Viruses From Hell

Otherworldly biology in Earth's most extreme environments

BY CHARLES W. PETIT

S HASTA COUNTY, CALIF.—On Memorial Day weekend at 7,000 feet in Lassen Volcanic National Park, snow can still be knee-deep. But spots with names such as Bumpass Hell and Devil's Kitchen stay bare all winter, warmed by subterranean heat from the leftover magma chamber of a vanished volcano. At one geothermal area called Sulphur Works, tourists watch from the nearby park road as microbiologist Kenneth Stedman and a few of his students from Portland State University skitter down a steep, gravelly slope. They carry a sampling vial on a long pole and try not to slip. All around them steam rises from scalding hot springs. Gray-brown gloop spatters from hot, viscous pools while bubbles big as baseballs burst with sulfurous gases. "Beautiful," Stedman says.

It is a fine spot for hunting some of the toughest, weirdest viruses on Earth. Harmless to people, like most of the viruses teeming on our planet, these so-called extreme viruses open a new window into the diversity and stubborn resilience of life. Their means of coping with an extraordinarily harsh environment could also lead to novel medicines and industrial chemicals. Some haven't a single gene resembling any previously known to science. Plus, Stedman says, "It is exhilarating to find a new virus and think, 'Nobody has seen this before.'"

As early as 1897 scientists were surprised to find that hot springs in Yellowstone were "vegetated" by microscopic organisms. Some survived in waters akin to boiling battery acid. Since then, researchers have found these "extremophile" organisms—bacteria and another ancient microbe lineage called Archaea—living in other spots that would once have seemed too hostile for life. They include deep-sea vents spewing 230-degree-Fahrenheit water at 200 times atmospheric pressure, the interiors of glaciers, and the interstices of the planet's crust, miles down.

Microbes are fully functioning cells, harnessing chemical or solar energy and loaded with tiny suborgans to make proteins and reproduce. But wherever microbes live, so do their smaller parasites, viruses. More like molecular machines than life-forms, viruses cannot reproduce on their own. Consisting mainly of a few genes wrapped in protein, viruses add their genetic instructions to those of their host cells, co-opting them to make more viruses.

For many microbiologists, the lean chemistry of viruses is a quick path to insight into how their larger prey work. And because many viruses literally attach their DNA to that of larger cells, they are ready-made genetic engineering vehicles for ferrying additional DNA, of the scientist's choosing, into those cells.

Viruses everywhere. Stedman got the extreme-virus bug in 1996 while working with chemist Wolfram Zillig at the Max Planck Institute for Biochemistry in Germany. There the first extreme viruses were discovered in the early 1980s infecting an Archaeal microbe called Sulfolobus, found in acidic, near-boiling hot springs around the world. Stedman himself has gathered Sulfolobus variants in Siberia, Italy, and Iceland.

And everywhere Sulfolobus lives, there are viruses as well, with at least half a dozen distinct kinds spotted so far. With names such as Fuselloviviridae and Guttaviridae, they have strange looks to match their strange chemistries. One, recovered first from hot springs in Iceland, looks like a tiny piece of limp spaghetti,
just 24 nanometers (billionths of a meter) wide but up to 2,000 nanometers long. That’s several times too long to fit in its host microbe, so it coils inside like a snake. Another elongated virus is stiff as a pool cue and sometimes protrudes from its host. Yet another, so new it hasn’t a name, has funny propellerlike appendages. What they do, nobody knows.

One extreme virus, shaped like a tapered spindle, has already been turned into a potential tool for biotechnology. Working with colleagues in Denmark two years ago, Stedman added genes to the virus for an enzyme from an extremophile microbe called Pyrococcus. Then he infected Sulfolobus with the modified virus. The new genes turned Sulfolobus into a tiny factory for the enzyme, which breaks down cellulose, a step in some food processing and in papermaking. The lure for industry is that the enzyme works at very high temperatures, and chemistry runs faster (and more profitably) when hot.

NASA is interested, too, for less practical reasons. “Viruses are parasites now, but life may have evolved from particles much like them,” says Baruch Blumberg, a Nobel Prize winner and director of the space agency’s Astrobiology Institute. Extreme viruses, living in Earth’s most otherwise locales, could carry hints about how life on other planets might emerge.

Viruses of Sulfolobus have attracted attention simply because the host microbe is easy to culture in the lab. There are hundreds or even thousands of other extremophile microbes, and most of them probably have their own viruses. Microbiologist Mark Young of Montana State University, Zillig, and Stedman—a former student of Young’s—plan to comb some of the 10,000 hot springs, geysers, and other geothermal features in Yellowstone to find still more viruses. They also hope to track the extraordinary bursts of evolution that the viruses seem to undergo as they cope with their changeable habitat. “The viruses in these strange environments are like biosensors,” Young says. “They change genetically much faster than any other organism we know of.”

The survey might yield clues to other mysteries, including how the viruses and their extremophile hosts have spread to remote volcanic areas in virtually every corner of the world. Last month, researchers reported signs that hot springs supporting such ecosystems may seethe at the bottom of a huge lake under Antarctica’s 2-mile-thick ice sheet, isolated from the rest of the world for millions of years.

At Lassen, after almost losing his collecting vial down a steaming fumarole, Stedman and his gang gathered 10 promising-looking samples. Late last week he reported that two of them are growing vigorous colonies of microbes, almost surely Sulfolobus. “We’re about ready to see if they include viruses,” he says. “I’d be amazed if they don’t. They’re everywhere.”