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The Invisible majority: How microbes shape health, food and environment

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Abstract

Microorganisms are invisible to the naked eye, so everyday life appears to be free of them, yet they are present in our bodies, food, soil, and water. Although microbes are commonly associated with disease, most are harmless or beneficial. This article explores the hidden roles of microorganisms in everyday life, with a focus on health, food, and the environment. It first shows where microbes are found. It then examines their roles in the fermentation of foods such as curd and bread, in the human microbiome, and in the decomposition of dead organic matter, and their use in medicine and biotechnology, including antibiotics and industrial enzymes. It also considers their contribution to soil fertility and plant growth and their role in global carbon and nitrogen cycles. Overall, microorganisms are essential partners in human health, food production, and the balance of ecosystems, and recognizing their work changes how we think about the microbial world.

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1. Introduction

We don't see microbes, so our ordinary life seems microbe-free, but nothing could be further from the truth. Microorganisms are living organisms too small to be seen without a microscope and they are present almost everywhere around us and working constantly, whether we notice or not. The term “microbes” covers bacteria, fungi, archaea, protozoa, and microalgae, a diverse group that differs greatly in structure and lifestyle (Leonard and Toro, 2023). Despite this, most people associate microbes only with disease and refer to them as "germs." A few microbes do cause illness, but this is only a small part of the story. Many others help us digest food, make the food we eat, keep soil fertile, and recycle nutrients through the environment.

Over the years, humans have also learned to use microbes for beneficial purposes.

This article explores the hidden roles of microbes in everyday life. It begins by showing where microbes are found, then examines how they shape health, food, and the environment.

2. Microbes Are Everywhere: Where Microbes Live

People often ask, "Where are microbes?" but the better question is, "Where aren't they?" Microbes are found in almost every habitat we deal with, including our own bodies, our food, the soil, and the water around us. Like us, they live in communities, and they can survive in places where humans and many other organisms cannot (Wettstadt, 2022).

On and inside the human body: The human body is home to a vast community of microbes called the microbiome. Microbes live on the body where they interact with one another and with the host. The gastrointestinal tract contains one of the most diverse and abundant microbial communities in the human body (Human Microbiome Project Consortium, 2012).

In food: In several foods, microbes are intentionally used during production, particularly in fermentation (Marco et al. 2017). Their detailed role is explained in the next section.

In soil: Soil is one of the richest microbial habitats on Earth, and its microbes drive processes such as decomposition and nutrient cycling (Fierer, 2017).

In water: Oceans, rivers, and lakes are home to microbial life, including microalgae, which play a major part in global nutrient and energy cycles (Babich et al. 2022).

3. The Kitchen Connection: Microbes in our food

What we call breakfast; microbes often call fermentation. Many of the foods we eat every morning, such as curd and bread, exist because of microbial activity. Fermentation is a process in which microorganisms break down sugars and other components of food into products such as organic acids, gases, volatiles, and alcohol. These changes alter the taste, texture, and shelf life of the food, and they help us preserve food, develop flavor, and in some cases add nutritional value (Marco et al. 2017). Figure 1 summarizes two common examples.

Curd and yogurt: Curd forms when lactic acid bacteria, such as species of *Lactobacillus* and *Streptococcus*, ferment lactose and convert it into lactic acid. The acid makes the milk sour and causes its proteins to thicken into a curd (Siddiqui et al. 2023).

Bread: Bread dough rises because of baker's yeast, *Saccharomyces cerevisiae*, which is a fungus rather than a bacterium. The yeast ferments sugars in the dough and releases carbon dioxide, and the trapped gas makes the dough expand (Cauvain, 2015).

Cheese and pickles: In cheese, microbial activity during production and ripening contributes to flavour and texture (McSweeney, 2007). In pickles and other fermented vegetables, lactic acid bacteria produce acid that helps preserve the food and some of these bacteria may also act as probiotics (Banik et al. 2023).

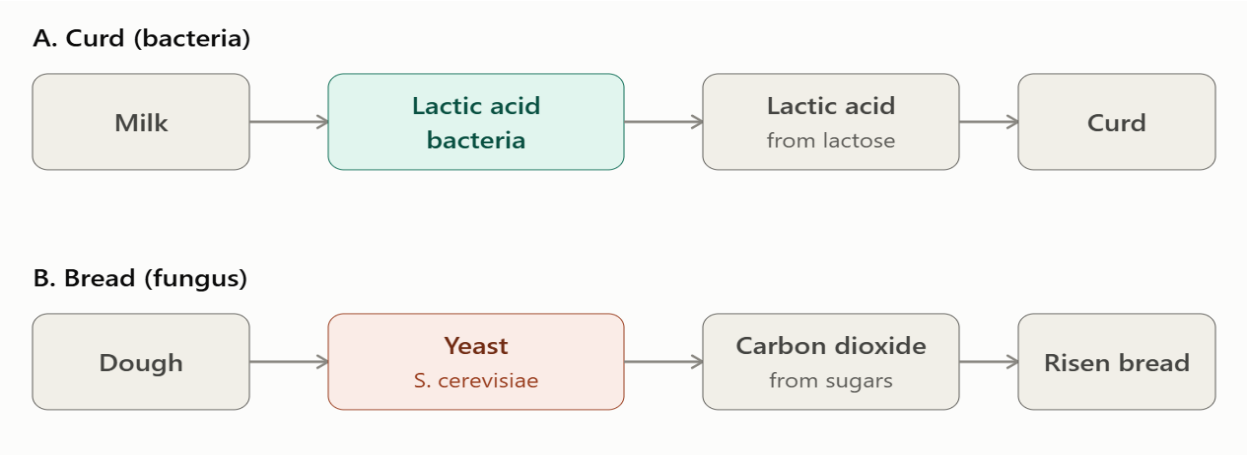


Figure 1. Fermentation of milk into curd by lactic acid bacteria (A) and of dough into risen bread by yeast (B).

4. The Roommates: The Human Microbiome

You are not living alone, as the human body hosts communities of microorganisms that live on and inside us, collectively called the microbiome. These communities interact with each other and with our own cells, and in most cases the relationship is cooperative. The microbes in one part of the body differ from those in another, because each site offers different conditions such as moisture, temperature, oxygen, and nutrients (Human Microbiome Project Consortium, 2012).

Skin: The skin is a dry, highly exposed surface, yet it carries its own community of microbes, which varies between body areas such as oily, moist, and dry regions. It acts as a physical barrier to prevent the invasion of foreign pathogens while providing a home to the commensal microbiota. (Byrd et al. 2018).

Gut: The gut, especially the large intestine, is among the most densely populated microbial habitats in the body. Its microbes help break down food components that our own enzymes cannot digest (Sender et al.2016; Thursby and Juge, 2017).

Mouth: The mouth is warm and moist, and it supports a diverse community of microbes that differs between surfaces such as the teeth, tongue, and cheeks (Ogunrinola et al.2020).

The microbiome supports digestion and the development and function of the immune system. These benefits depend on a balanced community, and changes in its makeup can have harmful effects (Ogunrinola et al. 2020).

5. The Clean-up Crew: Decomposition and Nutrient Recycling

Every day, fallen leaves, dead plants, and animal remain add to the organic matter on the ground and without a clean-up system, this material would pile up and the nutrients locked inside it would stay out of reach of living organisms, so, someone has to deal with the leftovers. Decomposition is the breakdown of dead organic matter into simpler substances. It is a significant ecosystem function that regulates nutrient cycling, soil fertility, and biomass production (Nie et al. 2024).

Bacteria and fungi are the main decomposers. They release enzymes that break down complex materials such as cellulose in plant litter, and they use the products as food.

As microbes break down organic matter, nutrients such as nitrogen are converted into forms that plants can take up, and part of the carbon is released as carbon dioxide. These nutrients return to the soil and are taken up by plants, which later become new leaves, so the cycle continues (Zhao et al. 2021) (Figure 2).

Decomposition therefore means a healthier ecosystem, because it keeps nutrients circulating instead of letting them stay locked in dead material.

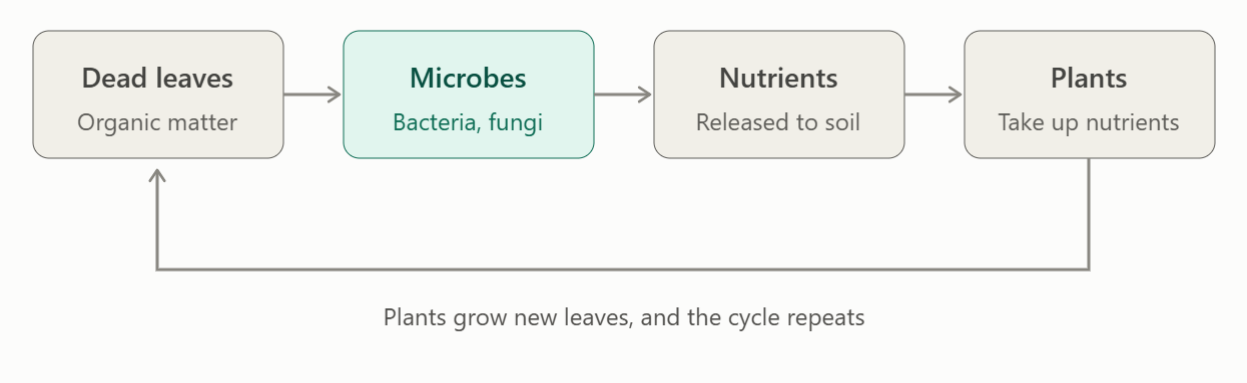


Figure 2. Decomposition and nutrient recycling. Bacteria and fungi break down dead organic matter and release nutrients, which plants take up to grow new leaves.

6. The Lab Assistants: Microbes in Medicine and Biotechnology

Over the last century, humans have learned to put microorganisms to work as sources of medicines, tools for research, and producers of useful substances. In simple terms, microbes are also recruited by humans for the benefit of humankind.

Antibiotics: Many important antibiotics originate from microorganisms, especially soil bacteria and fungi. A well-known example is *penicillin*, first described from cultures of the fungus *Penicillium notatum* (Fleming, 1929). Today, microbial compounds remain a major starting point in the search for new antibiotics (Hutchings et al. 2019).

Biotechnology: Microorganisms are also used in research, medicine, food production, and industry. Because microbes grow quickly and can be handled in the laboratory, they can be engineered to make useful products. A classic example is human insulin, which was produced in bacteria using recombinant DNA technology (Johnson, 1983).

Enzymes and products: Microbes are a major source of industrial enzymes, which are used in processes such as food processing and in detergents (Lewis et al. 2024).

We once called microbes "germs," now they have become partners in the way we make medicines and many everyday products.

7. The Farming Partners: Microbes in Soil and Agriculture

What looks like plain dirt to us is, in healthy soil, a living community. Just as people work in many different fields, the soil has its own workforce. Beneath every field and garden is a community of microorganisms that carries out work plants depend on.

Soil contains a very diverse community of bacteria, fungi, and other microbes essential to soil function and plant growth. One estimate suggests that 1 gram of soil

may contain 6000-50,000 bacterial species and up to 200 m of fungal hyphae (Mishra et al.2016). Together, these microbes break down organic matter and release nutrients that plants take up, which supports plant growth (Fierer, 2017).

Nitrogen is essential for plant growth, but the nitrogen gas that makes up most of the air cannot be used by plants directly. Nitrogen can be lost to the atmosphere when microbes convert nitrates into nitrogen gas (denitrification), and it re-enters the cycle through nitrogen fixation. Some of these bacteria live in nodules on the roots of legumes, where they exchange fixed nitrogen for nutrients supplied by the plant (Guo et al.2023).

Microbes living in and around plant roots, including bacteria and mycorrhizal fungi, can also support plant growth, for example by helping roots obtain nutrients (Guo et al. 2023).

The Planet-sized Job: Microbes and Global Balance

The workplace of microbes is bigger than our home. The tiny organisms we met in the kitchen, the body, and the field also work at the scale of the whole planet, helping keep the Earth in balance. Elements such as carbon and nitrogen move continuously between the air, water, soil, and living organisms, and life depends on this movement (Hallin and Bodelier, 2020).

Carbon: Microbes release carbon dioxide when they respire and decompose organic matter, while photosynthetic microbes, such as microalgae and cyanobacteria, take carbon dioxide up and convert it into organic matter, so carbon moves between living things and the atmosphere (Hallin and Bodelier, 2020).

Nitrogen: Microbes carry out the main steps of the nitrogen cycle, converting nitrogen between forms. Some microbes fix nitrogen gas from the air, while others convert nitrogen compounds into other forms, so nitrogen stays available to plants and other organisms (Kuypers et al. 2018).

Recycling nutrients: Decomposition returns nutrients to the system so they can be used again. For example, photosynthetic organisms take up nitrogen and phosphorus from seawater, and when they die, microbes decompose them and release these elements back into the water. Without this recycling, nutrients would stay locked in dead material and become unavailable to living organisms (Falkowski et al. 2008).

All this work is done entirely out of our sight, yet microbes are crucial for balancing the planet.

Conclusion

Microbes are a workforce that we rarely notice, yet they shape almost every part of daily life. As this article has shown, they live on and inside us as part of the human microbiome, turn milk into curd and dough into bread, break down dead matter so nutrients can be used again, support healthy soil and plant growth, and help keep carbon and nitrogen moving through the planet. Humans have also learned to put them to work as sources of medicines and as tools in biotechnology.

This does not mean that every microbe is a friend. A few causes disease, which is why hygiene still matters. But disease-causing microbes are a small part of a much larger story and seeing microbes only as “germs” hides most of what they do for us.

Microbes were never the problem; they were the workforce we failed to notice. There is still much to learn about their roles, so the case remains open.

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