

IAQ and Health: Impacts Beyond Airborne Viruses

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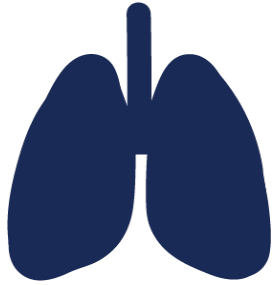
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- ▶ **Lisa Robinson, MPH:** Harvard T.C. Chan School of Public Health
- ▶ **John Levy, PhD:** Boston University School of Public Health
- ▶ **Dinesh Wadhvani CEO, Brady Shwartz, Sarmad Barrak, Barry Fleischer, Craig Behenna:** ThinkLite Air, Natick, MA

1. Understand how IAQ affects health beyond exposure to airborne viruses
2. Learn the power of air sensor data and medically-based analysis to reveal the health-impact of IAQ and guide effective remediation
3. Perform case studies that correlate IAQ, occupant health and productivity, and building energy consumption
4. Develop Return-On-Investment reports that include building-specific profitability of healthy occupants

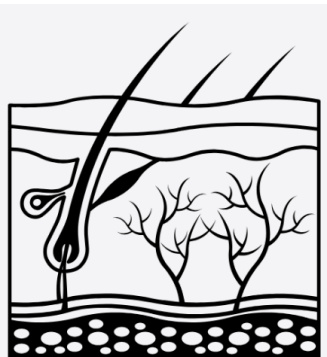
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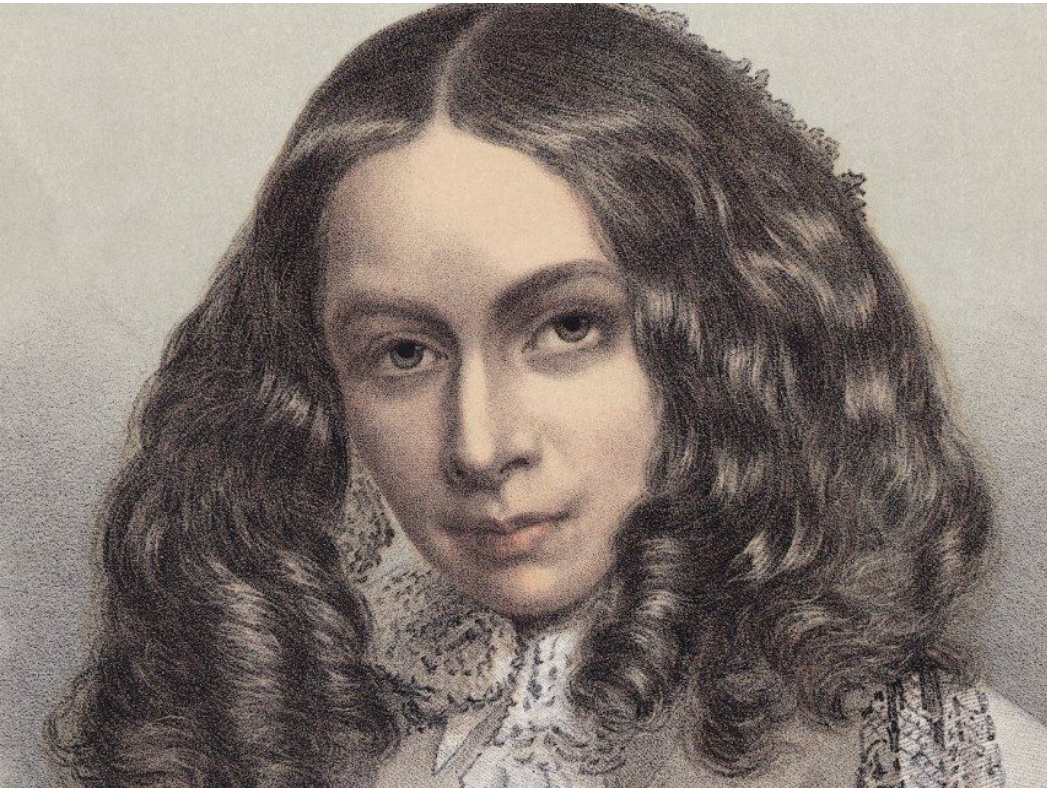
- Gas exchange surface area of an adult's lungs is **$\sim 70\text{--}100\text{ m}^2$** through a thin membrane of $\sim 0.2\text{--}0.6\text{ }\mu\text{m}$



- **13,000 liters** of air are inhaled every day



- Surface area of adult's skin: $\sim 1.5\text{--}2.0\text{ m}^2$



*Elizabeth Barrett Browning 1846
modified by S. Taylor 2026*

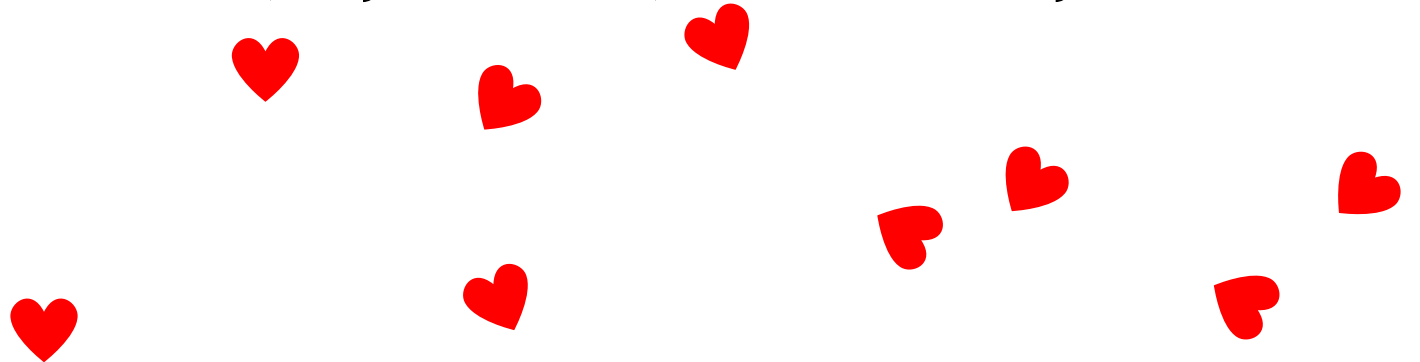
How ~~do I love~~ does IAQ impact thee?

Let me count the ways.

I impact thee to your depth and breadth and height
where all my particles and gases reach.

I impact thee in everyday's most quiet times,
whether lit by sun or candle-light.

I impact thee through the very breath of your life,
and, if you choose, I shall hasten your death.



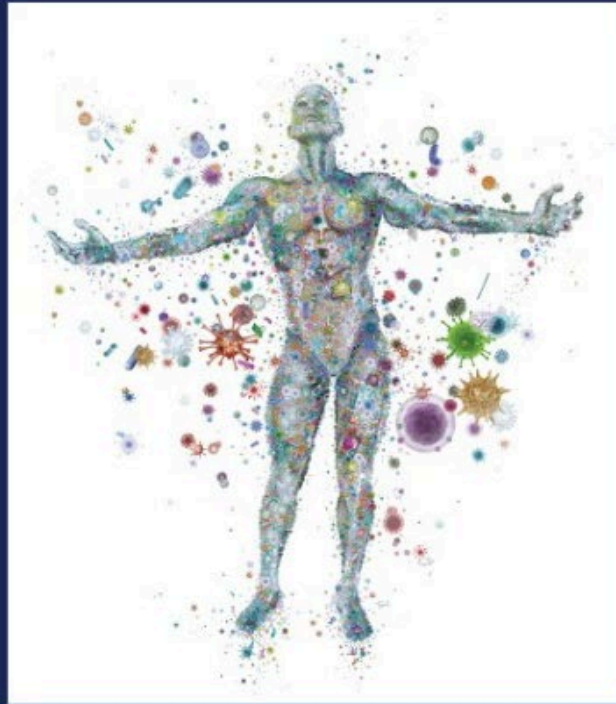
Metabolism

Immune system

Inflammation

Cell growth

Brain function

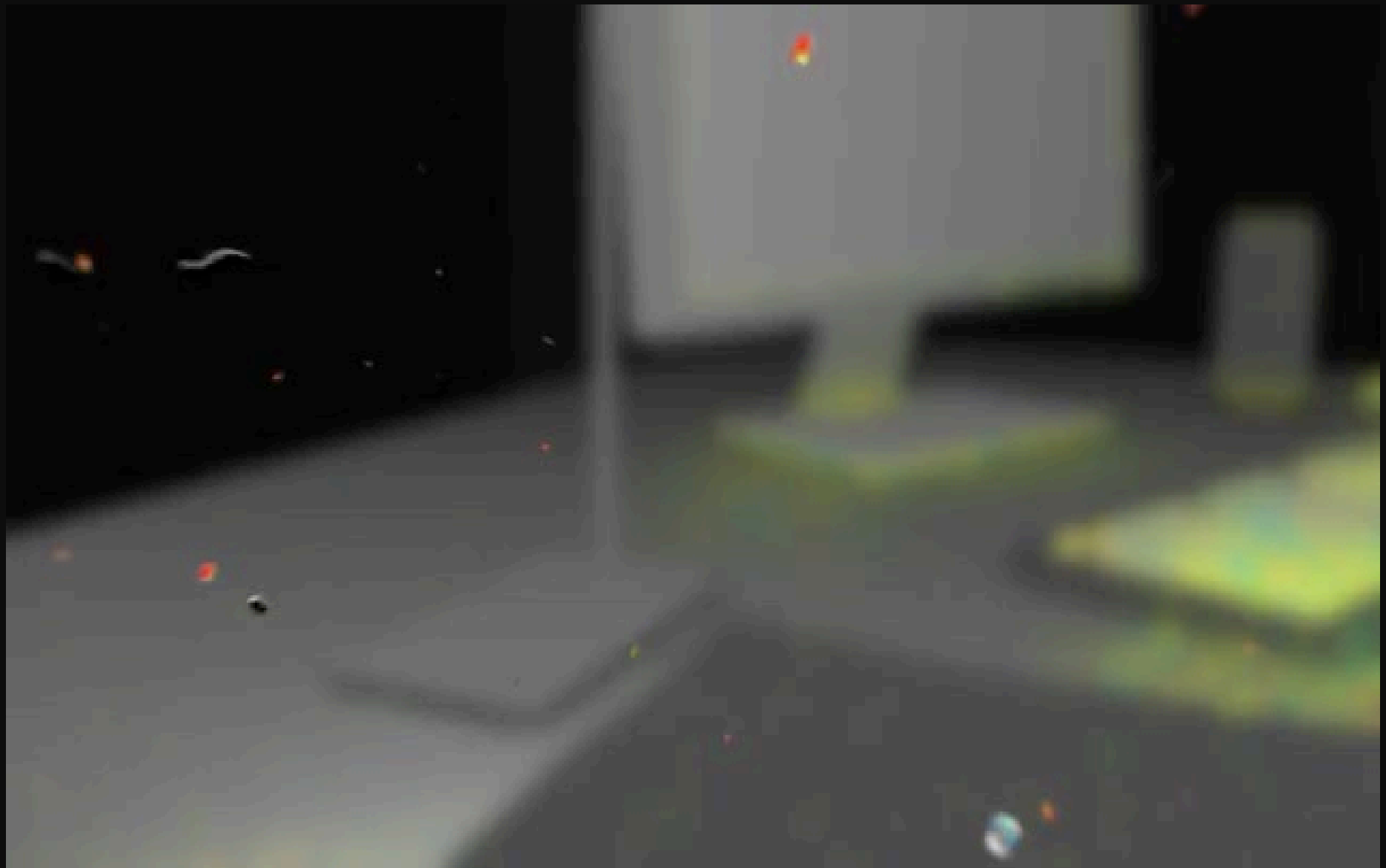


**IAQ effects on the human
microbiome**

Airborne bio-aerosols

Surface biofilms

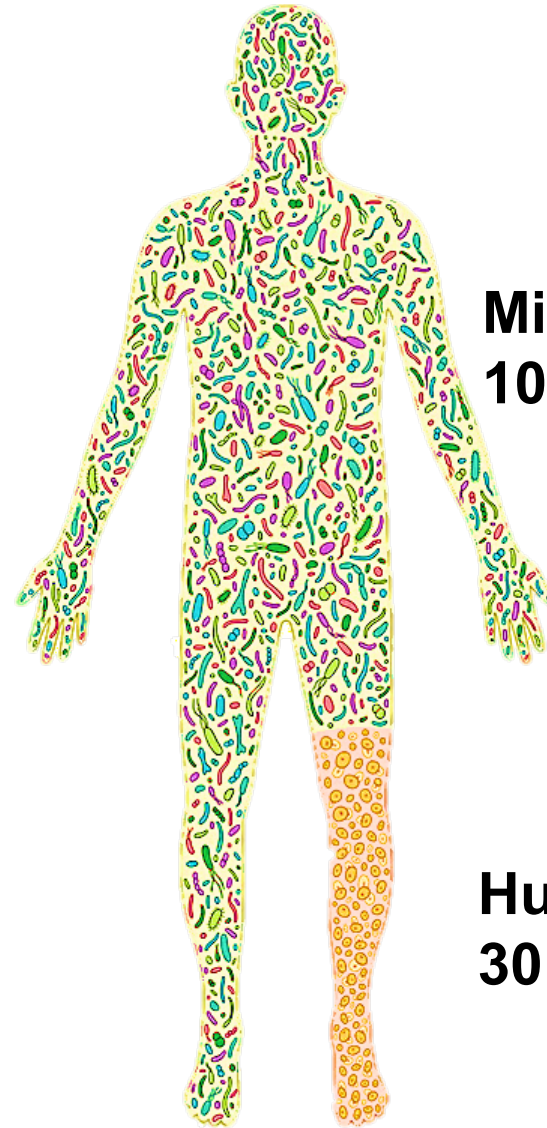
**Balance between "good"
and "bad" bacteria**



Trillions of microbes, mostly bacteria, with some viruses and fungi, colonize our skin, upper airways, intestines and vaginas (if you have one).

Don't worry, most of these microbes are good for us, helping our:

- ✓ digestion and metabolism
- ✓ mental health
- ✓ immune system

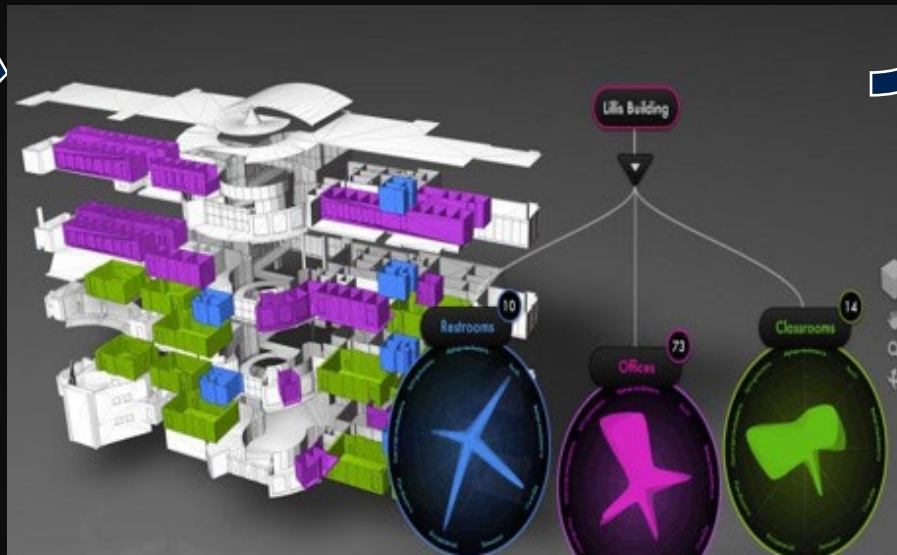


**Microbial cells ~
100 trillion**

**Human cells ~
30 trillion**

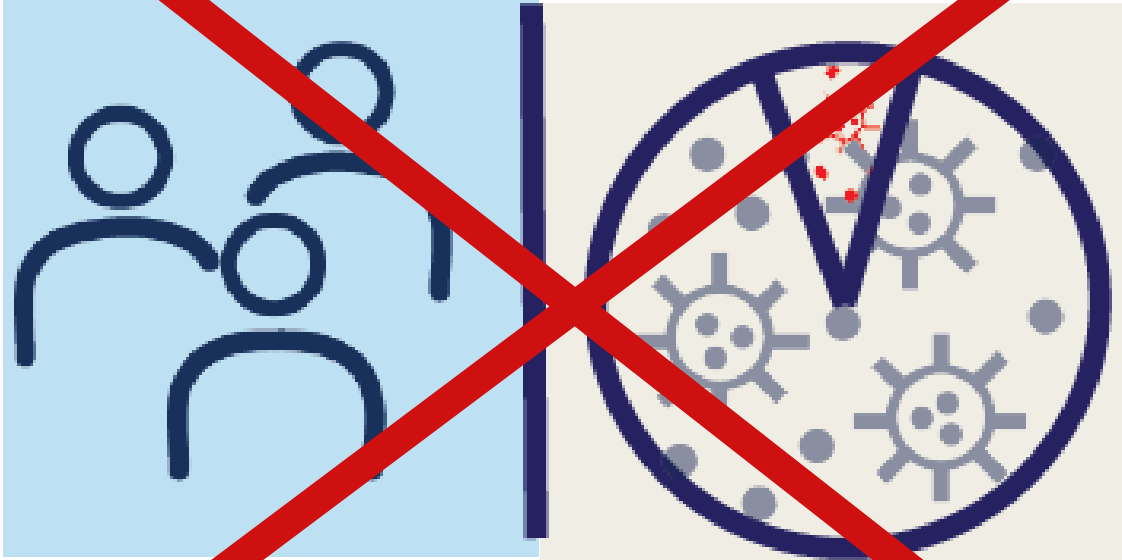


Occupants send microbes into buildings
(37 million microbes per person per hour)



Building materials and IAQ determine which microbes survive indoors and interact with occupants

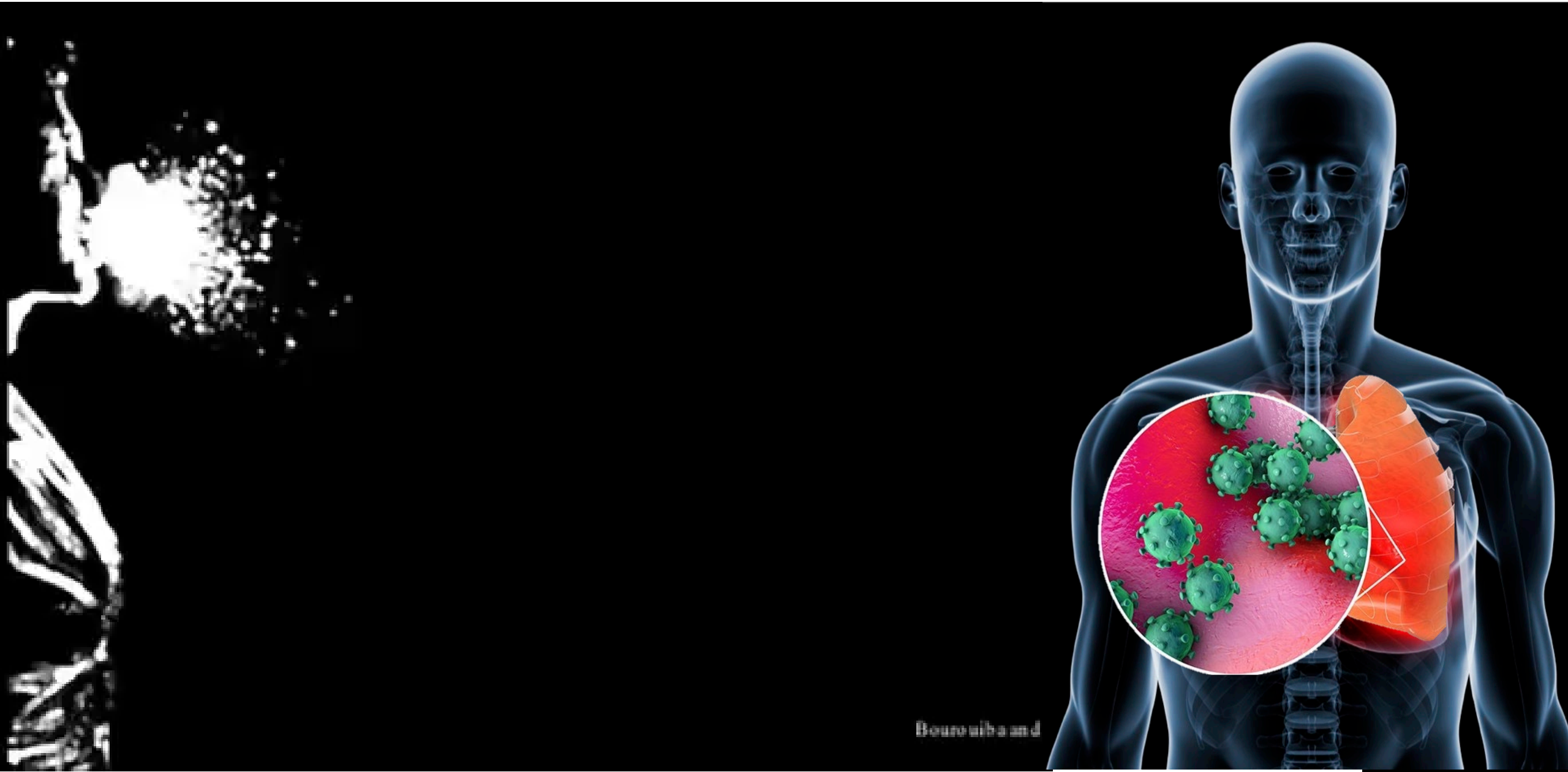
Historical (and Incorrect)
Approach to Hygiene



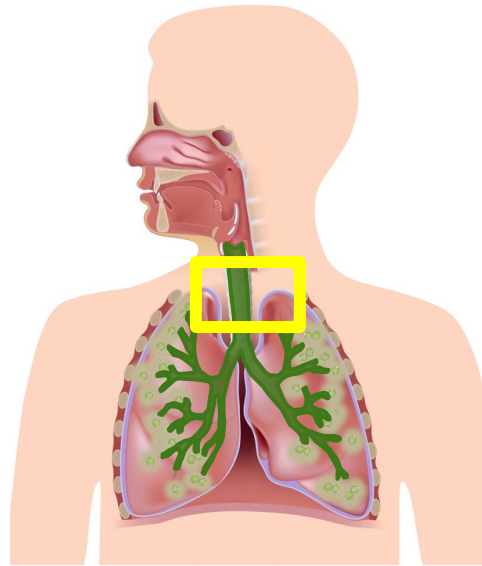
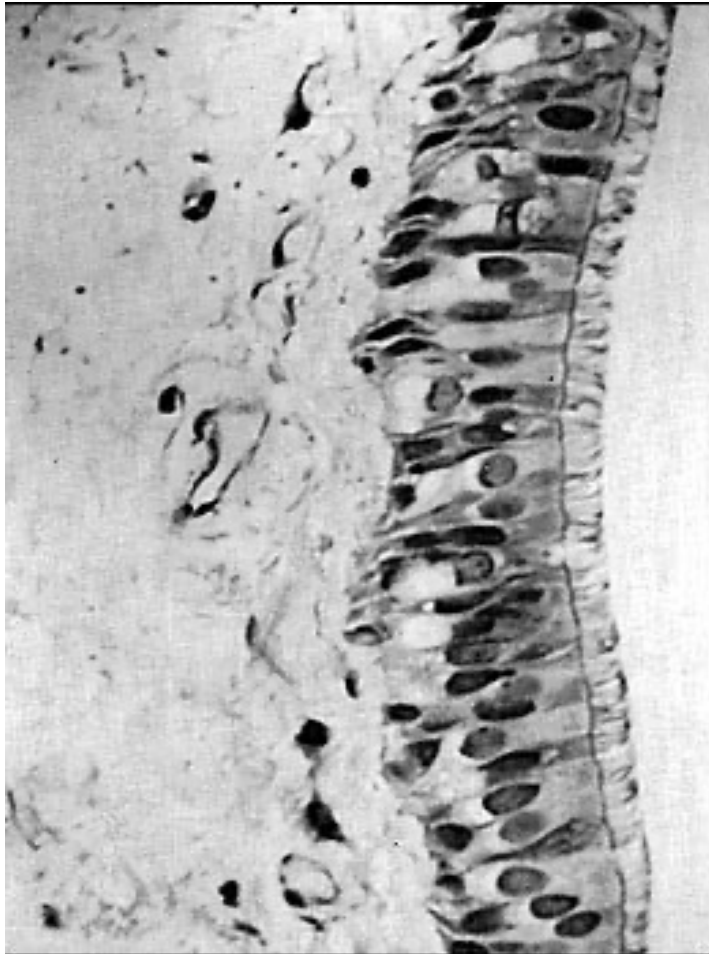
"All microbes are bad germs that require total eradication."



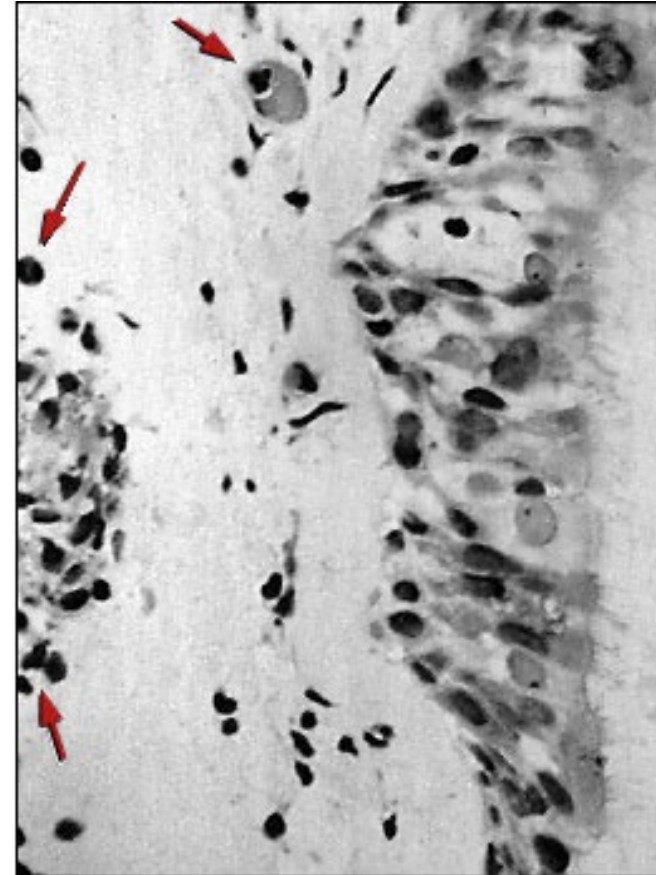
Research shows **having a cat** can double your risk of **schizophrenia**



Bourouiba and



Magnification: x400



Inflammatory cells

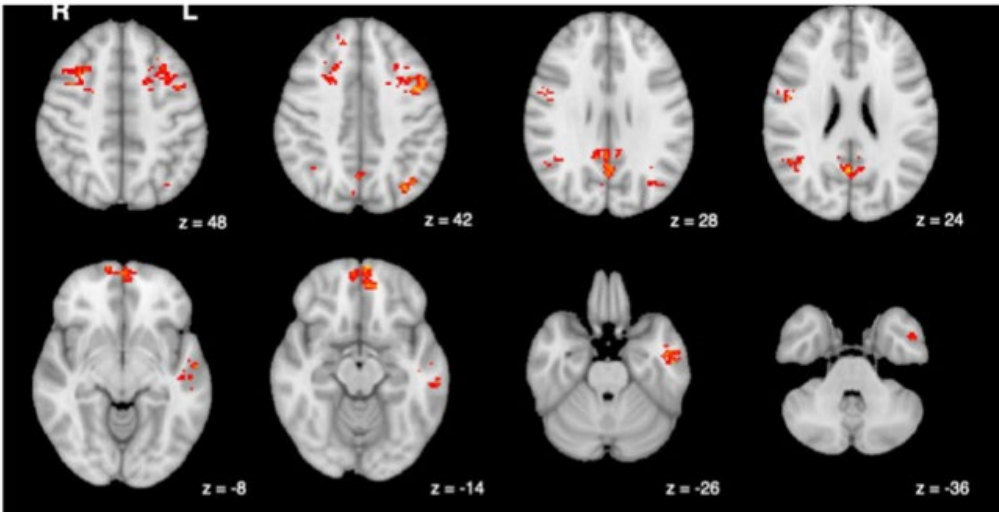
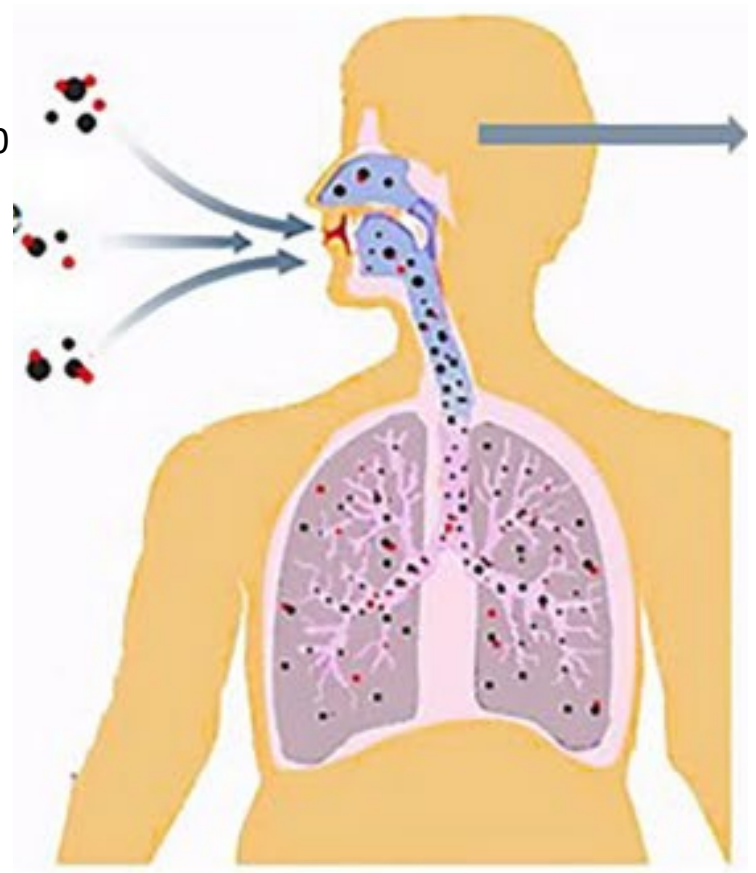
Disrupted cell architecture

Dysfunctional cilia

Healthy airway of a person with cilia functioning to protect the lungs from inhaled particles

Damaging inflammation from ozone, particles and low relative humidity (<40%)

- PM_{2.5}
- PC_{0.1-10}
- ozone
- NO₂
- SO₂
- CO
- etc.



- Oxidative stress
- DNA damage
- Cell dysfunction
- ↓neurotransmitters



Fatigue

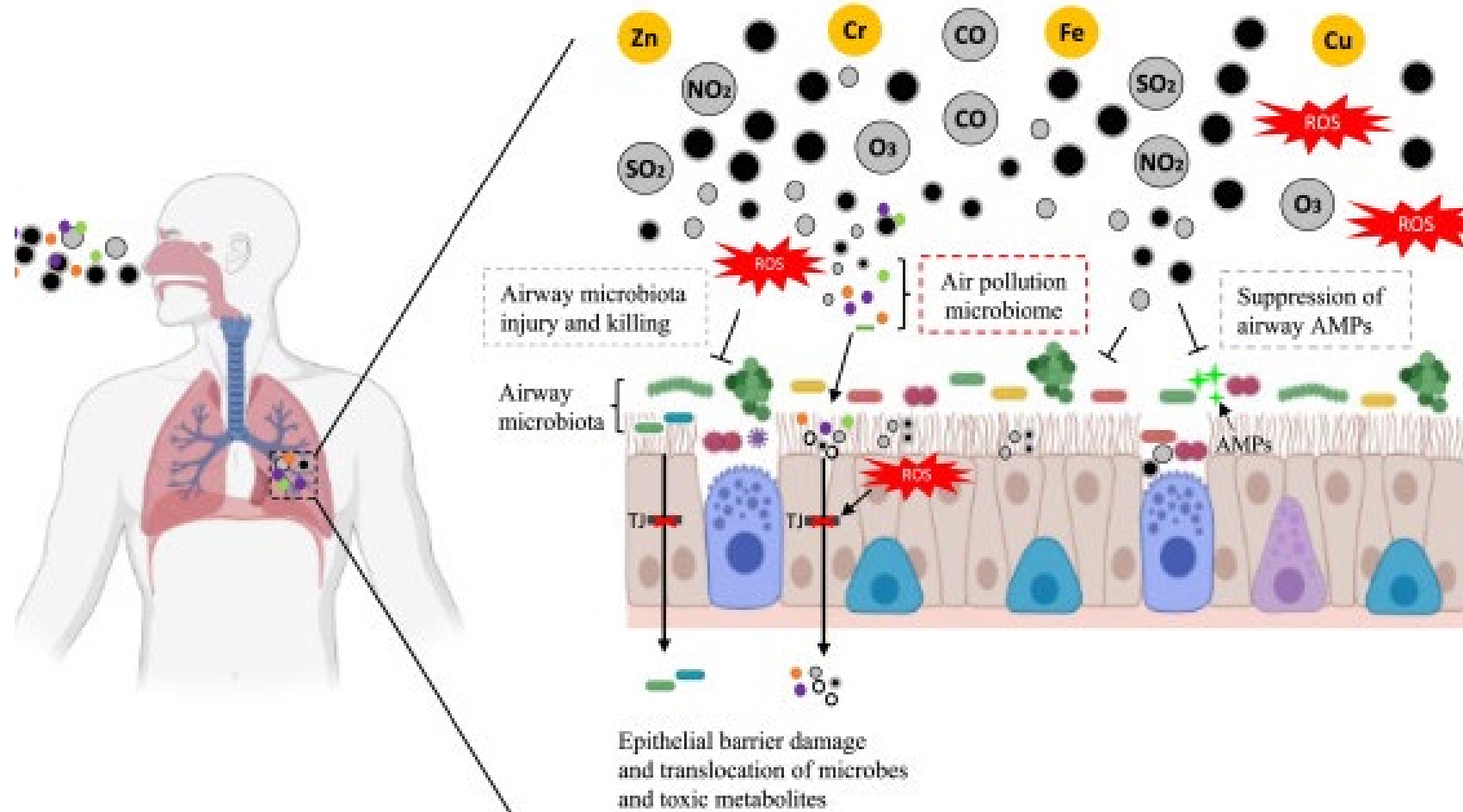


Poor memory



Alzheimer's / Parkinson's

IAQ actively reshapes the human microbiome, which affects immunity, inflammation, and disease susceptibility



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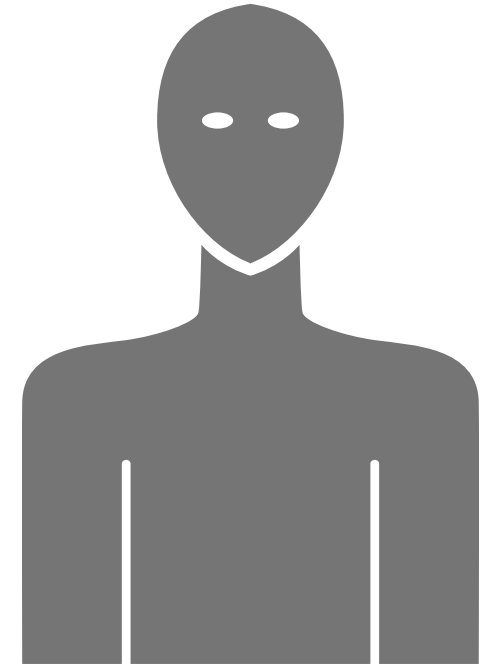


Building Management

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



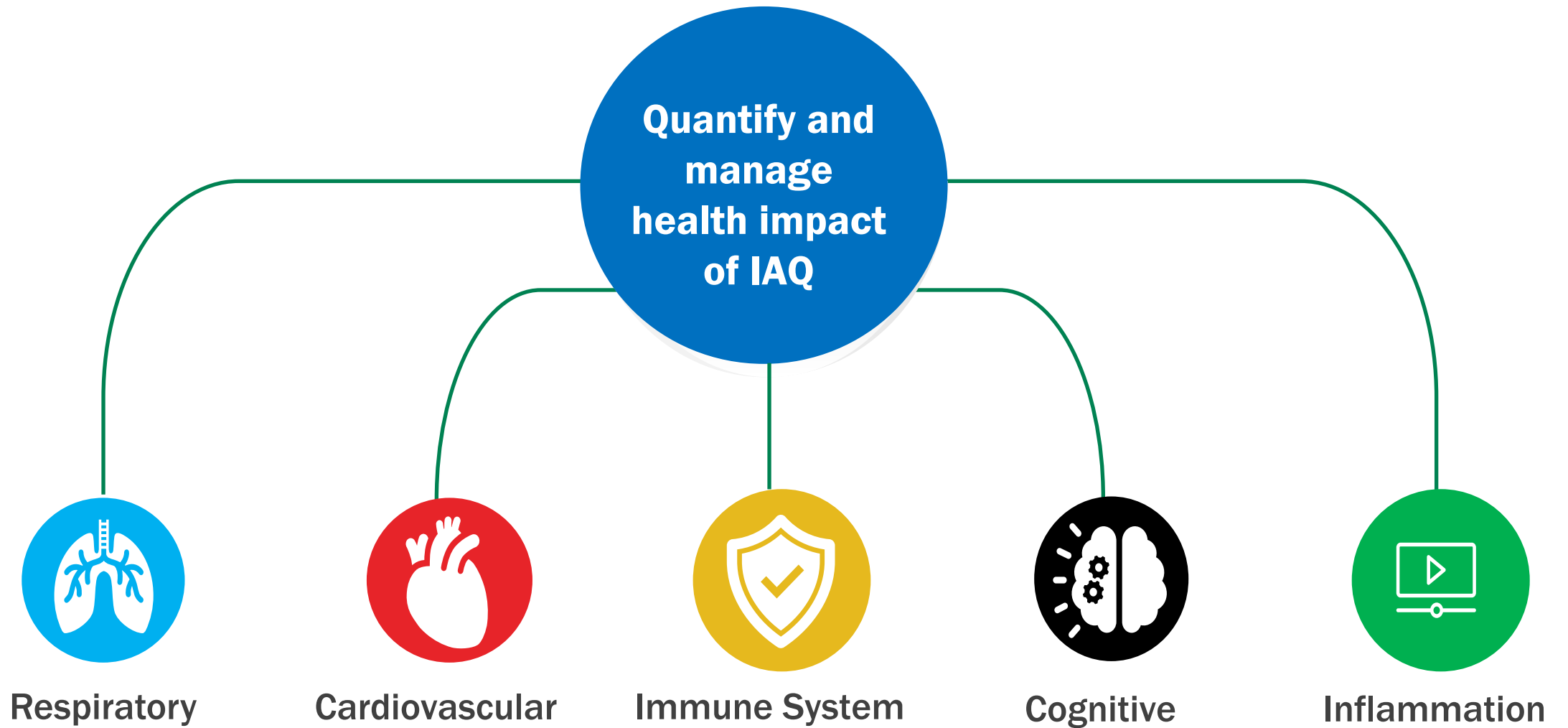
Make occupant health the
NORTH STAR for IAQ
management



Medical Care

- Heal patients
- Follow clinical protocols
- Avoid lawsuits

The solution - a human-centered IAQ platform



We do this in 4 steps

1 MEASURE

CONTINUOUSLY
MONITOR INDOOR &
OUTDOOR AIR



Indoor
Sensors

In-duct
Sensor

2 ANALYZE

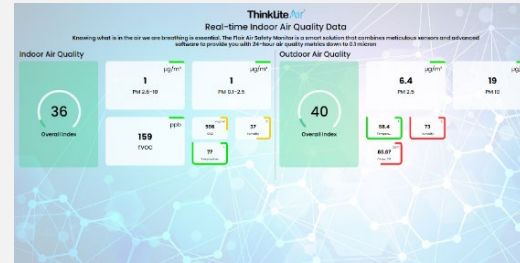
CALCULATE OUTDOOR
& IAQ HEALTH IMPACT



IAQ & HEALTH
Analysis

3 COMMUNICATE

REPORT TO CUSTOMER



4 REMEDIATE

IMPLEMENT ENERGY
EFFICIENT IAQ
MANAGEMENT AT THE
CENTRAL OR IN-SPACE
LEVEL

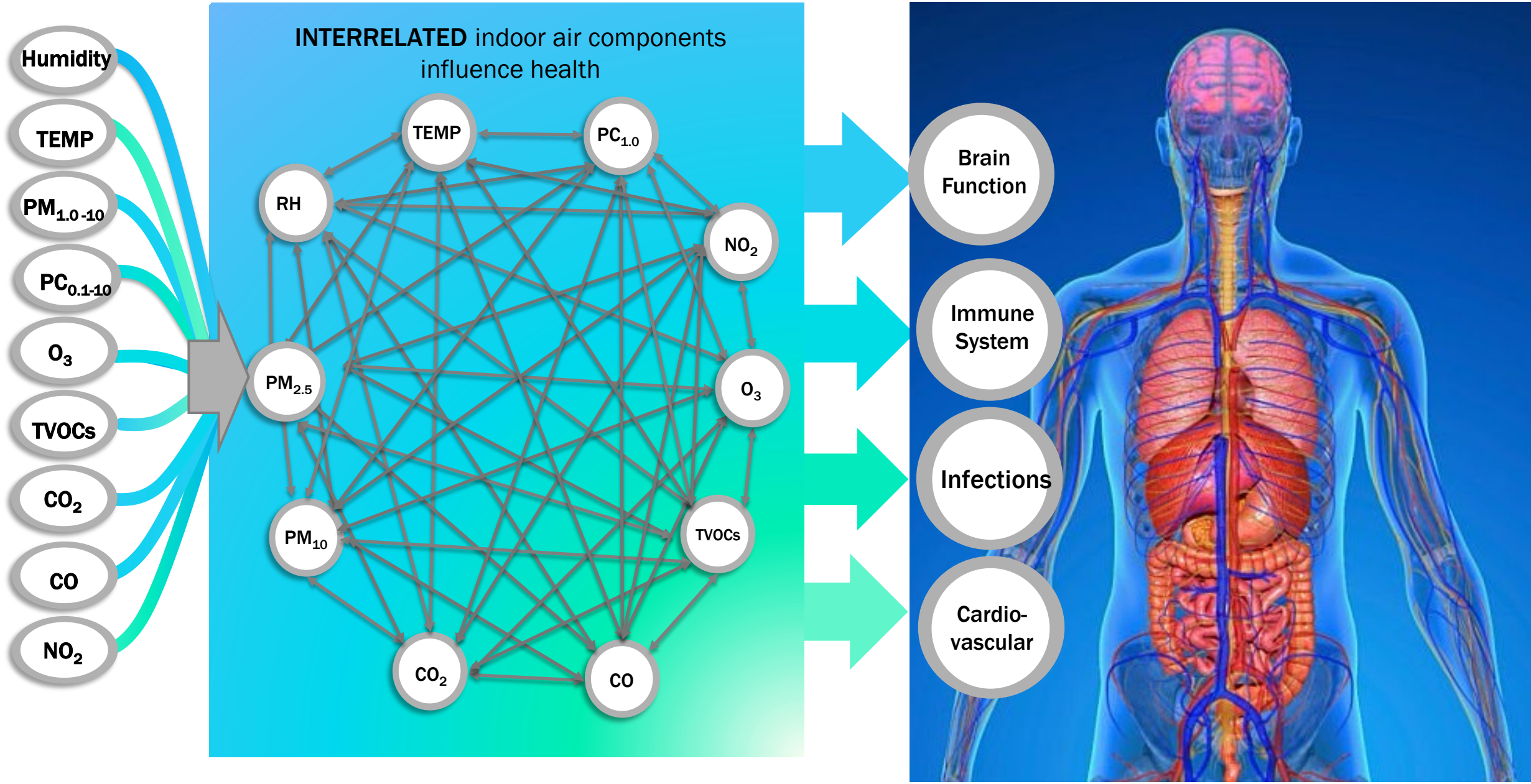


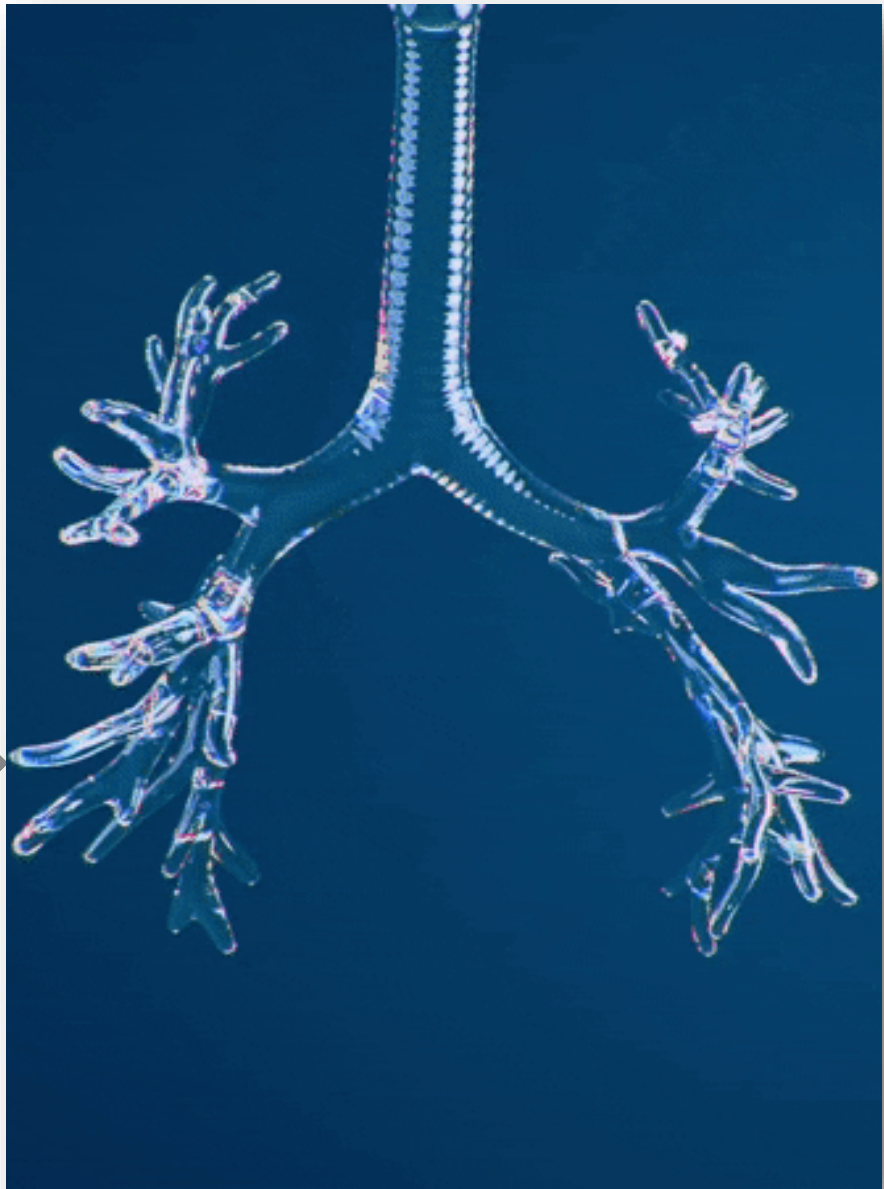
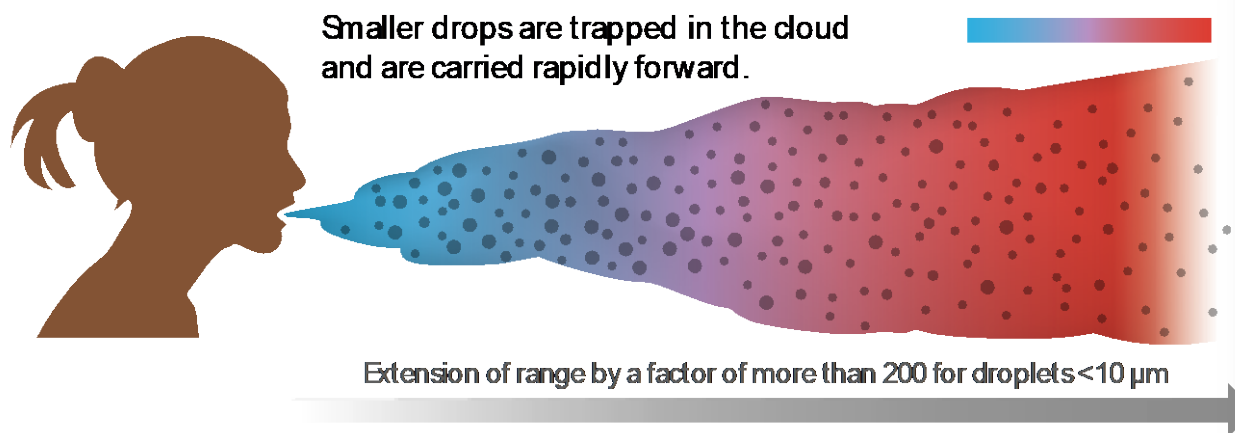
Customizable in-room sensor



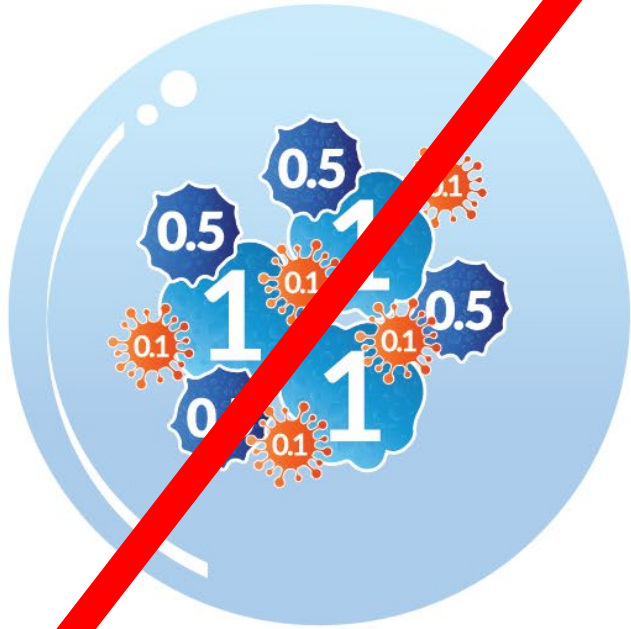
Intake duct sensor for outdoor air quality



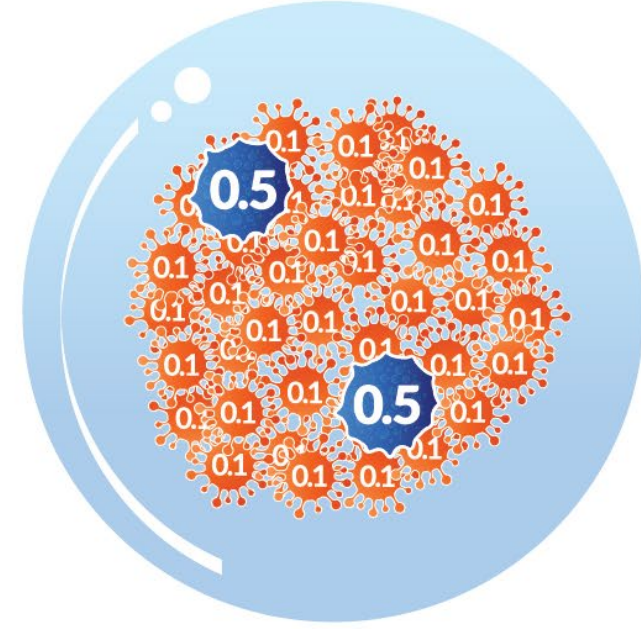




PM



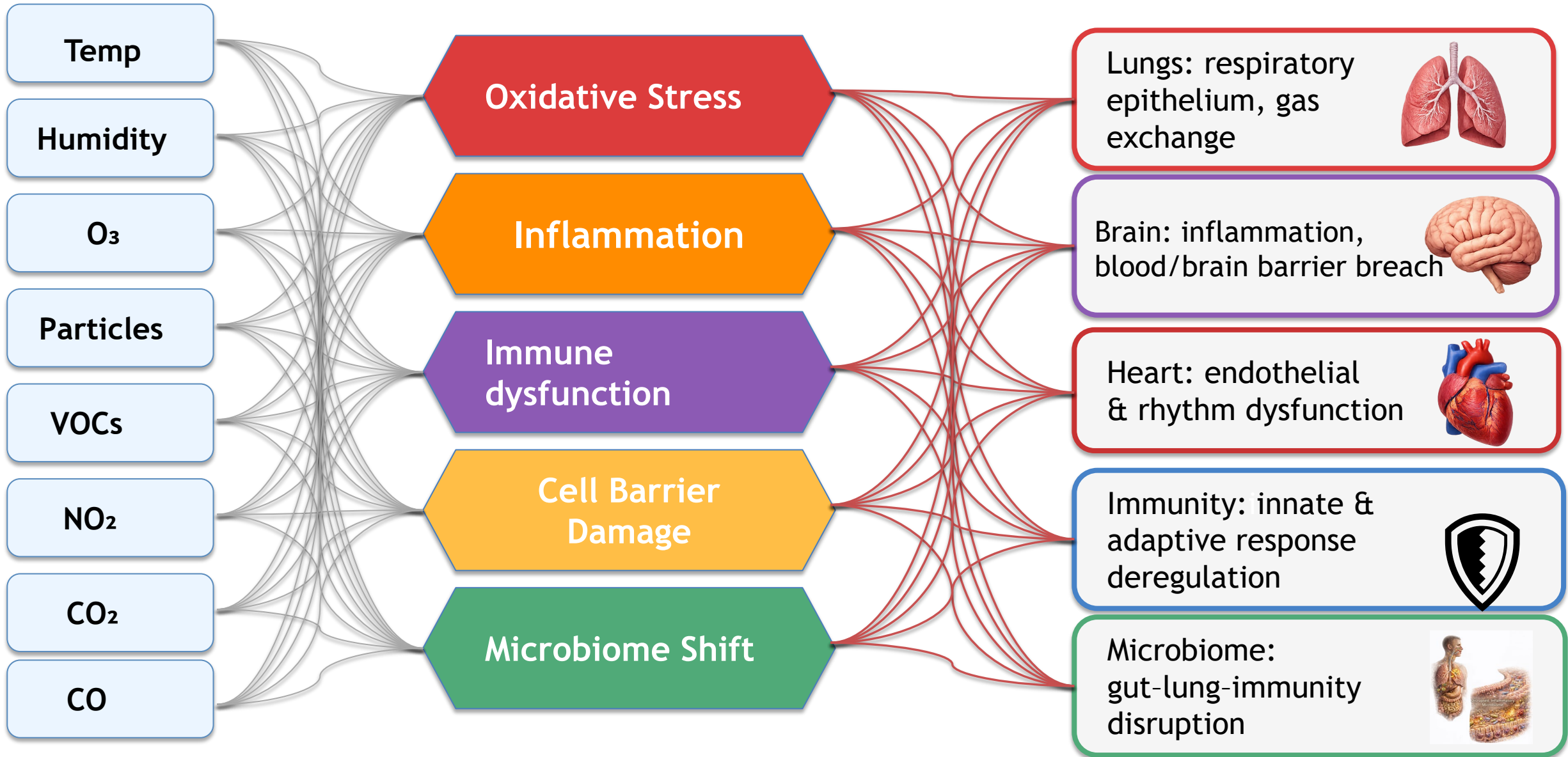
PC



 1 micron

 .5 micron

 .1 micron



Lungs: increased respiratory epithelium leakiness, broncospasm



Asthma exacerbation, acute bronchitis, reduced lung function, eye/throat irritation

Brain: neuroinflammation, blood/brain barrier disruption



Headache, dizziness, cognitive impairment, fatigue, decreased hand-eye coordination

Heart: endothelial & rhythm dysfunction



Chest tightness, angina, myocardial infarction, arrhythmias

Immunity: innate & adaptive response suppression



Mucosal drying, increased barrier penetration, increased susceptibility to infections

Microbiome: gut-lung-immunity disruption



Decreased microbiome diversity, higher number of pathogenic organisms

3. Communicate

1 MEASURE

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OUTDOOR AIR



Indoor
Sensors

In-duct
Sensor

2 ANALYZE

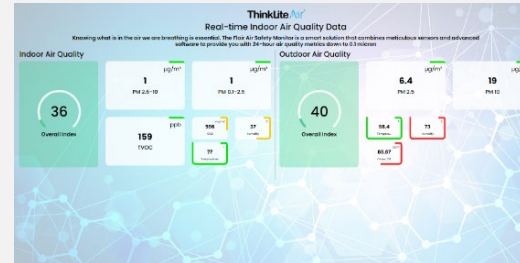
CALCULATE OUTDOOR
& IAQ HEALTH IMPACT



IAQ & HEALTH
Analysis

3 COMMUNICATE

REPORT TO CUSTOMER



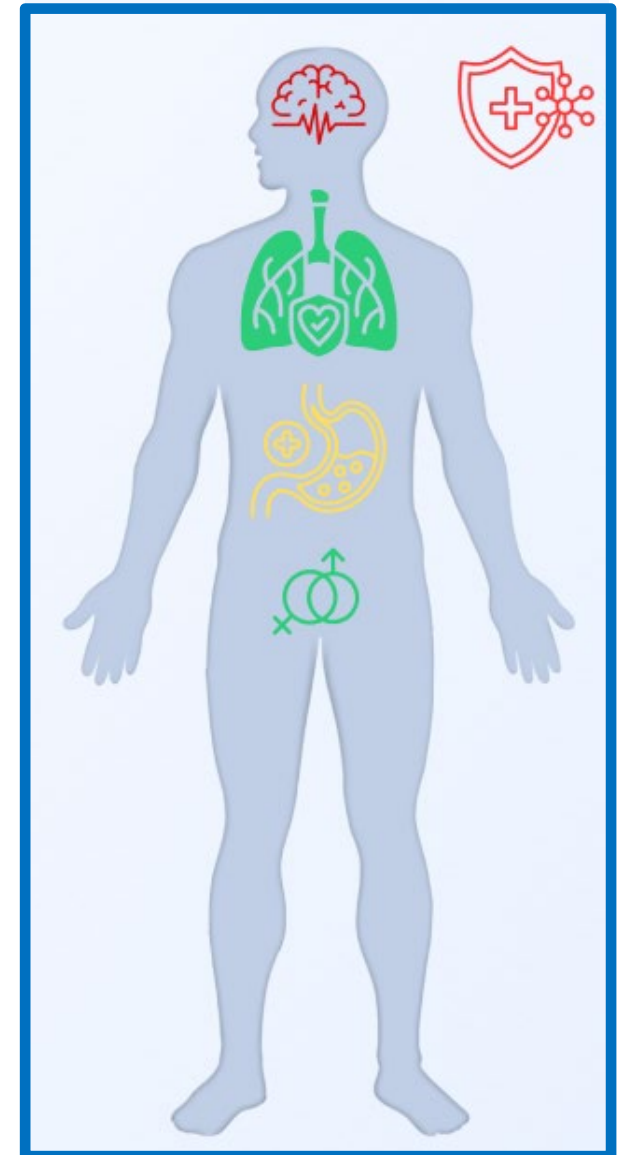
4 REMEDIATE

IMPLEMENT ENERGY
EFFICIENT IAQ
MANAGEMENT AT THE
CENTRAL OR IN-SPACE
LEVEL



Example Contaminant Clusters	Lungs	Brain	Heart	Immunity
PM _{2.5} /UFP + NO ₂ + O ₃ + low RH	Red	Orange	Red	Orange
VOCs + O ₃ (oxidative chemistry)	Orange	Red	Orange	Yellow
Low RH + particles	Red	Yellow	Yellow	Yellow
Heat + high RH + particles	Orange	Orange	Red	Red
CO (hypoxia)	Yellow	Red	Red	Orange

In this example, IAQ was found to be most harmful to the brain and immune system



Main Lobby 2

Status: Battery:

US

39

AQI Overall Index
Baseline: 80

19 F Temperature	565 ppm CO ₂ Baseline: 800	48.9 % Humidity	530 ppb TVOC Baseline: 500	1 ppb Ozone, O ₃	40 Mold Index	
11 µg/m ³ PM 10	5 µg/m ³ PM 2.5 Baseline: 20	0 µg/m ³ PM 1.0	1 µg/m ³ PM 0.5	0 µg/m ³ PM 0.3	0 µg/m ³ PM 0.1	
0 Count PC 10	4 Count PC 5.0	4 Count PC 2.5	25 Count PC 1.0	96 Count PC 0.5	270 Count PC 0.3	17808 Count PC 0.1

Last updated 20 seconds ago.

View Outdoor Readings

Split Graph

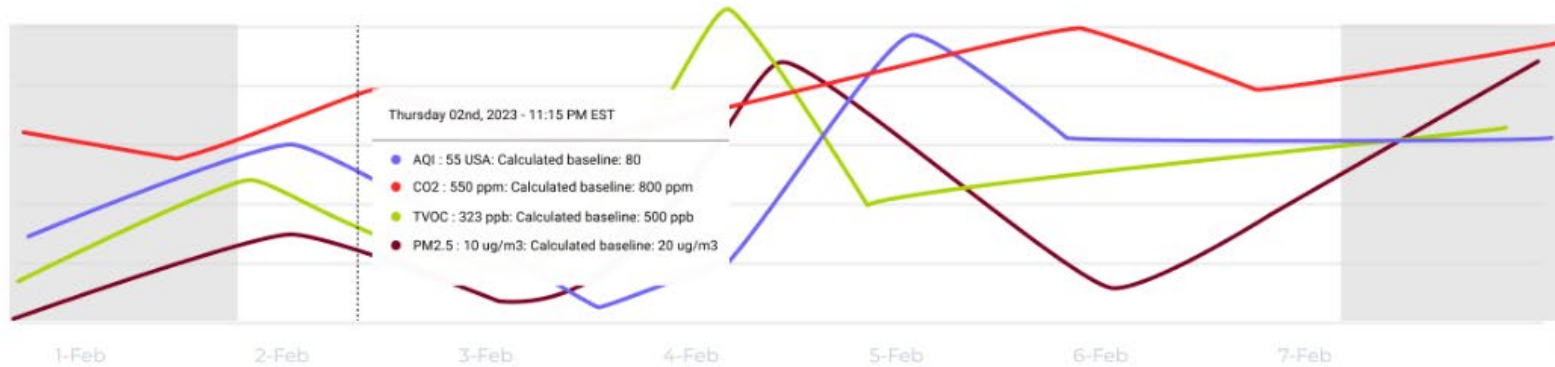
Export Graph Image

Export Data

Air Quality History

Last 7 days

Zoom out



Navigation bar with buttons for: AQI, Battery %, Temperature, CO₂, TVOC, Humidity, Ozone, O₃, PM 10.0, PM 2.5, PM 1.0, PM 0.5, PM 0.3, PM 0.1, PC ≥ 10, PC ≥ 5.0, PC ≥ 2.5, PC ≥ 1.0, PC ≥ 0.5, PC ≥ 0.3, PC ≥ 0.1, Mold Index.

Select operation hours:

- Monday 08:00 am - 06:00 pm
- Tuesday 08:00 am - 06:00 pm
- Wednesday 08:00 am - 06:00 pm
- Thursday 08:00 am - 06:00 pm
- Friday 08:00 am - 06:00 pm
- Saturday 08:00 am - 06:00 pm
- Sunday 08:00 am - 06:00 pm

Non-operation hours:

Hide Show

Baseline Configuration:

Calculated Average Baseline

Hide Show

Manual Baseline:

Select a metrics:

AQI

Enter baseline value:

80

Save and Update

4. Remediate

1 MEASURE

CONTINUOUSLY
MONITOR INDOOR &
OUTDOOR AIR



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Sensors

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Sensor

2 ANALYZE

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**IAQ & HEALTH
Analysis**

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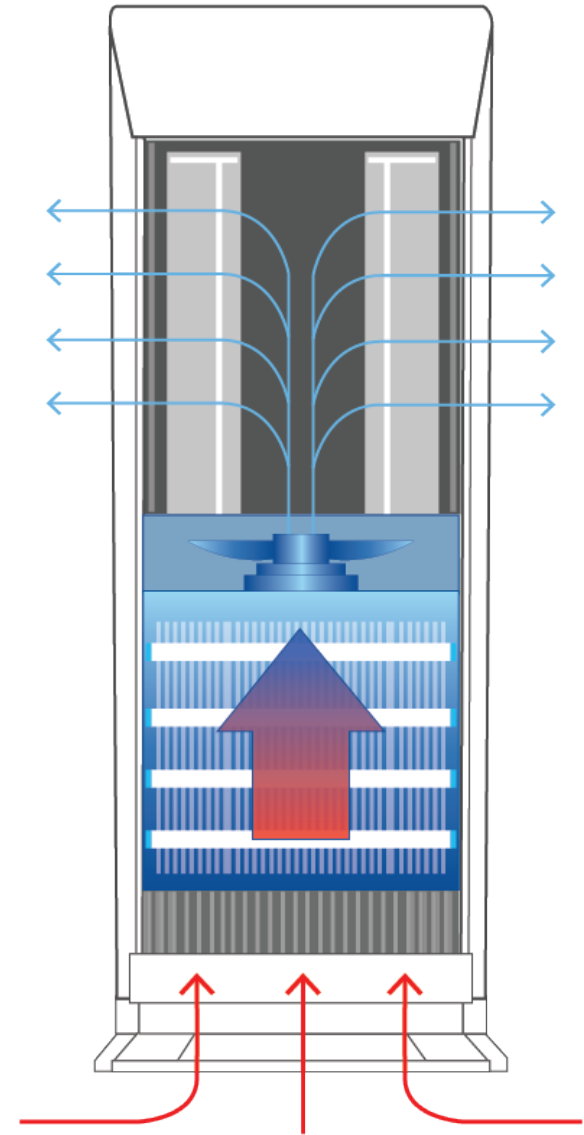


4. Remediate: examples of in-space air cleaning solutions

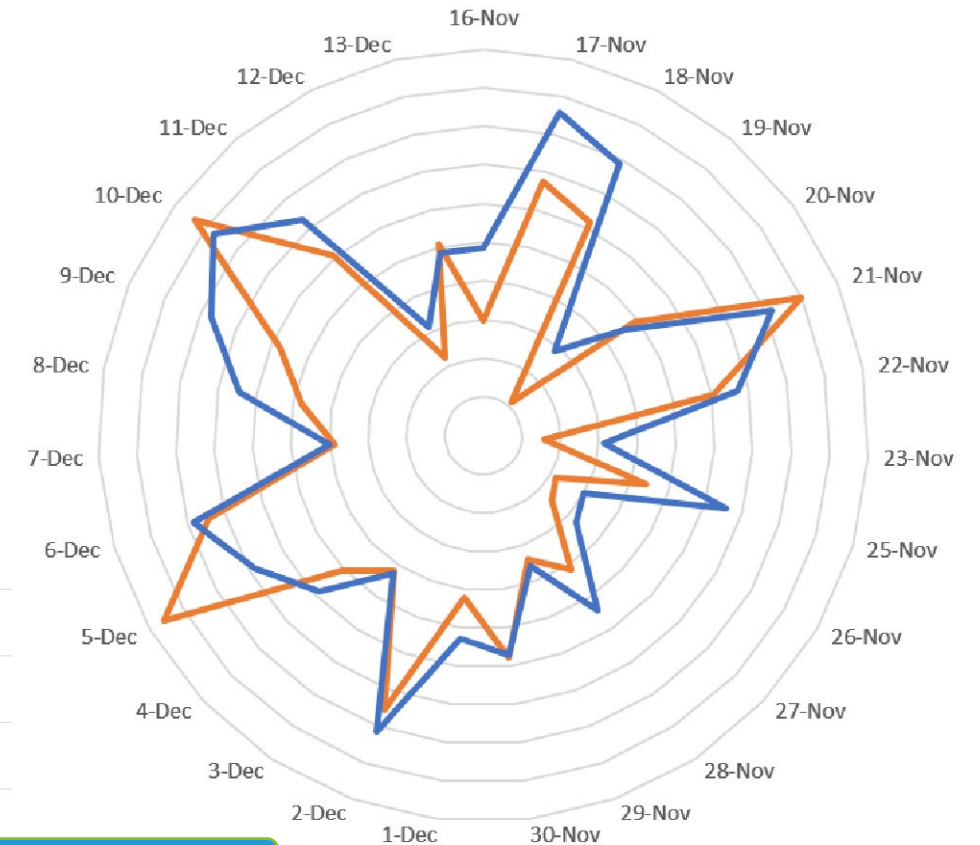
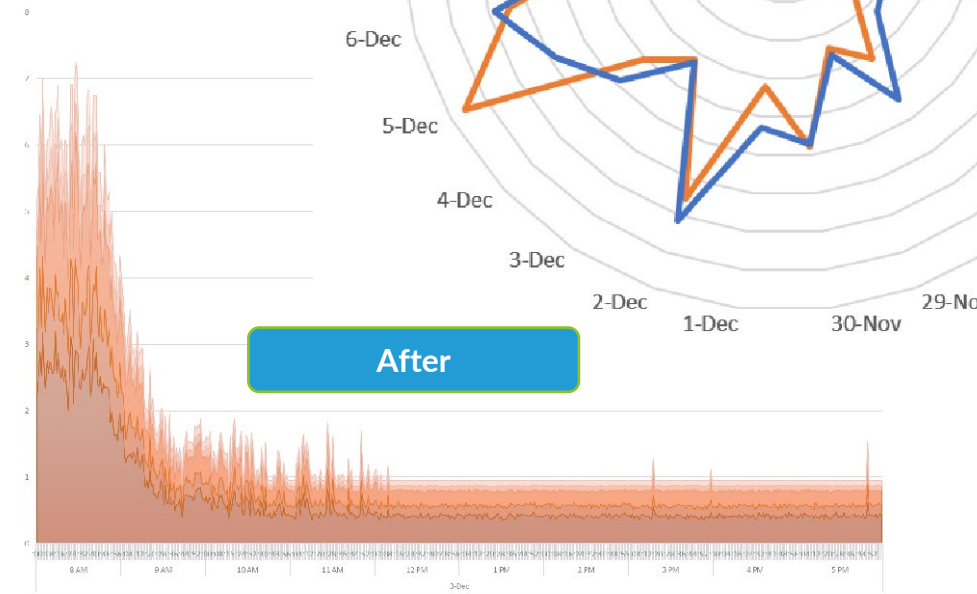
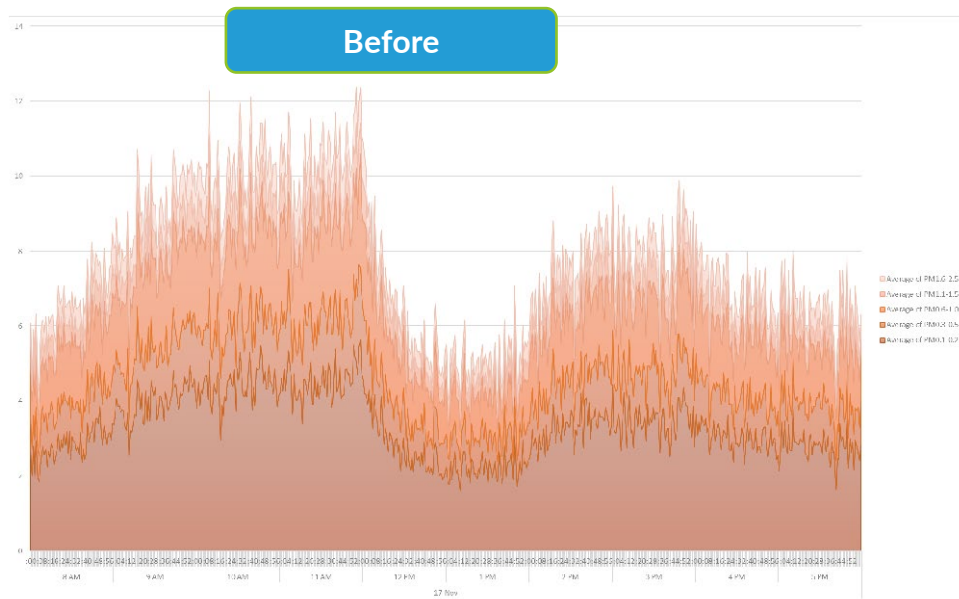
light fixture as an air purifier



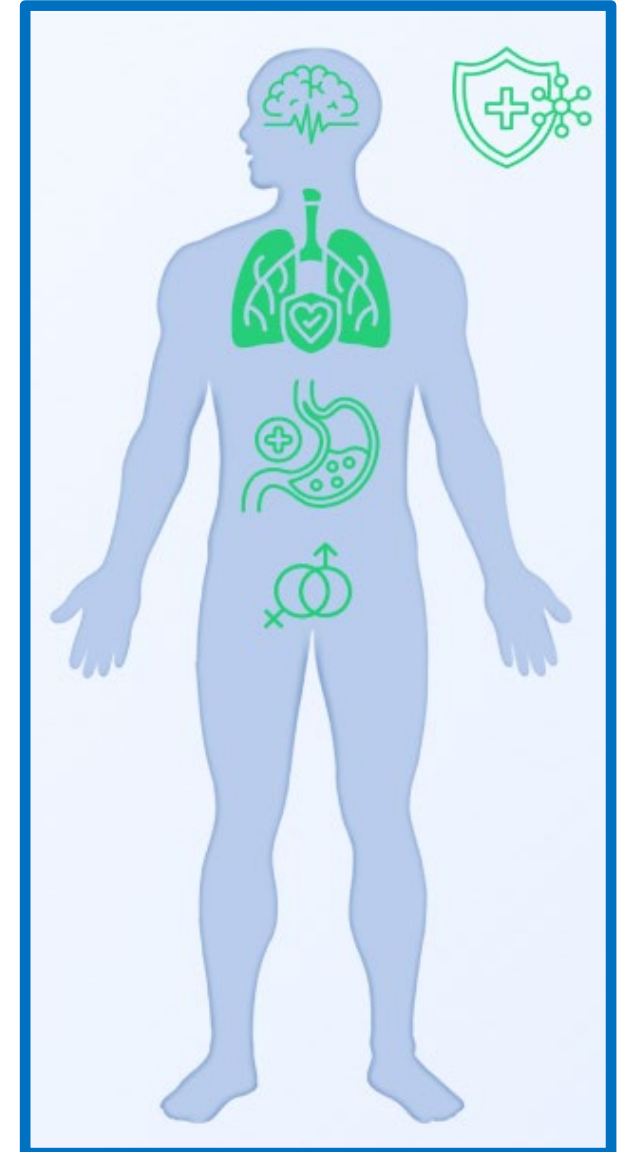
Stand alone,
In-room



- Detailed analysis of air quality metrics
- The correlation of outdoor air quality versus IAQ is illustrated
- The data is normalized to show the value of ventilation and/or indoor air purification



IAQ supports all systems



- Correlate IAQ improvement with patient health & staff absenteeism
- Report ROI

4. Evaluate multi-domain outcomes

1. Create IAQ management plan

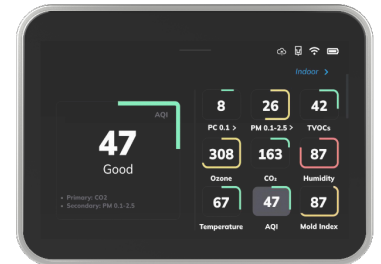
2. Measure & Analyze

3. Identify contaminant sources; remediate

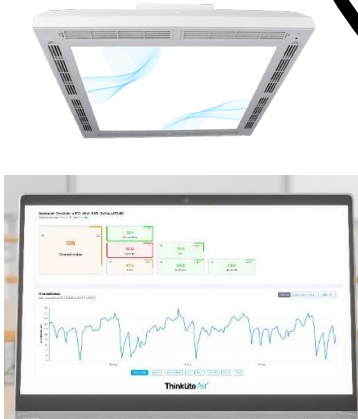
Keep going

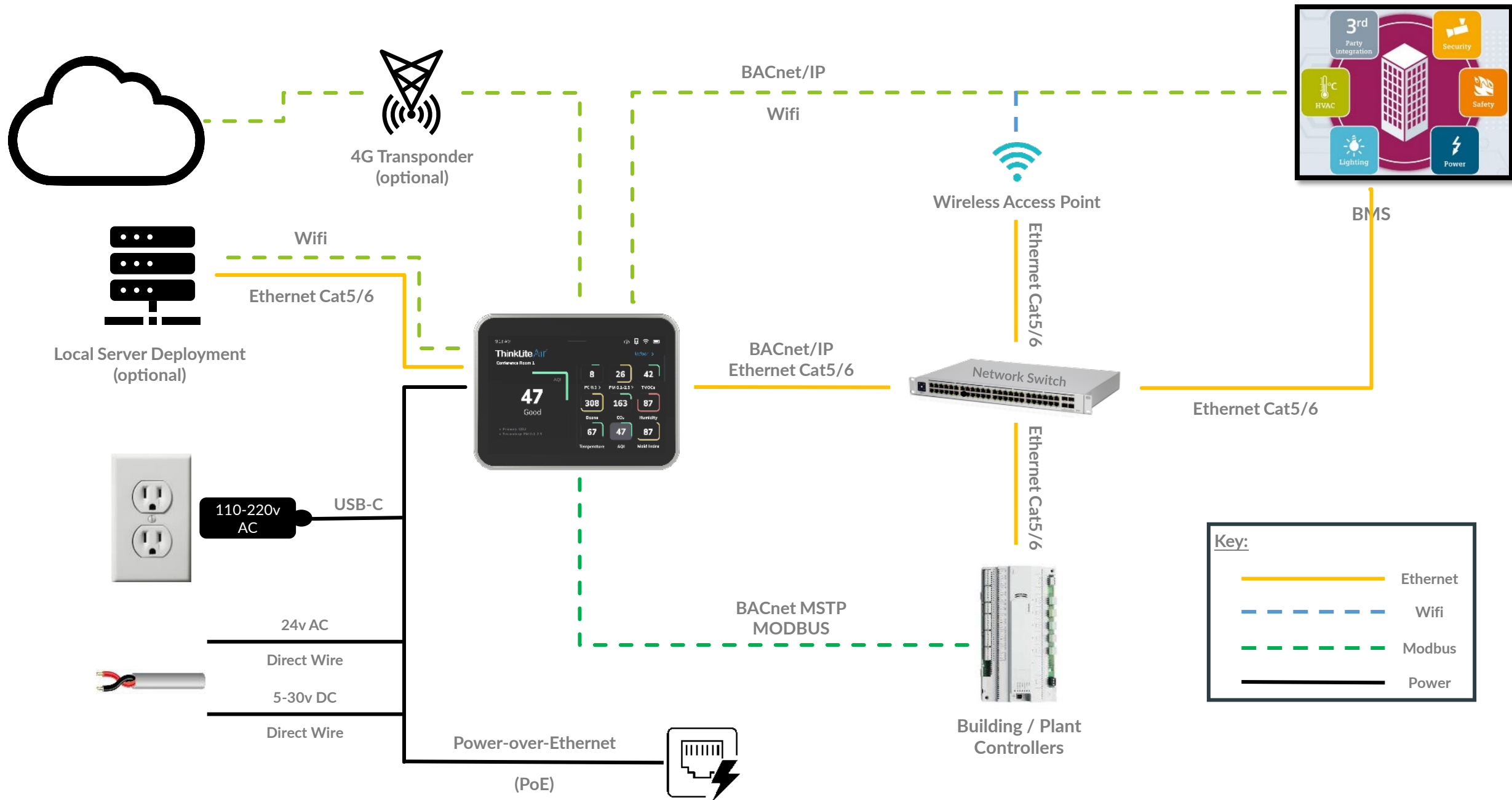
- Identify stakeholders
- Determine budget
- Agree on sensor placement

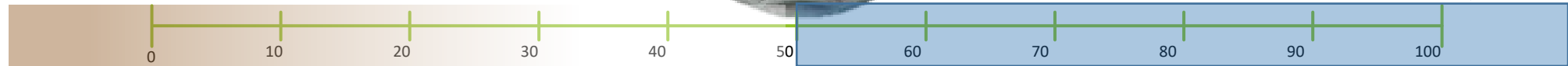
CONTINUOUSLY MONITOR INDOOR & OUTDOOR AIR



CALCULATE HEALTH IMPACT





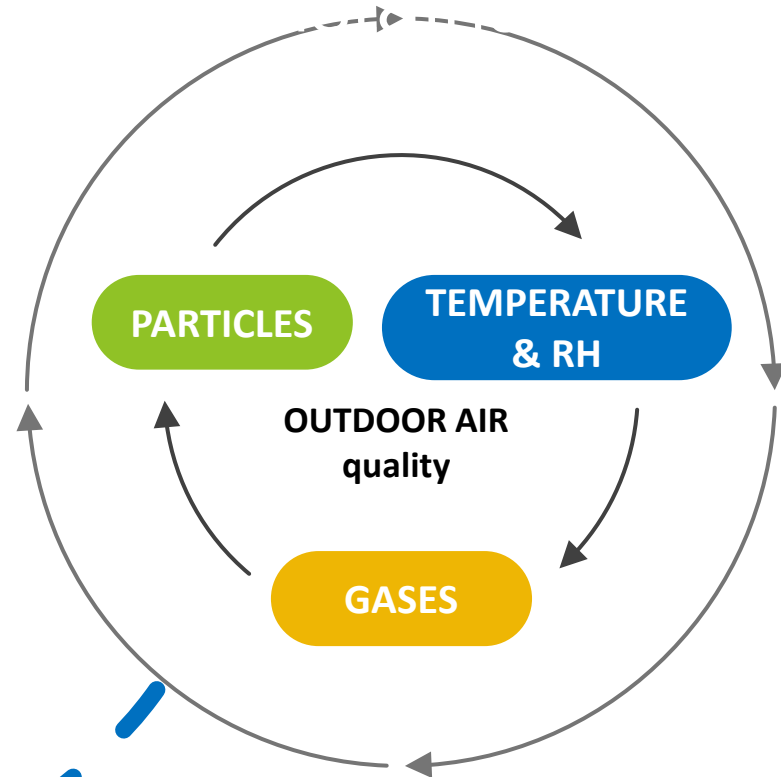
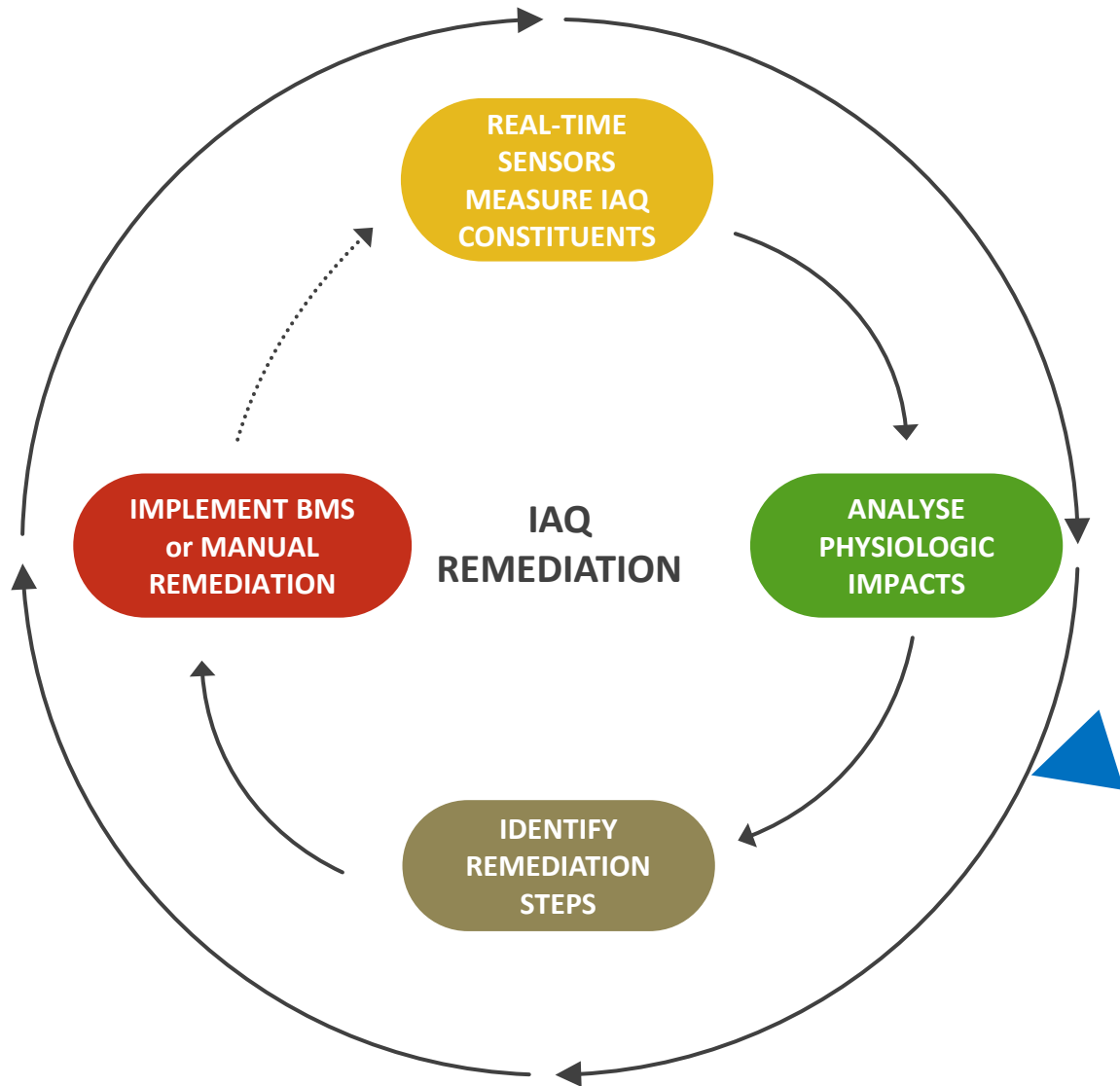


Reduce energy consumption

- Energy costs are immediate
- Decarbonization is a high priority

Manage IAQ for occupant health

- Decrease infections
- Reduce staff absenteeism
- Increase work performance



Outdoor air quality determines the most effective ventilation, filtration and air cleaning schedule

2025 report: HEPA alone did **not** lower the odds of *high* viral exposure, though it modestly reduced viral *diversity*. This argues against single-lever thinking.

Conclusions: Because multiple environmental drivers matter, **“multicomponent interventions are needed”** (e.g., combining filtration with maintaining 40-60% RH).

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Operating Room Suite Environmental Quality Improvement (EQI) Map



IAQ was comprehensively monitored and managed in operating rooms

- RH was kept between 35%-50%
- Ceiling obstacles were minimized to direct supply air over surgical and back tables

When OR IAQ was managed for patient safety:

- 87% Reduction in patient infections
 - 80% reduction in HAIs/liability payouts
 - Air change rates were decreased by 20%, saving significant energy
-
-
-

Post IAQ monitoring and remediation

Particles: ↓ 40–70%

- Reduced airway & vascular inflammation

Relative Humidity: Stabilized 40–60%

- Improved mucosal defense & immune response

CO₂: ↓ 300–600 ppm

- Improved cognition, ventilation, pathogen dilution

Health & Financial Response

Weeks 1–4:

- Fewer acute illness exacerbations
- Reduced admissions from ED

Months 2–6:

- Decreased Length of Stay
- Improved staff productivity

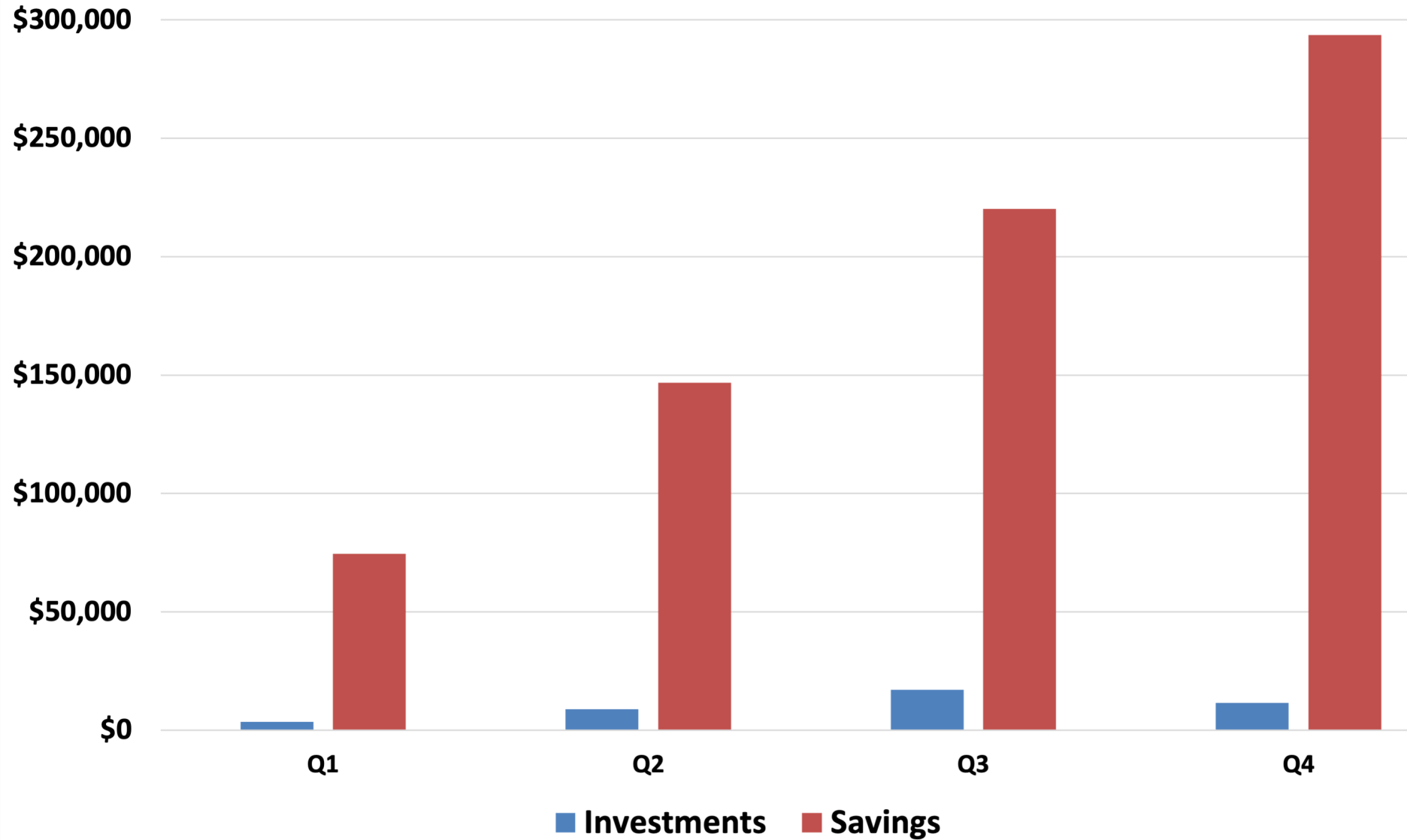
Months 6–12:

- Slowed chronic disease
- Durable cost stabilization

Payback Period

- Typical IAQ upgrade break-even: 6–18 months
- Faster (3–9 months) in ICU, elderly care, high-acuity facilities

Cost/Benefit Analysis of Improved IAQ in a Critical Access Hospital



IAQ Levers

Ventilation / ACH
CO₂, Particles, VOCs
RH 40-60%
Filtration upgrades

Health & Learning Mediators

↓ Absences (asthma, infections)
↑ Attention / cognition
↓ Headaches, drowsiness

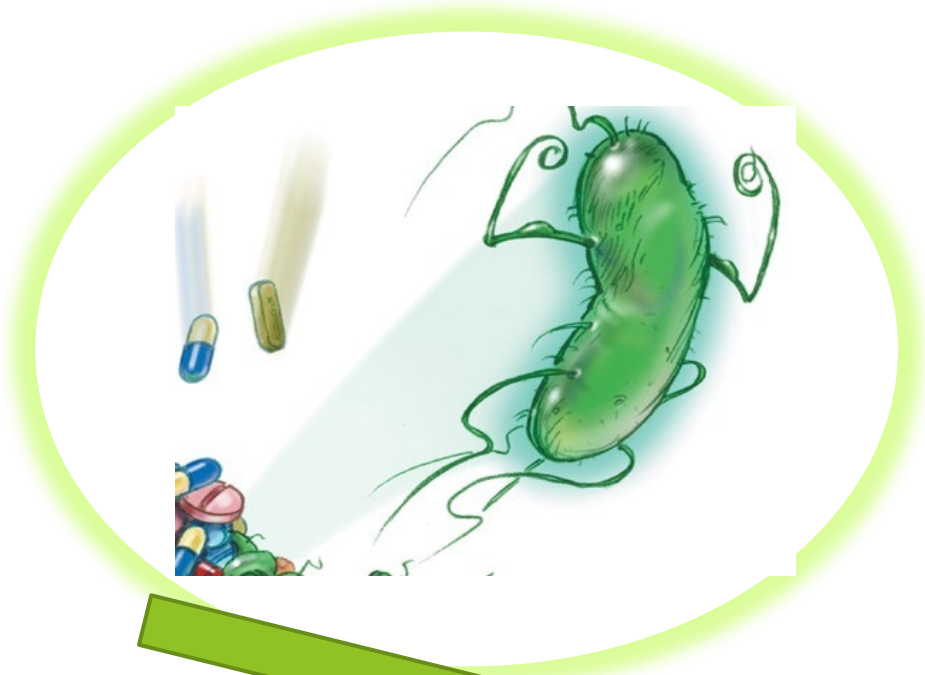
Academic Outcomes

↑ Test scores / growth
↑ Graduation & on-time promotion
↓ Failure & retention

Funding & Resources

Stable / ↑ enrollment
Better academic performance ratings
More grant & bond success

- 1-3% test score gain → higher rating tier
- 2-4% higher enrollment retention over 5 years
- Greater community support for levies / bonds
- Eligibility for performance-linked grants
- Each 1% enrollment retention in a 5,000-student district
≈ 50 students × \$12,000 = \$600,000/year preserved

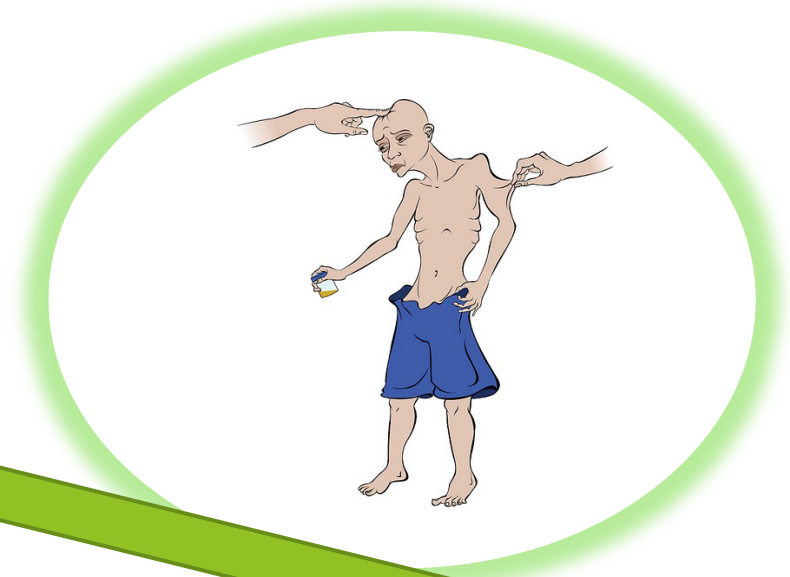


Increased pathogen strength:

- Enhanced transmission
- Increased infectivity
- Selection of “bad” over “good” microbes

Weakened humans:

- Impaired respiratory defenses
- Compromised immunity
- Damaged organs





Supports good microbes:

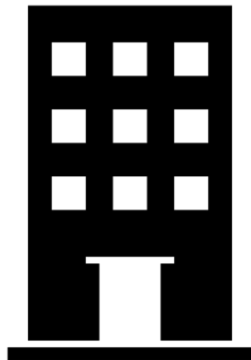
- Cleaner air environment
- Healthy microbial diversity
- Pathogens less infectious

Healthy humans:

- Decreased allergies
- Functioning immunity
- Optimal cognitive performance

The past

- Based on limited, STATIC DATA
- Scheduled HVAC run-times, resulting in unnecessary energy costs
- Unknown impact on occupant health



Energy



A better future

- Continuous Data Measurement
- Evaluate Impact on Human Health
- Manage to real time conditions
- Choose the most efficient options

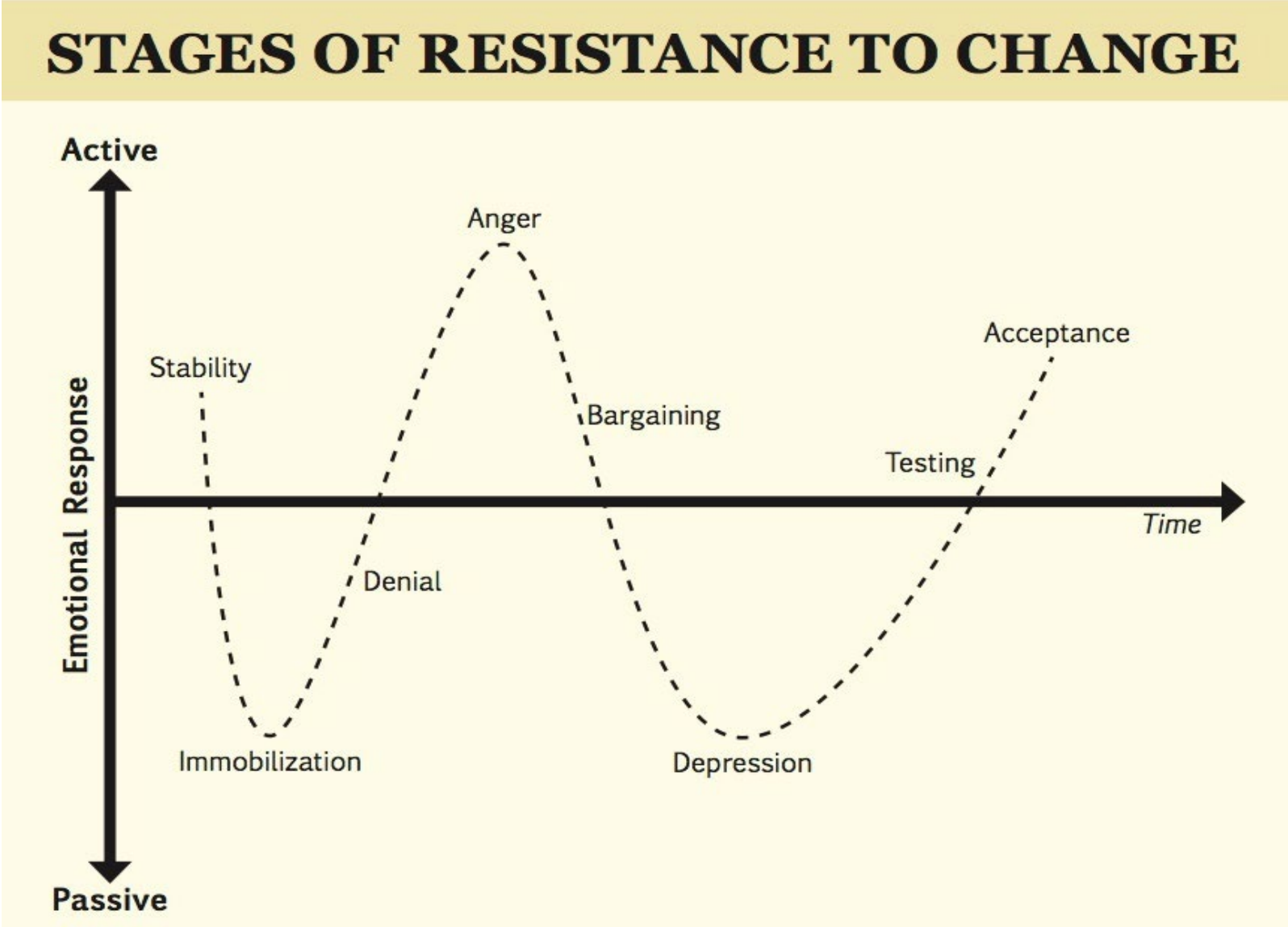


Energy
+
Health

Embrace change!



People resist and often choose to not even listen



2016 answer....



“[our work] is the design, specification, selection, installation, and operation of HVAC equipment. Research on IAQ and occupant health will suggest complex, esoteric, unproven ‘solutions’ to health issues that will not be helpful and ultimately have **little meaning to ASHRAE** members”.

Energy Dominates Facility Agendas

- ▶ Measurable, fundable, low-risk: Energy KPIs are universal
- ▶ Turnkey capital: Rebates, and decarbonization grants make financing easier
- ▶ Clear ownership: Facilities control energy; clinical outcomes live elsewhere

THE
SOURCES AND MODES
OF
INFECTION

BY

CHARLES V. CHAPIN, M.D., Sc. D.

SUPERINTENDENT OF HEALTH, PROVIDENCE, R. I.

AUTHOR OF "MUNICIPAL SANITATION IN THE UNITED STATES"

1916

An influential physician discounted airborne transmission of germs, and then the Spanish Influenza hit.....

”It will be impossible to teach people to wash their hands if they understand that the air is the chief vehicle of infection.

It will be a great relief to most persons to be freed from the specter of infected air.”



ASHRAE President
Bill McQuade



"Healthy Buildings:
Designing for Life"



IAQ Paradigms— The Next Generation

BY MAX SHERMAN, PH.D., FELLOW/LIFE MEMBER ASHRAE

ASHRAE’s Vision is “a healthy and sustainable built environment for all.” The “healthy” part of that vision primarily has to do with providing appropriate indoor air quality (IAQ). For the first century of ASHRAE’s existence, that meant determining and providing minimum ventilation rates. Over the last few decades, however, research both within ASHRAE and in the health community has shown us that the ventilation-only approach cannot always achieve the vision because of the diversity of sources and the potential contributions of other removal mechanisms. On the other hand, consideration of sources and their impacts can lead to improvements in both health and sustainability. This article covers the evolution from the first paradigm—ventilation rate—to the emerging harm paradigm, which has recently been enabled by some important research.

IEQ’s Future

Bridging Metrics and Health Outcomes

BY JOHN MCKEON, M.D., ASSOCIATE MEMBER ASHRAE

Indoor environmental quality (IEQ) has profound implications for health and well-being. This evolving field is crucial for shaping sustainable, health-optimized buildings of the future. The pursuit of healthier indoor environments remains paramount as we continue to innovate and refine our understanding of IEQ. As the field advances, there is an increasing recognition of the need to establish comprehensive standards that both assess and enhance IEQ, ultimately contributing to improved public health outcomes. This column provides a glimpse into the evolving field of IEQ metrics, highlighting the intersection of IEQ and human health.

"GLOBAL PUBLIC HEALTH LEADERS SIGN HISTORIC PLEDGE DECLARING HEALTHY INDOOR AIR A FUNDAMENTAL HUMAN RIGHT"



Please ask questions!

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