They live in places that are, essentially, "Humans Keep Out!" zones — the coldest, driest, darkest, hottest and most acidic places on Earth. Three College of Biological Sciences researchers aim to better understand how "extremophiles" do it and put that knowledge to work.

Imagine the most extreme environment possible. It's likely a place without much obvious life. As it turns out, even the most inhospitable spots often teem with microorganisms. In places that seem devoid of other life, these microbes show an incredible capacity to thrive.

These organisms are dubbed "extremophiles" for their ability to survive in physically or geochemically extreme conditions like frigid mountaintops, sulphurous hot springs or arsenic-rich lake sediment. Still, it's important to remember that the "extreme" description is one given to these organisms by humans. As an example, we may require oxygen to live, but some extremophiles thrive without it.

Extremophiles interest scientists for many reasons, including the ways they've adapted to over-the-top (or way-down-deep) surroundings by keeping their cellular proteins stable and active.

What do these small-but-mighty microorganisms have to teach us about the past, the present and the future of life here on Earth? Three College of Biological Sciences researchers are studying extremophiles, in all their hardy glory, from samples taken in locations all over the world. Here's a peek into their labs to learn more about what they study and why.

ENZYMATICALLY PROMISCUOUS

The adage about one person's meat being another person's poison is exemplified by the research conducted by Mikael Elias, a faculty member in the Department of Biochemistry, Molecular Biology and Biophysics and the BioTechnology Institute. While arsenic is highly toxic to humans, Elias has studied extremophiles that thrive in arsenic-rich environments. "It's a poisonous molecule, yet these microbes survive in it, and my work looked at how they manage to do that," he says.

The journal *Nature* published his findings, which were also the topic of many popular science articles. In describing the importance of the extremophiles he studied, Elias cites the butterfly effect (in which a small change in a complex system can have large effects elsewhere). "One little molecule can have a very big impact at the phenotypic level."

These days his lab focuses on halophilic proteins, which are extremophiles that thrive in salt. "We take genes from organisms found in extremely high- or extremely low-salt lakes in South America, mostly from

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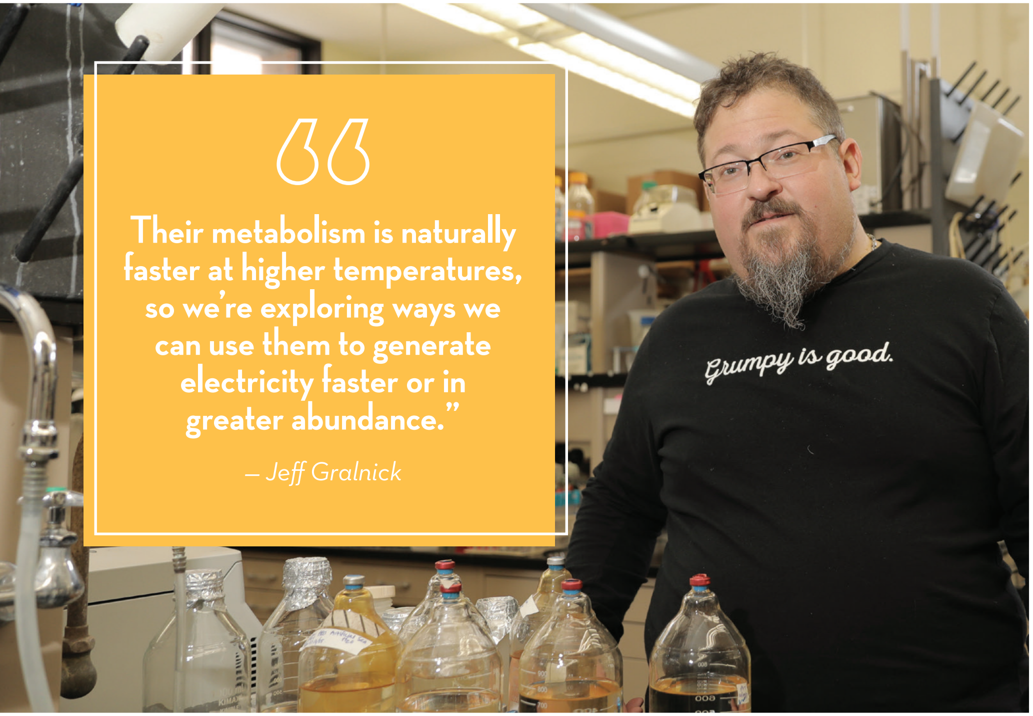
— *Mikael Elias*

high-altitude lakes in Argentina and Chile," he explains. Elias works at the molecular level to make and produce pure proteins, then "tricks" the bacteria to produce proteins of interest.

"I'm interested in biological molecules that are enzymatically promiscuous," he says. "Enzymes are special proteins that can accelerate chemical reactions, and I'm looking particularly at ones that have the ability to catalyze a reaction different from the one for which it has been selected." Work like this could play a role in evolving new enzymes, perhaps ones that could be useful in industrial processes and production. The work could also play a role in bioremediation and bacterial control. "We might be on the road to creating an alternative to antibiotics, or we could find a way to hack bacterial communication to prevent them from becoming virulent."



"Their metabolism is naturally faster at higher temperatures, so we're exploring ways we can use them to generate electricity faster or in greater abundance."

– *Jeff Gralnick*

AN ELECTRIFYING PURSUIT

When most people think of Hawaii, they probably picture palm trees, tropical birds and sandy beaches. For Jeff Gralnick, the extremophile *Mariprofundus ferrooxydans*, which gets energy through chemical reactions, comes to mind. A professor in the Department of Plant and Microbial Biology, and a member of the BioTechnology Institute, Gralnick studies a neutrophilic, chemolithotrophic, gram-negative bacterium which grows by oxidizing ferrous to ferric iron. His lab is full of samples from Lōihi Seamount, an active submarine volcano 22 miles off the coast of the island of Hawaii. "They're collected from a thermal vent. The samples are collected about 1,000 meters down, and when you see them, they look like mats of orange fluffy stuff, busy making an iron stock and projecting it out one side of their cell."

Another location Gralnick uses for sampling is much closer to the University's Twin Cities' campus. In a story reminiscent of Jules Verne's *Journey to the Center of the Earth*, he has descended 2,341 feet in Minnesota's Soudan Mine to observe and sample communities of extremophiles that live and even thrive despite the absence of light. "In some ways, the Soudan Iron Mine is not only a window into the deep subsurface, but also a portal back in time," he says.

In his lab, Gralnick studies heat-loving thermophiles that generate electricity, which were isolated from an iron-rich hot spring in Russia. "Their metabolism is naturally faster at higher temperatures," he says. "We are exploring ways we can use them to generate electricity faster or in greater abundance.

"Some of the bacteria that we're seeing are able to convert iron(II) into iron(III), essentially forming rust or iron oxide," says Gralnick. "Nobody knows how those bacteria do what they do." Saying that he's interested in "cool microbes that do neat things that could be used to solve problems," Gralnick adds, "We're looking for signatures of life in these unusual environments. You never know what will pan out."

HERE BEFORE US

Trinity Hamilton might be something of an extremophile herself. She was born and raised in rural Montana, where isolation was the "extreme" element in her environment. "I grew up in the middle of nowhere in Montana," she says. The skills she gained on countless horseback rides and camping trips served her in good stead during her Ph.D. research in Yellowstone National Park where she studied, among other things,