The great indoors

Our homes, offices and even gadgets are teeming with microbial life, but is it the kind we want? Ecologist **Jessica Green** tells **Amy Maxmen** why it's time for designers and architects to consider the ecosystems that thrive in and on their creations

You began your career as a civil engineer. How did you come to study microbes?
When training as an engineer, I was applying fractal mathematics to model patterns of plant diversity. I was trying to answer questions in conservation biology, like "If you chop down a portion of the rainforest, how many species do you expect to lose"?

In 2001, a researcher in Australia asked if he could use these mathematical theories to make predictions about microbes in soil cores, and I ended up collaborating with his team. Microbes have remained interesting to me ever since. Even though they make up the majority of the tree of life, so little is known about them. And the more I learn, the more I realise how critical they are for the ecosystems they are associated with, and for our health.

Do we need to be proactive about conserving microbial diversity?
We don't know yet. I've heard colleagues say that deliberate conservation is not important because microbes are so ubiquitous and redundant in the environment. Then others advocate microbial conservation, arguing that if certain species go extinct, it could have major implications for the ecosystem or for human health. For example, some strains of *Helicobacter pylori*, the bacteria known to cause stomach ulcers, are now endangered. Microbiologist Martin Blaser at the New York University School of Medicine has found some evidence that people may be more prone to asthma and obesity without them.

Can we create optimal environments for the microbes that are important to our health?
That's not clear yet. I advocate not being in the dark and consciously building our indoor environment. As the planet gets hotter, we are going to design and operate buildings differently from the way we do now. We spend 90 per cent of our time indoors, so we should start trying to understand how design affects the biology within buildings. I don't just mean pathogens, but the entire microbial community indoors.

Then as we learn about the microbiome and human health, we can combine that information to make mindful choices about who we live with inside. Right now we are not at a point of making links to health or making suggestions on design choices. We are raising awareness that designers unconsciously promote these invisible DNA cities.

You investigated the microbial make-up of a building at the University of Oregon. What did that reveal about its indoor ecosystems?
We found that microbes vary depending on a structure's form, organisation and function. For example, bathrooms, classrooms and offices vary in their microbial content, and how the designer puts the rooms together makes a difference: spaces that are closer together have more similar microbes than those that are farther apart.

So, offices may be organised to encourage people along a particular corridor to exchange ideas with each other more often than with people across the building. But we found that people aren't just exchanging ideas when their offices are close together – they are exchanging microbes too.

How much does it matter if windows are open?
Microbes do vary depending on the type of ventilation. Offices on one side of the hall were ventilated with natural air through windows, while the other side had mechanical ventilation. Designers originally did this so that faculty could decide whether they wanted air conditioning or fresh air in their office. In the mechanically ventilated rooms, we found that there was a lot of *Deinococcus* bacteria, some of which are notoriously robust in extreme conditions like desiccation and

PROFILE
Jessica Green is an engineer, ecologist and co-director of the Biology and the Built Environment Center at the University of Oregon in Eugene. She explores the transmission of beneficial microbes among urbanites in the forthcoming graphic novel, *Cities Unseen*

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It's impossible to tell from the photo, but Jessica Green stands in the midst of a microbial cloud

UV rays. The rooms with windows contained more *Methylobacterium*, bacteria commonly associated with plants and soil.

How did changing ventilation alter the microbial make-up of a room?
In four classrooms, we left open louvres that let in outdoor air and shut off the mechanical ventilation; in another four rooms, we closed the louvres and turned on the mechanical ventilation. We then sampled every day for eight days and found that in the naturally ventilated rooms, microbes indoors reflected changes seen in the microbes outdoors; there was a lot of flux in airborne bacteria. In the rooms with mechanical ventilation and closed louvres, microbial diversity remained stagnant. This is important to think about because we know that air turnover is important to air quality and naturally ventilated rooms are cheaper to operate.

Tell me about your investigation into how ventilation can make a difference in a hospitals.
In an initial study we found that hospital rooms with mechanical ventilation contained more airborne microbes common to the human mouth or skin, whereas rooms with open windows had more microbes associated with plant leaves and soils. We also compared the DNA sequences of the bacteria we found with sequences from known bacterial pathogens such as *Staphylococcus haemolyticus*. On average, the DNA sequences from the mechanically ventilated rooms were more closely related to those from pathogens. So although we don't yet know for sure which type of ventilation is better or worse, I would prefer to be in a room with open windows.

"People don't just exchange ideas at the office – they exchange microbes too"

You are now studying our individual "microbial clouds". How do you go about doing that?
We are carrying out experiments to see how the microbes on and around us – our microbial clouds – are affected by temperature and relative humidity. To do this, we are using a climate-controlled chamber. Individuals shed their microbes just by sitting down in an environment. We suck up the airborne microbes with these little cones that have filters attached to vacuum pumps, and we also place Petri dishes around their chair to collect bacteria that sloughs off of them.

How much is my microbial cloud like that of people I live and work with?
There is evidence to suggest that we exchange microbes with each other and organisms in our living environment. My lab looked at the transfer of microbes among people playing roller derby, for example. We found that women from different teams have different skin microbes before the game, but after they came into contact with each other during the game, their skin microbes became mixed and homogenised across the teams.

How can we answer the big question about the way microbial diversity influences our health?
I'm studying this with fishes – zebra fish and sticklebacks. When I think of people moving in a building, I imagine fish moving in tanks. They are surrounded by microbes in the water just as we are surrounded by them in the air.

Now we are asking fundamental questions. When the fish are surrounded by a particular microbial community, which ones get into their guts? How does that change when you alter the temperature or the genetic make-up of the organisms? How does it change when the density of the fish in the tank changes from a single fish, to a few, to many? Also, we are looking at how the fishes' immune responses vary depending on the microbes they are exposed to.

You have said that one day we might design objects like smartphones to harbour beneficial microbes. How pie-in-the-sky is that idea?
It's reasonable to assume that the types of materials we design our products with influence the microbial communities that live on them. There are a couple of strains of bacteria that destroy the bacteria behind bad breath, and a recent study discovered a strain that may protect against acne. So I'm wondering if it would be possible to promote the growth of these "good" microbes on the objects and surfaces that we come into contact with every day.

A place to start learning about this would be to compare the microbial communities of products that have human-made attributes with more natural contraptions: a product that has more wood in it might be colonised by microbes naturally associated with wood outside, for example. If you find that those ecosystems are different, the next big question is which one is healthier. ■