

Ode to All Microorganisms on Earth – the Invisible-yet-mighty Teachers

“Ask not what your microbes do for you but what you can do for your microbes”

Inspired by the quote from President John F. Kennedy's famous call to civic action from his 1961 Inaugural Address

“What would the world be like without microorganisms?”

That was the question a Grade 4 student in Mr. Agar’s class at the Cayoosh Elementary School in Lillooet asked me at the end of our two-hour class visit. The community outreach was sponsored by Science World through the Scientists and Innovators in Schools program in March 2024 (unfortunately, this program was ended due to budget cuts in 2025). I was elated. In my 25 years of teaching at Thompson Rivers University and my volunteer visits to schools across BC over the past 15 years, no student had asked me this question before. For me, this is huge, and this means **HOPE**. So, my microbial friends, we can hope that if we continue to advocate for you – the invisible yet mighty microorganisms and your critical roles in our lives and ecosystem to children, starting them young – to foster a healthier and more positive attitude towards you, we can help turn the global, climate, and public health crises *Homo sapiens* – human beings – are facing around. Thanks to you, our overlooked and underappreciated microbial friends!

First off, I wanted to confess to you, my microbial friends. When I began training as a microbiologist from 1989 to 1999, I did not have such an appreciative attitude towards you either. I can only speak for myself, but I often looked at and treated you merely as the subject of my studies. My utmost sincere apologies.

Humans have many blind spots. One of them is the fact that we cannot see you naturally. Unfortunately, we don’t appreciate what we cannot see. Because of this, we often think of you as afterthoughts or not important – the invisible means to our end? This has to change.

Over the past 15 years, I have continued to volunteer in schools to advocate and be an agent of change – I want to give you the good name you deserve. I want to be a contributing participant in honoring and celebrating your roles and tremendous capacities. You are the masters of adaptation. You have adapted and evolved on the Earth's historical time scale that our human perception cannot even comprehend. Heck, your ancestors – the first single-cell bacteria/the precursors were estimated to have emerged around 3.5 or 4 billion years ago (and my friends, that is the math of 9 zeros – 4,000,000,000 years). You are my heroes. You, who not just survived, but adapted and thrived as Earth transformed from a far more inhospitable world. I will just go a bit further to refer to you as our ancestors, knowledge keepers, and ultimate teachers.

If our species is to claw its way out of all the crises we created from disrespectfully treating Mother Earth and nature, we will need to rely on you and your collective wisdom (Rappuoli et al., 2023; Cavicchioli et al., 2019).

Despite your invisibility, unconventional cuteness, and bad press, I think highly of you. I think highly of you, even though you are invisible, not visibly cute or cuddle-able; on top of

everything else, we call you names, and plague you with bad press. Our species has an out-of-sight, out-of-mind mentality about you. Not many people pay kindness or just attention to you, our friendly microbes, despite how many actionable services you provide to our species and ecosystems.

How many people really know and appreciate that only 1% of the microbes we know of make us sick? The remaining 99% of you are at work on behalf of all life on Earth. Moreover, we are learning that likely less than 1% of all microorganisms on Earth have been discovered (Jensen, 2025).

There are countless reasons why we do not know more about you. This is not your doing at all. It is not like you are hiding. It is us, we are rather inept as we are not that smart. We lack effective ways to learn from you. Only 1% or less of you can be grown in the lab, and we have not yet learnt how to study you in your own community and home. We try our best to simulate the homes where you have lived and adapted for the past 3.5 million years in artificial labs. On top of that, we study you individually as we have no capacity to interpret your relationship in your community with your friends and/or your foes. It is no wonder why we could not discover you in the lab. Hence, you, our microbial friends, have recently been dubbed “Microbial Dark Matters” as we still have lots to learn from you. You are our mystery.

When you are at work, you do so tirelessly and without resentment. You make oxygen for all life on Earth. You also facilitate the communications between animals, plants, and the ecosystem by making chemicals that function as language between species. Your fungal networks hold ecosystems together - check out the research dubbed the “wood wide web”. You are also the world’s best recyclers – you break things down, recycle, and transform nutrients back and forth between Earth, life, and environments (Cavicchioli et al., 2019). The nutrient cycles cannot continue without you.

Your virtues mentioned above are just the tip of the iceberg; I did not even go into the fact that you have a wide variety of incredibly useful genes that are the foundation of all food webs, degrading pollutants, fixing the unusable forms (atmospheric nitrogen gases) of nitrogen to the usable ones (ammonia and nitrate) for every life on Earth. We need you.

Let’s put this more into the perspective that we humble humans can understand. If we compare the amount of total DNA (size of our genomes) and the percentage of protein-coding genes between humans and bacteria, only 1-2% of our human genome is protein-coding genes, while 85-90% of yours are protein-coding genes. This estimated statistic alone is astounding, isn't it? Yet, you are so tiny – and we are about a million times larger than your typical size. My human friends – that is a 6-zero scale! The funny thing is that in human languages, we even have a popular saying, “good things come in small packages,” and this just reminds me of you, my microbial friends. Although you are tiny, you are versatile, adaptable, strong, effective, and capable.

Okay, so now let’s shift to some information that is closer to home – when you are at work in and on our body, what do you do? First, let us look at how many microbial friends we have in and on us every day of our lives to make us healthy. Scientists estimate the total number of bacteria in

the 70 kg "reference man" to be 38 trillion cells (Sender, Fuchs, and Milo 2016). Wait, how many zeros are in "trillion"? We are talking about a 12-zero scale. So basically, scientists estimated that the studied adult man with a 70 kg weight has 38,000,000,000,000 microbial cells in his body, which is estimated to have 30,000,000,000,000 human cells. That is an almost 1:1 ratio (exact number is more like 1.2667:1). Well, my human friends, this number shows us how important our microbial friends are.

If microorganisms were not critical to our health, then why, over the 300,000 years since our species first emerged in Africa (dated with the earliest fossil record - Stringer, 2016), did we get not rid of you from our body? We have plenty of time to adapt to do so. Then, can I boldly say that we cannot live without you? We are an ecosystem; we must be together, and we need to treat you well with utmost respect.

Let us break it down for our human friends as to what you really do when you live in and on us. You help us digest food, bring about nutrients and balance, and you make essential vitamins like vitamin K for us. Having you on our skin, in our gut, and in our important organs help us ward off the bad bacteria (the less than 1%) that could make us sick. You also train our human cells associated with the immune system. Actually, there are more things you do to make us healthier that we do not know yet. Recently our scientists found some links about your connections to our mental health and some complex syndromes and diseases (Ogunrinola et al., 2020; Hou et al., 2022).

Previously, we thought the gut-to-brain connection and communication was a one-way street. But in learning more about our microbiome (total microorganisms in one habitat), we have uncovered it is more of a two-way street. Our gut is another brain through you and your actions. You keep us sane, literally and actionably. Of course, you can teach us more about the 1% of the bad microbes, too, but I still strongly believe that instead of thinking more about getting rid of the bad ones, humans should focus more on getting to know and having a healthier relationship with the good ones☺ We need to be open to letting you teach us, too.

Oh, wait, I haven't credited you for what you do for our species in the food, agricultural, and industrial scenes. I will make a long story short. You help us preserve our food through fermentation. You make lots of beverages (alcoholic and non-alcoholic), proteins, enzymes, chemical solvents, antibiotics, and many more (Rodríguez-Frías et al., 2021). You are the human civilization shaper; you shape who we are. Can I call you lovingly as our creators?

Our species often forgets that we are a part of nature. We constantly want everything faster and more convenient. We forget the essence of living together harmoniously. We overlook that all life is inextricably connected with microorganisms, the fundamental units of life that connect us all. ***We are of nature.*** The conceptual diagram in Figure 1 below illustrates the intricate interconnection between the health of human beings, animals (both wild and domesticated), and the environment, with the presence of a continuum of microorganisms.



Figure 1. One Health and Microorganisms diagram – how microbes substantially connect all life on Earth and the very ecosystem we live in. (Couradeau et al., 2025)

So, my human friends, after this crash course in microbiology, what would your answer be if you were asked by the Grade 4 girl from Cayoosh Elementary School? “What would the world be like without microorganisms?”

If I asked our microbial friends, the answer is obvious: we would not be here and have nothing without microbes. There would be no hospitable world as it is today.

As a microbiologist, I have at times felt like a second-class biologist, researcher, and educator. Many important discussions have been arranged locally, nationally, and internationally about human crises, including climate, biodiversity loss, global and public health, and so on. Disappointingly, microbiologists are often not invited to the table. It is puzzling – is it because we did not do a good job of educating our species on how critically important our microbial friends are? We need to do better with microbiology literacy and education.

I commit this lifetime to be your advocate and ally, my microbial friends – to help rightfully show off your selfless service to all life on Earth and to the planet itself, to share how beautiful you are even though we cannot see you with our naked eyes. For me, you are my ultimate teachers and kins – you are the vital proof that all life on Earth is related. I appreciate you, my microbial friends and foes, and I appreciate all you have done for us to be here. I will help one school child or university student at a time to appreciate you, too. You are my everyday hero!

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