Remember Gary Larson's Far Side cartoons? One shows a line of people standing in hell. "Hot enough for ya?" one man quips.

Now rethink this image, but instead of the cartoon characters with bulbous bodies and long noses, picture a row of viruses. One is shaped like a strand of spaghetti. Others resemble soccer balls, lemons and crabs.

"They're fun to look at," commented Montana State University virologist Mark Young.

He's talking about viruses from hell. Or rather viruses from hot springs in Yellowstone National Park, which might as well be hell.

Young and others associated with the Thermal Biology Institute at MSU-Bozeman found these variously shaped viruses in pools of boiling acid. The pH can be below 1.0. The temperature hovers around 190 degrees Fahrenheit. The water is laced with high levels of arsenic and mercury.

Called extremophiles because they thrive in places once thought too hot, too acidic and too toxic for life, many of the microbes have never been seen before. Their very newness to science makes biologists feel like kids in a candy store.

"The bottom line is if you go to weird places, you find weird things," Young said.

Life on the weird side

Yellowstone National Park has had a reputation for weirdness for a long time. Indian tribes generally avoided the place, choosing to pass through the area on their way to more promising hunting grounds. (One exception is a band of Shoshone Indians called Sheepeaters, who lived in Yellowstone for hundreds of years.)

John Colter, a member of the Lewis and Clark party, might have been the first white man to explore park territory or "Colter's hell." He and other mountain men talked of the area's fire and brimstone to an unbelieving audience.

Even scientists today have wacky tales about working in the park. Blue jeans with holes in the legs from crouching on acidic soils. Sampling vials that melted from the heat. Animals that dug up and ate research equipment.
So much mercury, lead, arsenic and other toxic metals are found there that if the place weren't a national park, it'd be a Superfund site, MSU soil microbiologist Tim McDermott is fond of saying.

Not to explore such an intriguing complex place that's only 90 minutes away would be like saying "No thanks" to a bottomless bowl of chocolates sitting within arm's reach.

So Young and McDermott started the Thermal Biology Institute in 1999 to study their own kind of hell, so to speak. The microbial kind.

Their work is in addition to that of MSU microbiologist Dave Ward who for 25 years has studied microbial communities in the park's hot springs. Currently Ward heads a $5-million National Science Foundation project that's asking some very big questions about life at this level.

Two other projects are also examples of the outstanding research under way by Institute scientists. One is the discovery of new viruses in the park. The other is exploring how two species work together to survive the heat.

**Huge Failure Rate**

Most viruses, despite their bad reputation, don't cause disease. But scientists study them anyway because they're masterful at hijacking a normal cell and making it do something it wouldn't normally do, like manufacturing more viruses by the millions.

"They're fabulous tools for exploring how cells work," said Young, ticking off viral contributions to 20th-century biology.

That DNA is the code of life was figured out with the help of viruses, he said. That you can get DNA from RNA—like running a cassette tape backwards to hear the same song—was discovered with viruses. That segments of DNA can be spliced together to make new proteins was figured out with viruses.

Plus, the thinking goes, if life exists on other planets it will be microbial and living in extreme conditions like those in Yellowstone or Antarctica. If scientists know how to find weird, ancient life on earth then they'll have some clue as to how to look for it on Mars or elsewhere.

Still another reason for the Yellowstone viral studies, in case you're not convinced, is to better understand the tree of life. Charles Darwin's 1859 sketch of how species are related wasn't right. Scientists know that now, thanks in part to the microbes.

So far Young and his group have found up to 13 new viral families from Yellowstone. Only 75 viral families are known in the world, and a new one hasn't been discovered for years. Now Young has the phone number for the International Congress of Taxonomy of Viruses on speed dial.

"We didn't know what we were looking for," Young recalled of their early sampling trips on the park's west side. "We had a huge failure rate. We had to invent the techniques to find anything."

Now Young's group has sampled about 500 of the park's rough-
ly 10,000 thermal features. They were monitoring some sites every 30 days to detect subtle changes in the viruses, but the microbes evolve so rapidly that the team samples every 24 hours.

One of the group’s new viruses will appear in the journal *Science*, the academic equivalent of having your 8-year-old appear in a Super Bowl commercial.

**EVEN DESERTS GET COOL**

In *Science* last year was an account of another TBI discovery. A grass in Yellowstone can handle soil temperatures up to 140 degrees Fahrenheit if it gets a little help from a friend.

Hot springs panic grass, whose flat, narrow foliage can be found in geyser basins throughout Yellowstone, would die in that environment if not for a stringy, microscopic fungus on its roots.

“Even desert plants cool off at night,” said MSU plant scientist Rich Stout. “These plants don’t. That’s what makes them bizarre and interesting.”

Plant-fungal partnerships aren’t unique. They may date back 500 million years or more to when plants first began to evolve. Fungi on the roots help plants absorb water and nutrients. For their efforts, the fungi get a place to live and a steady supply of food and water. The relationship is called mutualism, known by the less scientific phrase as “scratch-my-back-and-I’ll-scratch-yours.”

But what’s unusual in this situation is the fungi don’t just help gather food and water; they make the plant roots tough enough to withstand the extreme soil temperatures. In fact, neither the plant nor the fungi could live in hot Yellowstone soils alone.

“We would have been surprised if the grass didn’t have a fungal partner,” said MSU microbiologist Kathy Sheehan, who worked with Stout, MSU microbiologist Joan Henson and scientists in Washington on the project. “What surprised us is that it imparts thermotolerance to the plant.”

Just how the fungus, called *Curvularia*, makes hot springs panic grass thrive in soil temperatures that would kill most other plants isn’t clear. The fungus could help spread the heat throughout the plant or it could act as a biological trigger that tells the plant to activate a stress response.

Whatever the mechanism, the steamy partnership is an exciting one, agreed Young.

“I was surprised that fungi are that involved in thermotolerance,” he said. “The next question is how they confer thermotolerance. We may never find out.”

If they do, one application might be agriculture. Crops have failed many times because the soil got too darn hot. But if the plants had a fungal partner, well, maybe the outcome would be different.

The Thermal Biology Institute has 11 scientists, 20 students, 10 postdoctoral researchers and seven full-time technicians. It is funded by an appropriation from NASA through the efforts of Sen. Conrad Burns. The National Science Foundation, the Department of Defense and several other federal agencies fund individual scientists as well.

Other MSU biologists study big creatures in Yellowstone, including elk, bison and wolves. Stories about them will appear in upcoming issues.

Yellowstone microbe that degrades phytic acid and some other microbes to formulate plant-based fish food that would be high-protein, nutritional, tasty to the fish, won’t give them diarrhea and won’t create environmental waste. If successful, the project could create a new market for Montana crops such as canola, safflower and barley, McDermott said.

Trout sales last year totalled $76 million, according to the Agricultural Statistics Service, Idaho, a hub of aquaculture in the U.S., uses 15,000 tons of fish meal a year and would be a likely buyer of a Montana-made fish food, Bradley said.

So far EnviroZyme is in its early stages but has received a grant from the National Science Foundation (NSF) to show that the idea will work. MSU’s TechLink and its partners also have money from the NSF to home-grow EnviroZyme and other new Montana businesses.

By winter the EnviroZyme team hopes to have some feed formulations ready to test on rainbow trout at the Fish Technology Center north of Bozeman.

The scientists note that any successful invention based on Yellowstone microbes would pay royalties to the National Park Service.

EnviroZyme has three employees and is located in TechRanch’s business incubator space in Bozeman.

**ANNETTE TRINITY-STEVENS**

Federal biologist Rick Burrows will test fish food samples right on trout at the Fish Technology Center north of Bozeman.