Prompt: Microbial life can easily live without us; we, however, cannot survive without the global catalysis and environmental transformations it provides." Do you agree or disagree with this statement?

Across 3.5 billion years, microorganisms have shaped the Earth to make it habitable for plants, animals, and humans (1). Beyond orchestrating the Great Oxidation event that significantly contributed oxygen to the atmosphere (1), microbes regulate global biogeochemical cycling, which keeps our planet's system in a relatively stable environmental state (2). Alongside microbes, humans have had a profound impact on Earth due to our superior intellectual and communicative abilities, which are unique to our species. The emergence of the industrial revolution has made mankind "major players in Earth's geochemical cycles" (3), and has allowed us to dominate the biosphere with remarkable scale through the appropriation of various ecosystems (4). Our continued technological advancement has also allowed us to manipulate biological entities to create artificial systems and decrease our dependence on nature (3). This paper will discuss how microbes and humans may be capable of living without one another, while also examining why a world without microbes would significantly reduce our quality of life.

Microbes do not need humans

Microbes are resilient and can survive in environments inhabitable by humans. Constantly evolving, the Earth we know today is vastly different than when microorganisms first emerged. The planet experienced massive bombardments and large impacts that had the potential of killing all forms of life (5). For instance, it is believed that the early Earth was once hit by a meteor, creating a period of time with extremely hot surface temperatures, nearing 100° C (5, 6). However, there is geological evidence of microorganisms, such as hyperthermophiles, that withstand these conditions (5), thereby demonstrating the robustness of microbial life. Today, we continue to observe microbes that can thrive in other extreme environments, such as deep ocean sediments, artic soils, and acid mine drainage (7, 8). In addition, microbes are able to produce and consume various metabolites, including peptides, complex carbohydrates, and antibiotics (7). This allows them to cross-feed and further establish themselves in highly specific niches, where they can ultimately maintain their existence (7).

The predominance of microbes throughout Earth's geological history is in part due to their simple structures, size, and metabolic diversity (9). These attributes enable them to resist various environmental conditions, such as pH, salinity, and temperature, that are otherwise lethal or toxic to vulnerable species, like ourselves (9). Unlike humans, prokaryotes have very few structures and mainly consist of DNA, RNA, lipids, and/or proteins (9). Some microbes also have a rigid cell wall that protects them from environmental trauma or engulfment by prey. Over evolutionary time, microorganisms have also kept their size relatively small (9). This property allows for efficient uptake of nutrients and release of wastes, which by comparison, energetically outcompetes eukaryotes (9). Furthermore, microbes can exploit various energy sources and utilize a range of electron acceptors for metabolism (9). For instance, about 2.5–2.3 Ga ago, atmospheric oxygen accumulated rapidly, causing previously insoluble uranium to dissolve into different bodies of water (7). Despite the high abundance of radioactive uranium, it was determined that some bacteria were found capable of sustaining such conditions by oxidizing uranium and using it as an electron acceptor during respiration (7). Given their structural simplicity, small physical size, and metabolic diversity, it is evident that microbes are adaptable to many environmental perturbations and undeniably capable of living without us.

Without microbes? Surviving, but not thriving

If all microbes on Earth were to suddenly disappear, would human life still exist? Yes. This hypothetical scenario has been previously investigated by Gilbert and Neufeld (10). In the absence of microbes, specifically *Rhizobia*, the fixation of atmospheric dinitrogen to form nitrate needed by plants, would disappear (10, 11). However, humans can address this issue by producing nitrate in the form of fertilizer through the Haber-Bosch process (10). This practice is currently being used across modern agriculture, given the already limited amount of fixed nitrogen produced by bacteria (11). In fact, with our growing demand for food, the Haber-Bosch process is currently responsible for approximately 45% of the total fixed nitrogen produced annually on Earth (12). Nonetheless, this example clearly demonstrates that humans are capable of manipulating systems, such as global biogeochemical cycling, and creating the necessary technology to fulfill our needs when microbes cannot.

With current technology available for synthetic nitrogen production, humans may amplify this process and distribute nitrogen on a global scale (11). In turn, though most oxygen sources would vanish in the disappearance of photosynthetic cyanobacteria, plants and algae are estimated to provide atmospheric oxygen up to 50% (10, 12). Photosynthesis continues and, therefore, without prokaryotes humans would still be able to breathe.

Moreover, humans can also solve the challenges involved in supplying food in order to survive. For example, through our advancements in food technology, we can now make synthetic meat using cow stem cells (13).Vitamins, antioxidants and other building elements for artificial foods can now be synthesized using nanotechnology (14). Other nutritional compounds can also be made, potentially through recombinant biotechnology with yeast as a surrogate host on a more extensive scale (10). Hence, with proper implementation of technologies, humans have the capacity to provide solutions and survive life without microbes.

Humans – better with microbes

Although human life can exist in the absence of microbes, global recycling of elements necessary for the continuation of life would eventually cease (10). Though we may be able to supply nitrate for plant growth, allowing for agricultural food production to proceed in a microbe free world, without the ability to recycle the nitrogen, significant amounts would no longer be regenerated – largely remaining stagnant as buildup on the ocean floor (10). Secondly, as a consequence of continuing animal respiration and human fossil fuel use, CO_2 levels in the atmosphere would inevitably increase, leading to global warming through the greenhouse effect (10). Thus, without microbes driving the regeneration of essential elements, such as nitrogen and carbon, via global biogeochemical cycles, our oceans and soils would become unproductive (10, 15). Of note, phosphorus in the ocean would begin to sequester to sediments and negatively impact marine primary production (10). Although we may be able to solve this issue using emerging technology, a limited supply of phosphorus mines makes the sustainability of this system improbable (10). Thus, we must appreciate the microbial processes that maintain the global biogeochemical cycles and how microbes make it significantly easier for us to survive.

In addition to recycling the nutrients necessary for the continuation of life, microbes are responsible for breaking down wastes and environmental contaminants (16). Fundamentally, if not for microbes, our planet would be filled with dead organisms, animal wastes, and hazardous materials. Although some insects, protists, slime molds and fungi initiate biomass decomposition, bacteria and archaea are needed to complete this process (10). They are also suited to perform such tasks under anoxic conditions (i.e. anaerobic respiration, interspecies hydrogen transfer, and methanogenesis) (10). Additionally, due to microbes' small size, they are able to contact and degrade contaminants easily (16). In fact, the current use of microbes by humans is extensive – particularly through microbe-based solutions for waste remediation. For instance, when there is an oil spill somewhere in the world, we use oil-degrading microbes to clean up the contaminated area (17). Microbes are also routinely used to treat sewage, clean abandoned mines, and degrade a variety of industrial chemicals (18, 19). Without microbes, we would be living in a world practically buried in waste, and our quality of life would be significantly diminished.

Conclusion

Across 200 thousand years of human history, microbes have been the essential linchpin in enabling our species to create healthy, dynamic, and prosperous communities around the globe. Given the number of menacing events that dramatically impacted the Earth across human history and well before our species, the presence of microbes today is a testament to their capability to survive throughout challenging environmental conditions. The structural simplicity, small physical size, and metabolic diversity of microbes allow them to adapt to various environmental changes and sustain themselves across millennia. Conversely, humans' remarkable advancements in technology give us the ability to potentially live a life independent of microbes. Our engineering success enables us to manipulate biological systems to create artificial products to meet our needs. That said, while a life without microbes is theoretically possible, the quality of life on this planet would be diminished. Microbes' vast influence in our biosphere, namely their roles in global biogeochemical cycles and waste remediation, are very challenging to replicate. Human life may still exist in the absence of microbes, but we certainly would not wish to live without them.

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