# The Indoor Microbiome: The Microorganisms We Live with

## Understanding and Maintaining
## A Guide for Owners and Occupants

# Table of Contents

# How many microbes does it take to make you sick?

The answer to this question depends on many factors, and not all microbes make you sick. In fact, life as we know it, would not be possible without microbes. Read on to discover some of the reasons why and what you can do to create and promote a healthy indoor environmental microbiome.

# Microbiology 101

**Contributors to the indoor microbiome:**

- **Bacteria** – single celled organisms without a nucleus (Procaryotes) that can be beneficial or harmful depending on genetic and environmental influences. They can replicate and metabolize without a host. They can be symbiotic, parasitic or pathogenic.
  - *Staphylococcus spp* – species are common and harmless on our skin but can be pathogenic when conditions are right.
  - *Escherichia coli (E. coli)* – gut bacteria can become pathogenic.
- **Virus** – a microscopic infectious agent, not a cell, which cannot replicate on its own and requires a host for multiplication and metabolism. Viruses are not considered to be 'alive'.
  - Can infect animals, bacteria (bacteriophages), fungi (mycoviruses), plants.
- **Fungi** – single or multi-cellular organisms with nuclei and membrane bound organelles (Eukaryotes) – includes molds, yeasts and mushrooms. They are considered decomposers but can be symbiotes, or pathogens.
  - *Aspergillus spp* – ubiquitous in environment, normally harmless but can cause pathogenic lung (and other) infections.
  - *Saccharomyces cerevisiae (*bread and wine) and *Penicillium roqueforti (*cheese) – food makers.
- **Other** – Archaea (single celled organism distinct from bacteria – some evidence indicating they play a role in the environmental microbiome; generally non-pathogenic).

# Good and Bad Microorganisms, *(Page 1 of 2)*

- **Commensals** – microbes that live in or on the body without causing harm and are often beneficial to the host organism
  - *Staphylococcus epidermidis (*skin)
  - *E. coli* (gut)
  - *Streptococcus mitis* (oral)
  - *Commensal virus and fungi ex needed*
- **Pathogens** – microbes that cause disease in animals and plants
  - *Salmonella* sp (bacterial food poisoning)
  - *Influenza* virus (flu)
  - *Aspergillus* spp (lung infections)
  - *Plasmodium* (protozoan that causes Malaria)
  - (bacteriophages can be pathogenic to bacteria; parasites are pathogenic but not likely to be in our indoor environments)
- **Colonization versus infection**
  - Microbial colonization – microbes live in or on the host without harm or triggering the immune system
  - Infection – microbes invade and cause harm, triggering an immune response
  - Ex: a patient can be colonized with drug resistant Staph (MRSA) without harm, but this same organism can spread to an
  - open wound on a different patient causing infection

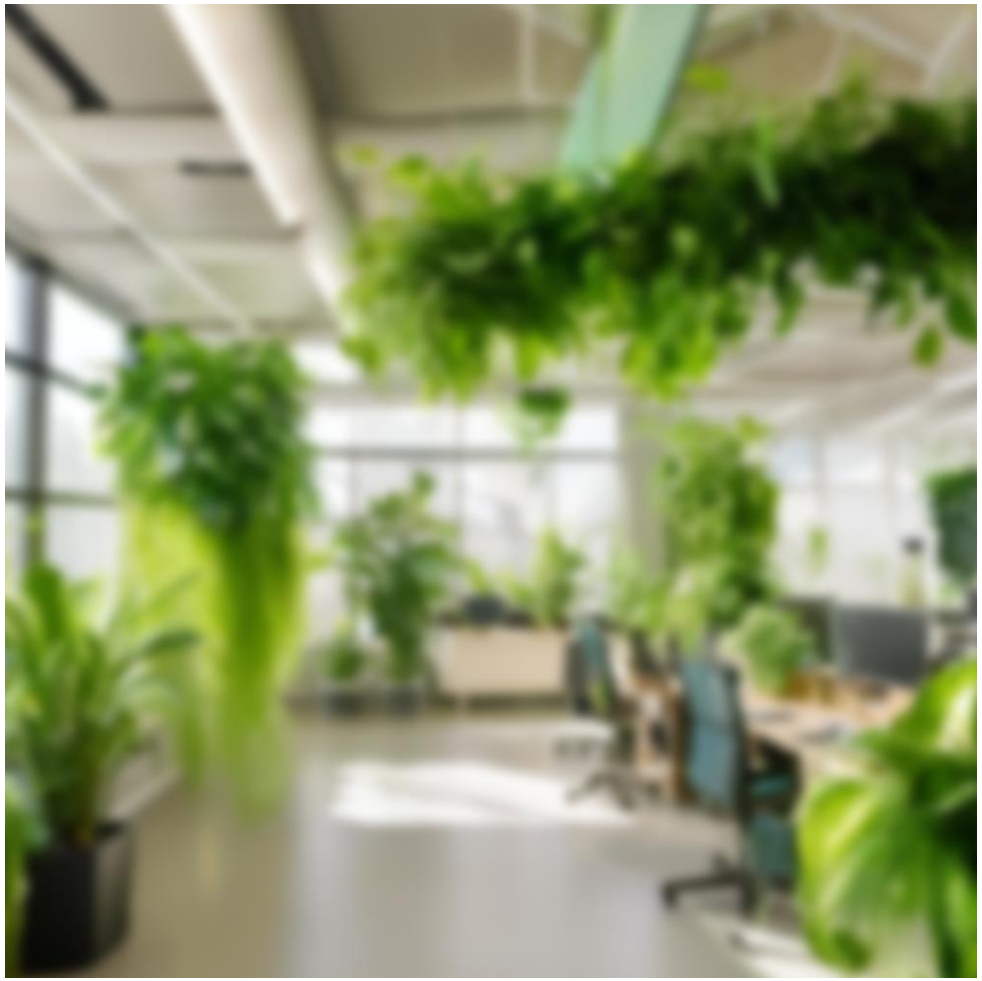
# Good and Bad Microorganisms *(Page 1 of 2)*

- **How and when does a commensal become a pathogen (opportunistic pathogens)**
  - Weakened host immunity (immunosuppressed)
  - Microbiome imbalance (antibiotics)
  - Injury or surgery (ex: common skin *Staphylococcus* contamination of surgical site incision or injury causing skin breach)
  - Environmental factors (ex: hospital stay)
  - Changes to the microbe (ex: genetic mutation resulting in increased virulence; good bacteria acquiring resistance genes)
- **Probiotics, prebiotics synbiotics, postbiotics**
  - Probiotics are beneficial living bacteria in the gut of animals such as *Lactobacilli*
  - Prebiotics are food for the probiotics and include inulin (ex: onions), oligosaccharides (ex: asparagus and dairy), pectin (fruits)
  - Synbiotics are a combination of the probiotics and prebiotics, ensuring the bacteria have the food they need to thrive (ex: yogurt with fruit)
  - Postbiotics are the beneficial byproducts of the probiotic digesting the prebiotic

# Commensals Become Resistant

- Why do antibiotics not work to resolve the common cold, flu or COVID? These are all viruses. Mechanisms of action of antibiotics will not disrupt or inactivate a virus.
  - Antibiotics kill bacteria.
  - Antivirals inhibit the replication cycle of the virus.
- Multi-drug resistance (MDR); extensively-drug resistant (XDR – resistant to more than 4)
  - MRSA and others (MDR)
  - *Acinetobacter baumannii, Pseudomonas aeruginosa, Klebsiella pneumoniae* (some of the worst hospital acquired) (XDR)
- Environmentally derived microorganisms vs. those that live on us and our pets
  - Outdoor soil, air and water harbor diverse populations that cross populate our indoor environments beneficially
  - Humans and dogs share some common commensals, such as *Staph* but also many distinct organisms, thus cross population by both increases the diversity of the built environment's microbiome
- There is copious evidence that cross population between indoor, outdoor, human and pets creates a highly beneficial, diverse indoor built environment that keeps the growth of individual microbiological species in check, resulting in better overall human health (Gilbert JA, Hartmann EM. The Indoors microbiome and human health. *Nat Rev Microbiol 22,742-755 (2024). http://doi.org/10.1038/s41579-024-01077-3)*

# The Probiotic Built Environment



- Indoor spaces designed and maintained to promote beneficial microbial communities *(Gottel et al. 2024)*
  - Natural materials – such as wood
  - Exposure to outdoor environments, green spaces and good ventilation
  - Avoid over-sanitization
  - Maintain humidity and temperature ranges

# Exposure Pathways

- Respiratory system – good and bad
  - Lungs
  - Nose, ears, eyes
- Digestive system – good and bad
  - ingestion
- Skin breaches – bad
- Eyes - bad

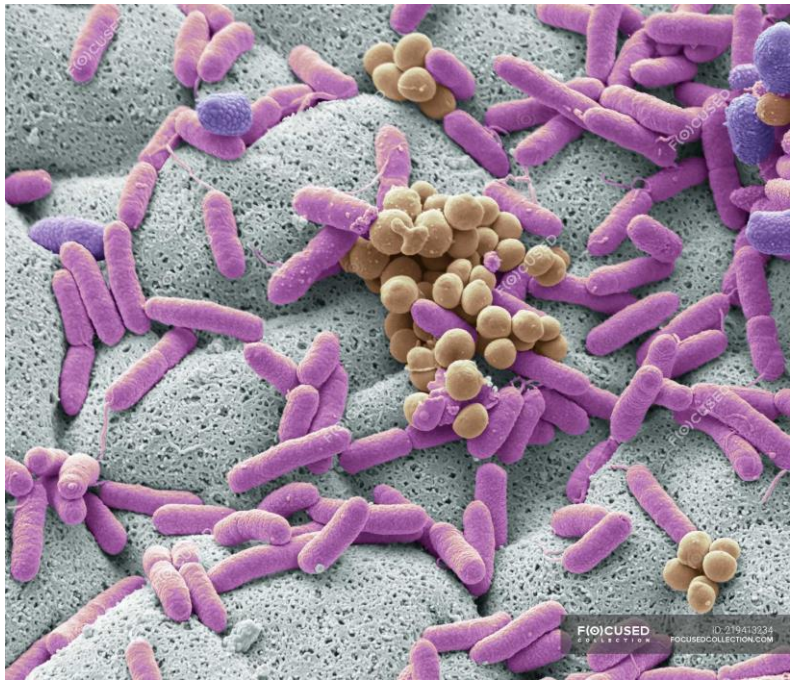
# Exposure and the Human Immune System

- Autoimmune disease
- Mental health disorders – anxiety and depression
- Asthma and allergy
- Metabolic disorders – obesity
- inflammation

- Beneficial exposures, symbiosis, and health promotion

- Did you know there is some evidence that bacteriophages (viruses that infect bacteria) exist in our blood streams and help our immune system fight off bacterial blood infections?

# The Human Microbiome




- The collection of microorganisms that live in and on the human body. Recent research suggests there are approximately as many bacterial cells as human cells in the human body (Sender et al 2016).

- Very diverse and dynamic
  - Diversity promotes balance
- Based on genetics, diet, lifestyle, environment, interactions with other animals etc.

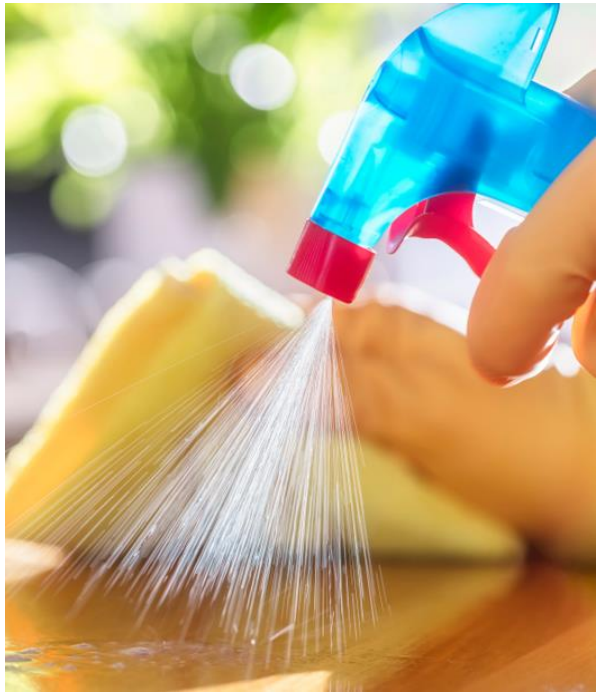
- Microbiomes vary across species and each species has a signature collection (or core groups) of microbes
  - Vary based on the basic functions needed to maintain health
    - Cows microbiomes specialize in breaking down plant fibers
    - Lions microbiomes specialize in breaking down proteins
  - Significant variance due to genetics, habitat, diet and evolution

# The Environmental Microbiome

- The diverse community of microorganisms found in natural and built environments
- Soil, water, air and surfaces
- Essential for nutrient cycling and ecosystem stability
  - Soil microbiome decomposes organic matter and regulates the carbon and nitrogen cycles
  - Built environment microbiome consists of organisms on surfaces, in water and in the air
    - Internal generation and external influence
    - *Staphylococcus*, *Aspergillus*, flu, bacteriophage
- The indoor and outdoor microbiomes do mix. Air is fluid and brings outdoor microorganisms into the indoor environment. Microbes also enter the indoors on shoes, clothes, pets, and plants. It is important to promote this diversification of the indoor microbiome.

# Human and Environmental Microbiome Interactions

- Constant interaction that influences each other both directly and indirectly
  - Air, water, surfaces, food
  - Natural and build environments
  - Microbial exchange
    - Shedding of skin cells and hair exposes the environment to the human microbes
    - Soil and water contact exposes the human to the environmental microbes (some can colonize the human)
    - Indoor air contains human/animal microbes which can become concentrated. Ventilation introduces diversity
    - Food and water introduce microbes to the gut microbiome. Fermented foods (yogurt etc.) introduce beneficial microbes
  - Disinfection and sanitation
    - Reduces diversity allowing for resistant organisms to become more abundant
    - Reduces the ability of the immune system to become familiar with the diverse microbiome when each individual species quantity is checked



# Biofilm

- A structures community of microorganism that adhere to a surface and collectively produce a protective matrix of extracellular polymeric substances.
  - Proteins, poly saccharides, DNA
  - Defense from environmental stressors such as disinfectants, antibiotics and the immune system
- Biofilms form in pipes, on teeth, on medical implants
  - Can be very difficult to remove
- Beneficial biofilms
  - Bioremediation, nutrient cycling – break down pollutants or cycle carbon, nitrogen and phosporus
  - Fermentation – used in food production
  - Probiotics – help to outcompete the harmful organisms
  - Plant growth – prevent harmful plant pathogens from causing disease

# How to Promote a Healthy Environmental Microbiome

- Goal: Reduce harmful microbes while preserving beneficial diversity
  - Remember most beneficial or commensal microbes can become pathogenic in the wrong conditions
- Understand the cleaning processes
  - What products are used and how often?
  - Is there balance?
  - Targeted cleaning v blanked sterilization
  - Mild, biodegradable cleaners regularly
  - Disinfect only when necessary (after illness, in hospitals, in kitchens
  - Avoid antibacterial and antimicrobial soap (the surfactant is sufficient to kill the microbes, antibiotics are not necessary in most cases)
  - Consider probiotic-based cleaners (though less main-stream)

# The Tools We Use to Measure and Monitor the Environment

- **Periodic monitoring**
  - Portable monitors used by a technician to collect and report data periodically - yearly, monthly
- **Continuous monitoring**
  - Installation of monitors that collect and report data continuously - hourly, daily
- **Air Quality monitors**
  - Measure CO2, CO, VOCs, particulate (PM2.5, 5.0; 0.5mm-10mm), formaldehyde and others
- **Humidity and Temperature**
  - Thermometer, hygrometer
- **Ventilation and Airflow**
  - Anemometer
- **HEPA filtration** removes 99.96% of microbes and particulates in the air. This is sufficient for reducing overcrowding and promoting diversity within the environmental microbiome
- **Alternative methods to indoor air purification** include ionization, UV, hydrogen peroxide, Ozone etc.
  - Refer to the ASHRAE Epidemic Task Force, CDC and EPA


- Environmental qualities ⇄ microbial populations

# Additional Resources

For more resources related to this guide, including References and Common Myths, visit the Microbiomes topic page with IEQ Resources on ASHRAE.org.