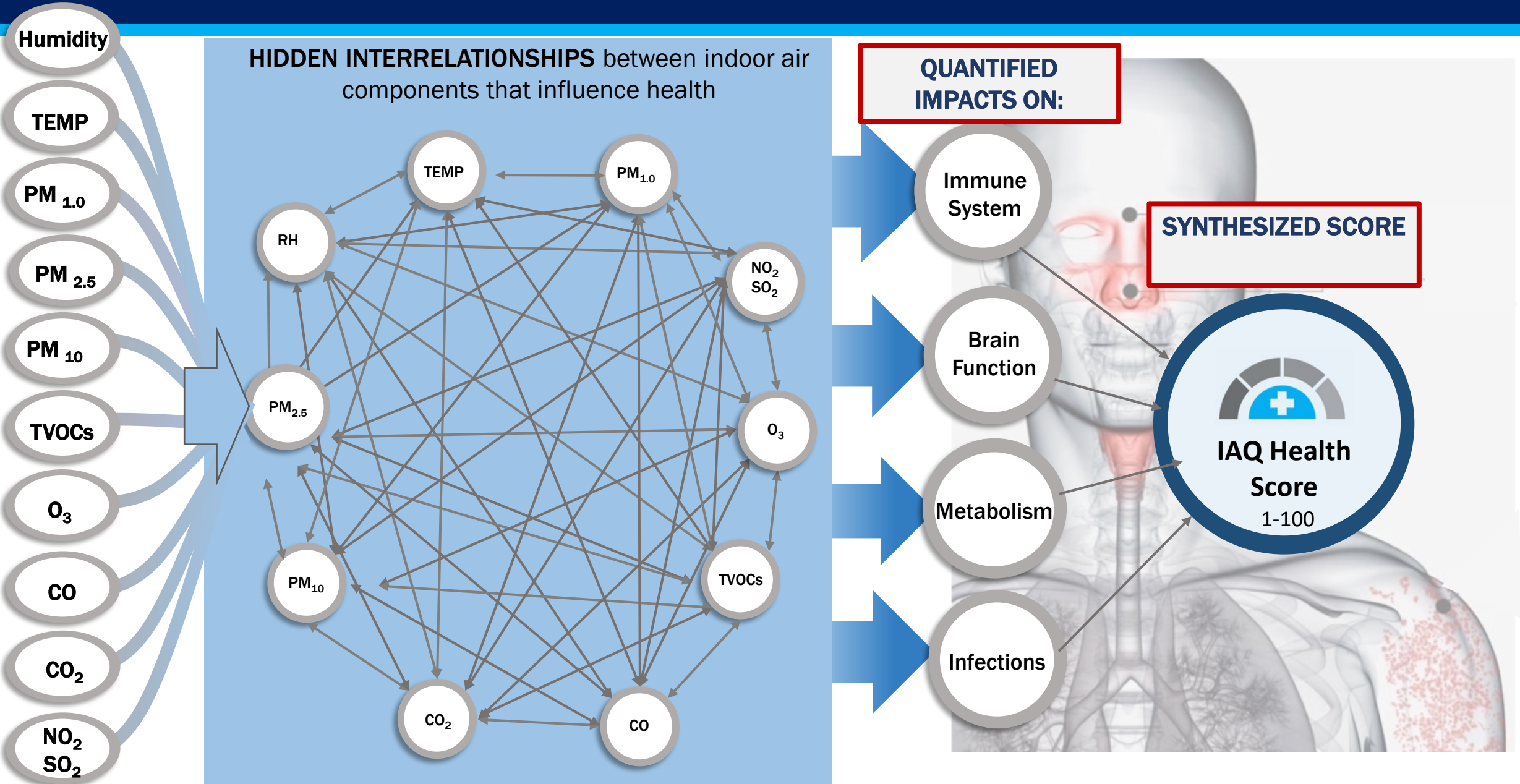
# Step 1: *Continuously monitor and measure* real-time data



Sensors continuously monitor ten medically-verified variables:

- Indoor and outdoor thermal metrics (e.g. temperature, relative humidity)
- Particle counts and densities
- Volatile organic compounds (e.g. benzene, formaldehyde)
- Other relevant gases (e.g. CO, CO<sub>2</sub>, NO<sub>2</sub>, SO<sub>2</sub>)

# Step 2. Analyze holistically the impact of individual and interacting on human physiology



### 3. Display real-time indoor health score and remediation recommendations based on outdoor air conditions

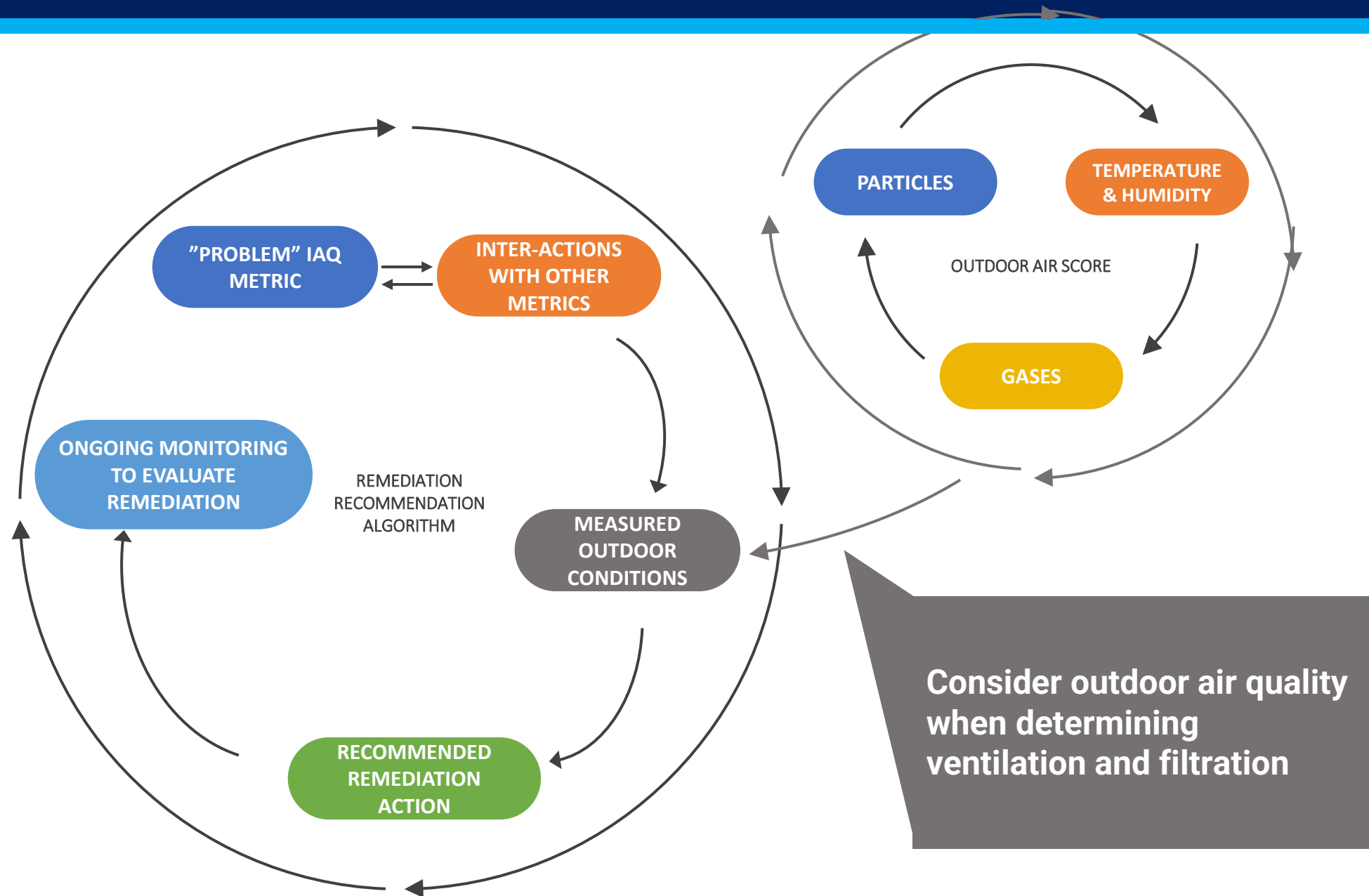


Report a comprehensive **Health Score** and its components in real-time

Recommend data-based interventions (humidity control, increased ventilation, filtration, etc.)

Continue monitoring to evaluate IAQ improvement

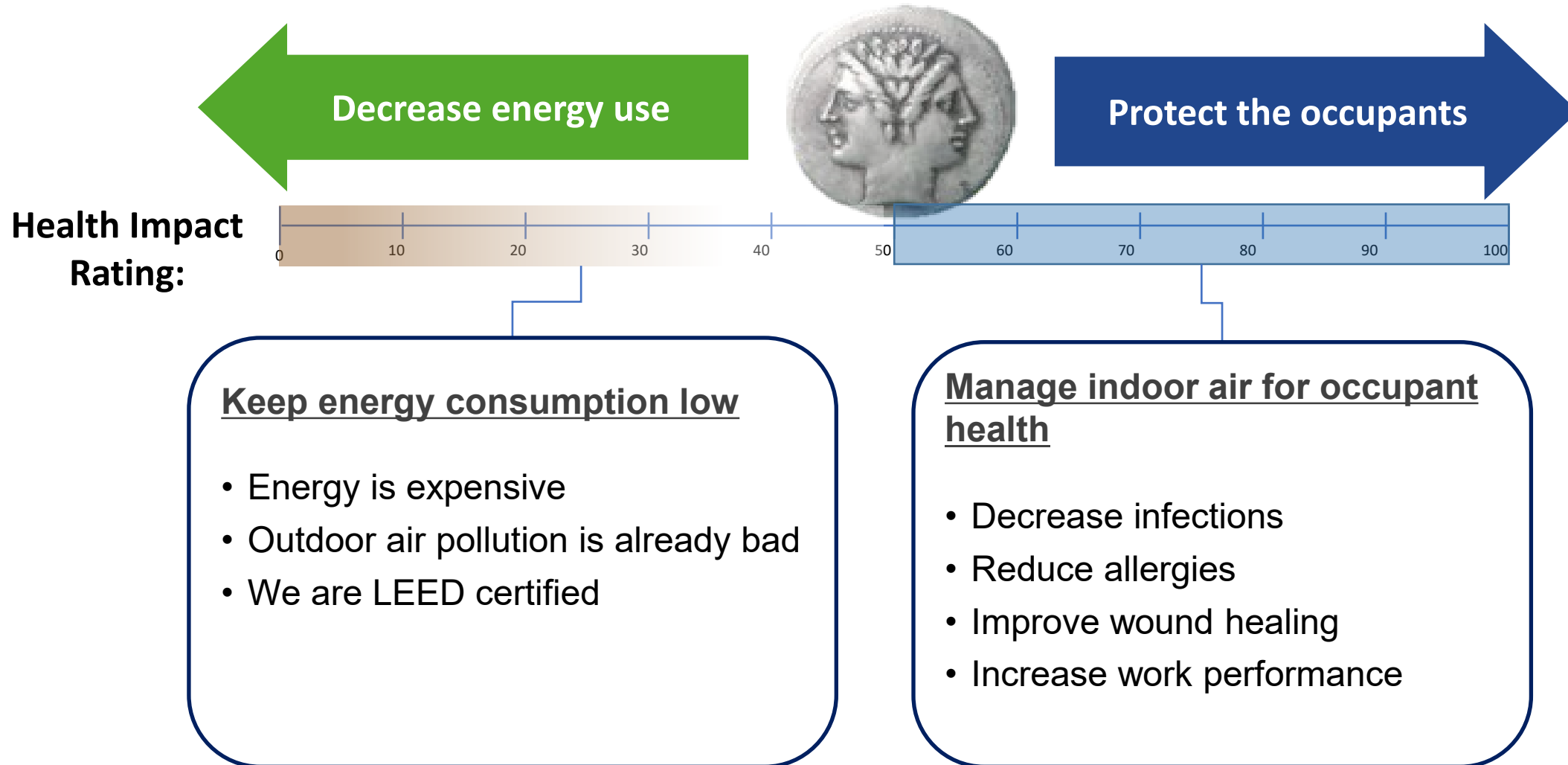
# Step 4: Monitor outdoor air so you can optimize ventilation, filtration



# Presentation Summary

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- ➔ 3. Why it Matters: Unlocking the value of health-based data**

# Should we focus on energy conservation or occupant health?



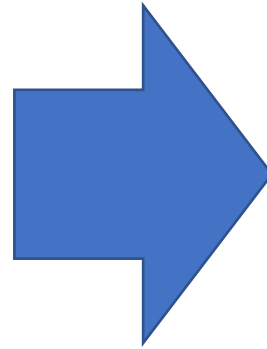
# We can achieve both by unlocking the value of IAQ data

## CURRENT IAQ PRACTICES

- Based on limited, often STATIC DATA, occupant *comfort*
- Scheduled HVAC resulting in potentially unnecessary energy costs
- Unknown impact on occupant health

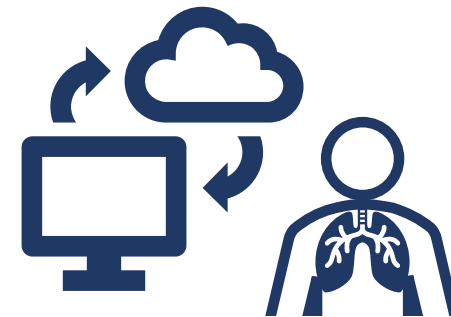


- Air Exchange
- Temp
- Humidity



## THE NEXT GEN IAQ

- Continuous Data Measurement
- Evaluate Impact on Human Health
- “Test before you invest”
- Manage to real time conditions
- Choose the most efficient remediation options





## Research

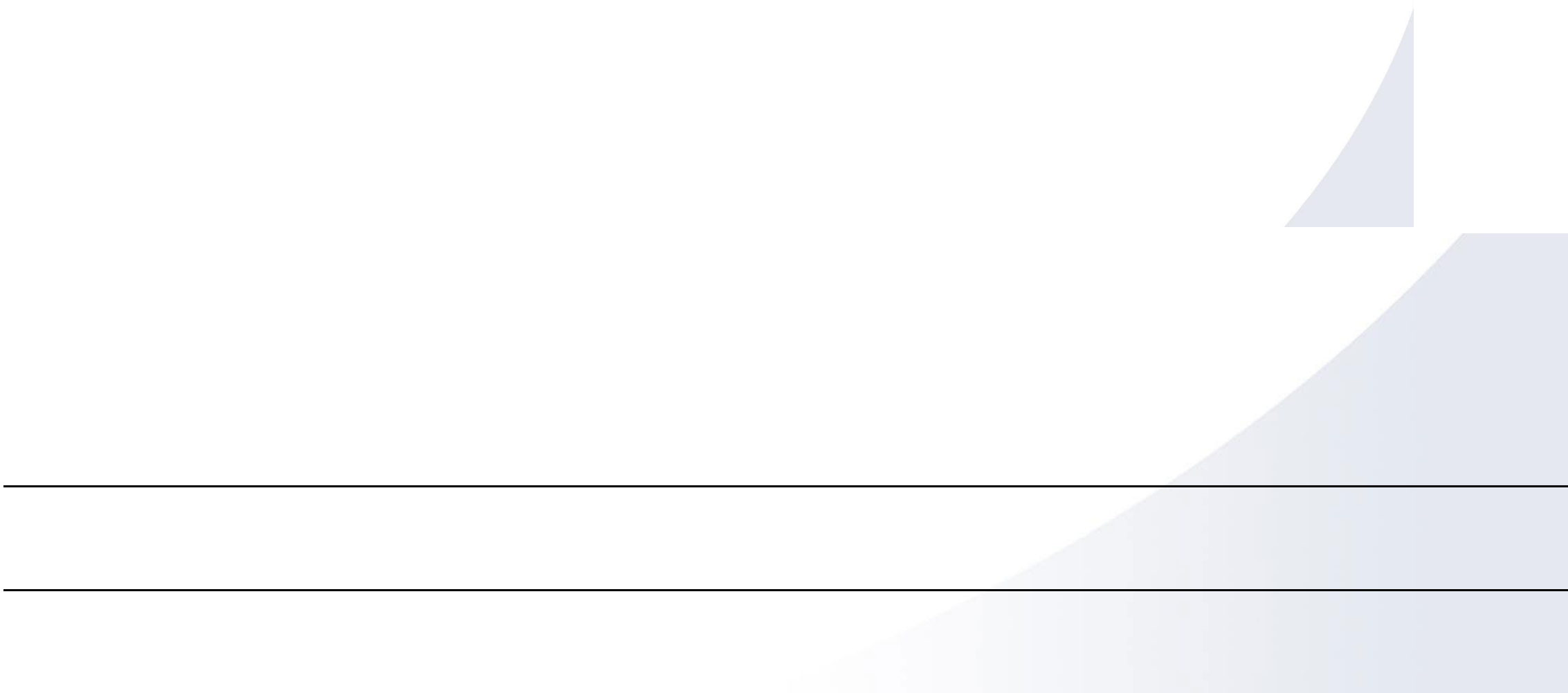
### Challenge:

Evaluate the role of Indoor Air Quality in Surgical Site Infections (SSI's) in Operating Rooms

### Key Strategies:

IAQ monitoring and remediation





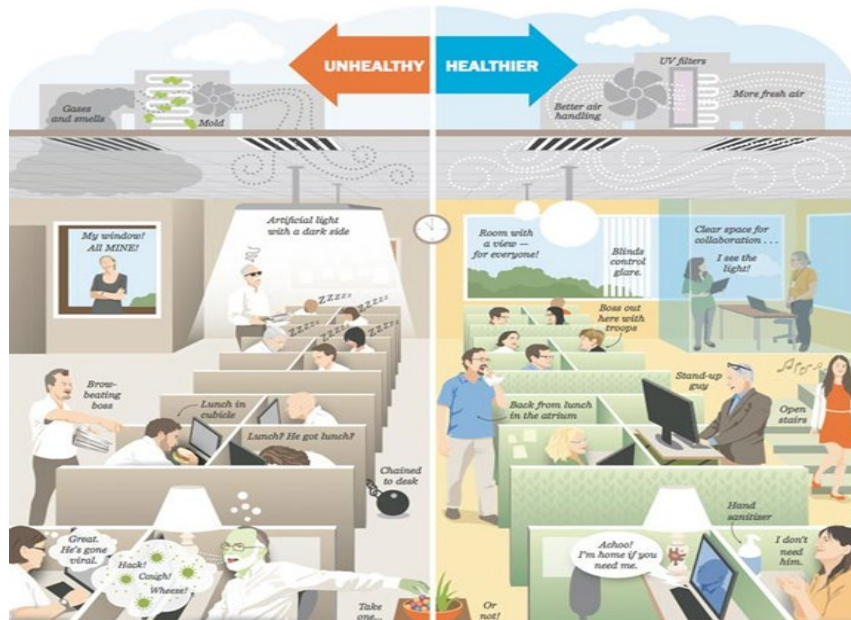
and Average cost per Hospital Acquired Infection

# Operating Room Energy Savings

<b>Building Utility Service Type &amp; Climate Zone</b>	<b>Annual Energy Savings per 5 ACPH Reduction*</b>	<b>Annual Savings for all EQI Modified Operating Rooms (x 14)</b>
<b>City Thermal Utilities Climate Zone 5</b>	<b>\$10,068</b>	<b>\$140,952</b>
<b>Campus Thermal Climate Zone 4</b>	<b>\$7,052</b>	<b>\$98,728</b>
<b>Self-Generated Thermal Climate Zone 4</b>	<b>\$5,218</b>	<b>\$73,052</b>

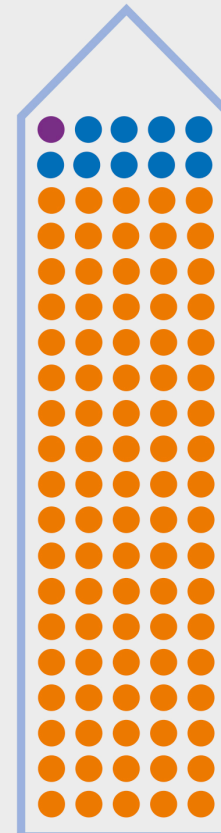
The average air change rate per OR before the EQI modifications was approximately 29. After the EQI modification the average air change rate was 24. This resulted in a 5 ACPH rate reduction per OR.

# Investments in a healthy workplace environment pays off



Communicable respiratory illness costs the workforce U.S. \$225B per year

## Typical business operating costs<sup>1</sup>



- 1% Energy costs
- 9% Rental costs
- 90% Staff costs in salaries and benefits

### 10% Variation

A 10% variation applied equally to each cost has a far from equal impact

**+/- 0.1%**

Energy costs

**+/- 0.9%**

Rental costs

**+/- 9.0%**

Staff costs



**ROI**  
Unlock the Value  
of Data

# REMEDIAL

## Unlock the Value of IAQ and Outdoor Air Data for Better Health and Building Efficiency

Deliver remediation intervention recommendations based on indoor and outdoor contaminant levels

A Health Score determines which strategies are effective (e.g. ventilation, filtration, humidification, and others)

# IAQ for Health creates economic returns for diverse building types



## Commercial Businesses

Communicable respiratory illnesses cost the workforce over \$225 billion per year due to absenteeism and presenteeism.<sup>1</sup>



## Schools

Poor IAQ reduces individual student grades by 3-7% and lowers the number of students performing in the highest standardized test categories in both math and reading by 3-4%.<sup>2</sup>



## Senior Care

Optimized indoor environments decrease acute illnesses requiring transfers to hospitals, improve patient memory and balance.<sup>3</sup>

# Thankfully, IAQ STANDARDS ARE EVOLVING

## ASHRAE

OLD: ASHRAE 62.1  
Focus on occupant  
comfort

NEW: ASHRAE goals are to  
protect occupants against  
both indoor and outdoor  
airborne threats through  
IAQ optimization

## USGBC

OLD: LEED 4.0 focus on  
energy conservation

NEW: LEED v5 integrated  
IAQ management for health  
into decarbonization steps  
in the new LEED v5

## Building CODES

OLD – focus on  
catastrophic building  
failures

NEW: Standards to  
measure, report, and  
enforce IAQ  
Guide IAQ as De-  
carbonization  
mandates roll out  
globally

# Conclusions

- By giving visibility to the health impact of the indoor environment, we have a scientific basis for managing IAQ to support occupant health, productivity and learning
- Humidification to RH 40%–60% is a **foundational step in** supporting health
- Healthy people increase the profitability of businesses and the success of our species

**Thank you!**

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