IN LIVING COLOR

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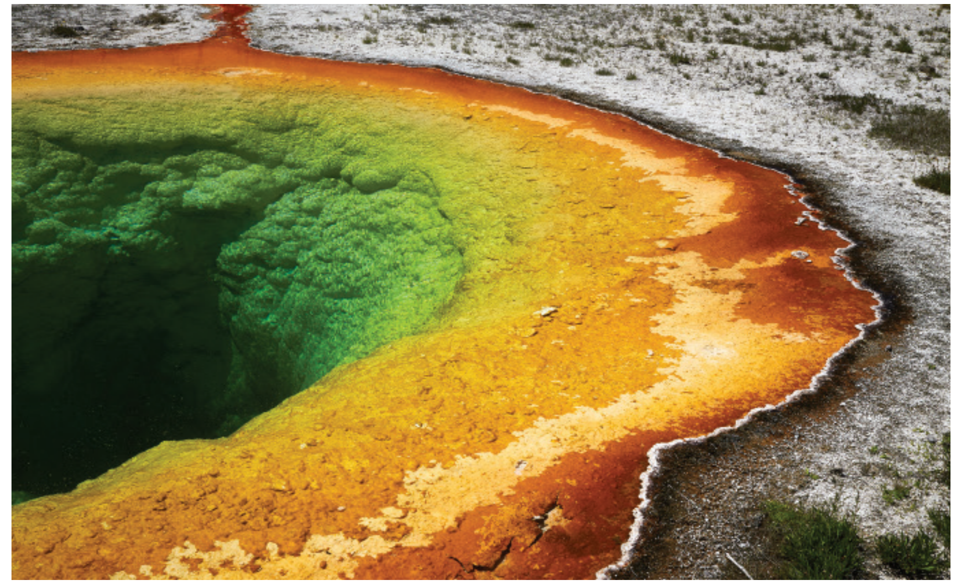
MRAUST/ISTOCK

MICROFAUNA PLAY AN ESSENTIAL ROLE IN SUSTAINING LIFE ON EARTH. ISN'T IT TIME WE RECOGNIZED THIS AND STARTING FOCUSING CONSERVATION EFFORTS ON THEM?

MOST CONSERVATION EFFORTS worldwide tend to focus on charismatic megafauna — bears, big cats, elephants, great apes and such — because when we protect them, we also safeguard a range of other species that share their habitats. But when we consider that all ecosystems are dependent upon a food web, our system of conservation is "absolutely inverted," says Mark Young, PhD, professor of virology at Montana State University's Thermal Biology Institute. While megafauna generally occupy the top tier of food webs, ecosystems are largely driven by invisible processes carried out by microfauna at the bottom; chief among these activities is the recycling of critical nutrients. No species can survive without a ready supply of nutrients. The organisms responsible for making nutrients available are themselves too small to see and may be the least appreciated of all Earth's organisms, but they're ust as important as megafauna when it comes to conservation.

Microbes are best known for things like strep throat, food poisoning and other, far more severe diseases, but the vast majority of microbes do not cause illness and many are absolutely essential for the continued existence of life. In fact, according to Bill Inskeep, PhD, professor of geomicrobiology at the Thermal Biology Institute, "…microbes take center stage in nearly all environments. We just don't recognize it."

Microbes break down wastes of all types, turning them into usable nutrients that can be taken up by plants and eventually passed along to animals. In this way, microbes are necessary to life on Earth. Not even our grain crops could grow without a healthy community of microbes delivering nutrients to them. If all our ecosystems are completely reliant on microbial life, we should be conserving them too, but how do we go about it and are there examples of microbial conservation already taking place? The answers to these questions lie in Yellowstone National Park.



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***Page 60:* Grand Prismatic Spring gets its bright orange hue from the cyanobacteria *Calothrix*. *Right:* Once a deep blue, Morning Glory Pool's color has changed as tourists have thrown coins, rocks and other debris into it.**

Founded as the nation's first national park in 1872, Yellowstone has been a symbol for the conservation movement since day one. In 1903, Teddy Roosevelt visited Yellowstone, saying that nowhere else in the world "…is there to be found such a tract of veritable wonderland, made accessible to all visitors, where at the same time, not only the scenery of the wilderness, but the wild creatures of the park are scrupulously preserved." Since that time, visits to Yellowstone have increased dramatically. Last year, 4.2 million visitors came to the park to witness one of the only places where a full complement of predators (grizzlies, wolves, etc.) still coexists with their natural prey (bison, elk, etc.).

Another main attraction, the park's thermal features, is on full display at locations such as Mammoth Hot Springs, the Norris Geyser Basin, and Old Faithful. Temperatures within the geysers, hot springs, mud volcanoes and sulfur cauldrons typically reach more than 200° F, often superheated to well above boiling point. These waters can also be extremely acidic, yet despite these harsh conditions, a unique community of microorganisms lives in Yellowstone's hot springs and geysers. Visitors are instructed not to stray off boardwalks as much to preserve the integrity of these systems as for their own protection.

From a safe distance one can see a variety of colorful mats of what look like algae living under Yellowstone's superheated waters. These are, in fact, made up of not only algae but also bacteria and a group of more recently discovered microbes, archaea. Perhaps the most stunning example of these multicolored communities can be found at the famed Grand Prismatic Spring. These huge orange, brown, yellow and green mats are evidence of dense colonies of bacteria, including *Calothrix*, *Synechococcus* and *Thermus*. Just up the road at the Norris Geyser Basin, the same colors are produced by different microbes — the archaea *Metallosphaera*, *Caldisphaera* and *Sulfolobus*, and a red alga, *Cyanidioschyzon*.

While these bacteria, archaea and algae form beautiful masses within Yellowstone's hot springs, most people would be hard-pressed to come up with a reason to care much about these species. Not Inskeep, however. With more than two decades of experience working in the park, he has made a career of studying Yellowstone's microbes. With advances in genetic technologies, Inskeep and others have been able to characterize many of the park's microorganisms.

In 1998, realizing that most microbiologists at the time didn't have a background in chemistry, Inskeep decided to complement existing research through work on the interactions between microbes and the chemistry of their surrounding environment. This work caught the attention of several large government agencies, including the Department of Energy (DoE) and NASA.

Why would an energy agency and a space exploration agency be excited about the invisible critters of Yellowstone? In the case of the DoE, they were interested in understanding how microbial communities within soil and other habitats form and interact. The limited number of species living within the park's hot springs provide a simple model system for understanding how members of a community cooperate and compete. Given basic information on these processes between only a few species, DoE researchers could then attempt to understand much more complex communities such as those involved in the production of biofuels.

NASA was interested in Inskeep's work for a very different reason. Researchers have known for quite some time that the environment of early Earth was much different than it is today. Currently, it's believed that conditions were much more extreme, exhibiting very high temperatures. Under these conditions, the initial forms of life appeared. Known as "thermophiles," or heat-loving organisms, these single-celled microbes were the building blocks for all living things. One place where thermophiles exist in abundance today is Yellowstone. Studying microbes within the park can provide NASA with a better understanding of how Earth's earliest life forms interacted, evolved and gave rise to multicellular beings, including humans, which could lead one day to the discovery of life on other planets.

In addition to the bacteria, archaea and algae inhabiting Yellowstone's hot springs, there is another category of microbe that is every bit as important as the others. Not even considered "alive" in the traditional sense, viruses play a hugely important role in regulating the rest of the microbial and non-microbial world. According to Young, viruses and cellular life coevolved, both dependent on the other for survival. Counter to the popular notion that viruses are purely destructive, Young says that many cells, microbial and otherwise, form a symbiotic relationship with viruses. When a cell contains non-harmful viruses that are related to pathogenic ones, it is actually protected from infection. In exchange, the virus symbionts are protected by the bacteria and are allowed to multiply. This occurs not only in benign environments but also in extreme conditions like those in Yellowstone. According to Young however, these hot springs viruses look totally different from any others, physically and genetically. As part of the microbial community, the interaction between viruses and their bacterial or archaean hosts has also become an important model for understanding how predators and prey evolve to combat each other over time. While bacteria, algae and archaea are the ones regulating an ecosystem's chemical and nutrient supply, viruses are the ones regulating them.

Yellowstone's microbes have provided more than just academic knowledge. On a trip to the West Coast in July of 1964, Thomas Brock, PhD, a microbiologist from Wisconsin, took a detour through the park. He was fascinated with the various colors produced by the bacteria, archaea and algae. "Once I got knowledge of the system, I realized there were lots more implications and applications," he says. Brock soon established a laboratory in West Yellowstone, MT, and began to bring other researchers and students there. By 1967, Brock had hit pay dirt, publishing his discovery of unique thermophiles in the journal *Science*. Two years, later, with the help of undergraduate student Hudson Freeze, Brock was able to isolate and grow a bacterium that formed long, pink filaments in Yellowstone's hot springs. Known as *Thermus aquaticus*, this bacteria was the most extreme thermophile known at the time. Importantly, Brock showed in subsequent research that the proteins in *Thermus aquaticus* were able to operate at high temperatures, even after being removed from the bacteria.

Brock's findings would ultimately change the course of the biological sciences and make him one of the fathers of biotechnology. In 1983, using the temperature-stable proteins found in *Thermus aquaticus*, researchers developed a technique known as polymerase chain reaction (PCR) that could take a single strand of DNA and replicate it millions of times. This technique is integral to all genetic work that has been done since then, leading to great leaps in criminal justice, medicine and conservation.

Given that microbes are vitally important members of the ecological community, have led us to a greater understanding of how life evolved on Earth, and provided the raw materials needed for some of our most important technological advances, how can we better preserve them? Even in Yellowstone, where microbes have arguably left the greatest impression on humans, the impetus for preserving the land has not been to protect microbial life, but it should be — after all, just because something can only be seen with a microscope doesn't mean it is worthless. It does however make conservation efforts all the more difficult.

While further research is needed in order to conserve microbial life, there are some practical ways in which we can move towards that end. First, some have suggested that microorganisms be monitored more carefully. An environmental change that has no impact on larger species may in fact drastically change a microbial community. And due to the interconnectedness of nature, changes to a microbial community may simply have a delayed impact on the system as a whole. Secondly, some locations harbor microbial communities that are found nowhere else or exhibit extraordinary diversity of microbial life. Examples include high-temperature iron-oxide mats in Yelowstone, rock-dwelling microbes of the Niagara Escarpment in Canada, and some regions of the Arctic. All that's required is that the habitats in which these communities live be protected. Whether there are other habitats that should also be preserved for the sake of the associated microbes is "…a good thing to ask of the scientific community," says Inskeep.

Lastly, we need to start asking ourselves how much we value microbes, intrinsically and for their benefits to us. "I have seen thermal areas in New Zealand, Iceland, Italy and Japan that have been destroyed by developments," says Brock. Education about this unseen world is a good place to start.

Species must constantly evolve and gain advantage over one another simply to survive. This "evolutionary arms race" has played out over the entire 3.8 billion years life has existed on Earth. For most of that time, all life was microbial. In a time when one species, humans, so dominates this planet, is it not our responsibility to ensure all creatures are able to continue in that race? **WH**

Discover more about Yellowstone's microbial wonders at the Thermal Biology Institute's website, tbi.montana.edu.