Discover

Life in Boiling Acid!

A booklet that reveals the wonders of life found in the boiling acid of Lassen Volcanic National Park

Revealing wonders of life in boiling acid

Lassen Volcanic National Park is a wondrous landscape full of natural treasures. Among the volcanic features, mountain lakes, alpine forests, and sweeping vistas, you are sure to encounter a wide range of plants and animals. Hidden here is another life form, too small to see with the naked eye. A closer look reveals an astonishing array of unique tiny creatures: microorganisms. Everywhere, from seemingly barren volcanic landscapes to boiling acid mudpots, these small beings flourish.

Image above is of Upper Sulfur Works

The cover photograph shows Boiling Springs Lake. The region around the lake is a Designated Wilderness Area. This makes it a special, unique, and respected resource where there is little evidence of human presence. Visitors are required to stay on trails and boardwalks in all hydrothermal areas. Keeping this area pristine is essential and up to you. Thank you for your help in keeping Lassen wild.

Remember to stay on trails at all times

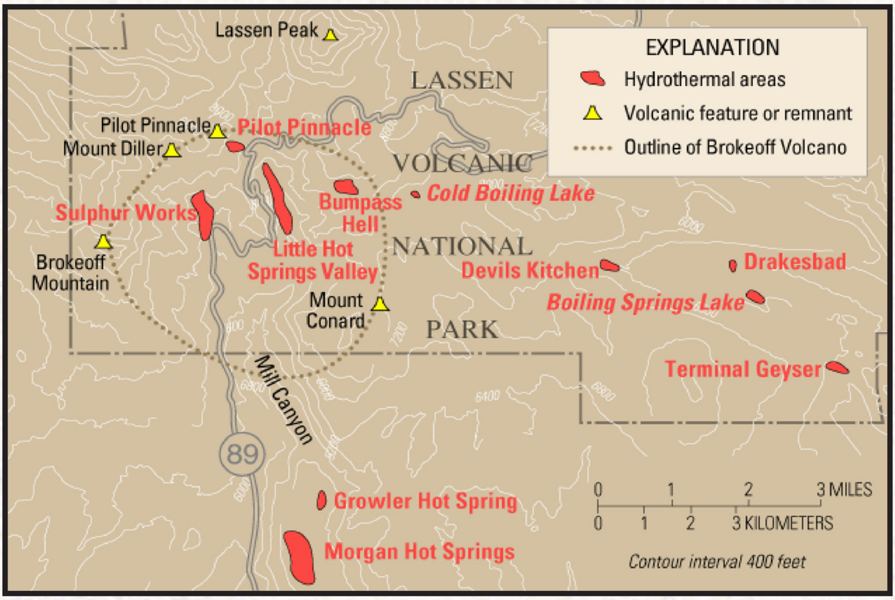
The National Park Service preserves unimpaired the natural and cultural resources and values of the national park system for the enjoyment, education, and inspiration of this and future generations.

NATIONAL PARK SERVICE

The following pages reveal many of the hidden features surrounding life in the hydrothermal (hot water) systems of Lassen Volcanic National Park (LVNP). Delve deep beneath the Earth's crust to discover what causes these hydrothermal features and then resurface to see the thriving life that attracts modern scientists.

Microorganisms are the oldest, most diverse, and most abundant life forms, and some are capable of living where other organisms would perish. These incredible organisms are still mostly unexplored, and the researchers who study them are bringing this wondrous world into the light. By revealing the mysteries of microorganisms, we can come to an exciting new understanding of life on planet Earth.

Lassen's hydrothermal areas



Map courtesy of the U.S. Geological Survey

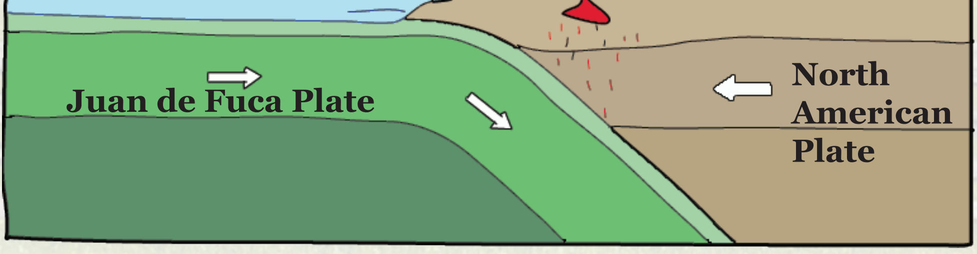
Stay on trails and watch your step!

As you explore the life in and around boiling acid at Lassen Volcanic National Park be aware many of these beautiful and captivating resources are potentially dangerous. What may look safe can hide a boiling environment. The volcanic features of this park are best enjoyed from a safe distance.

Revealing geologic forces in Lassen Volcanic National Park

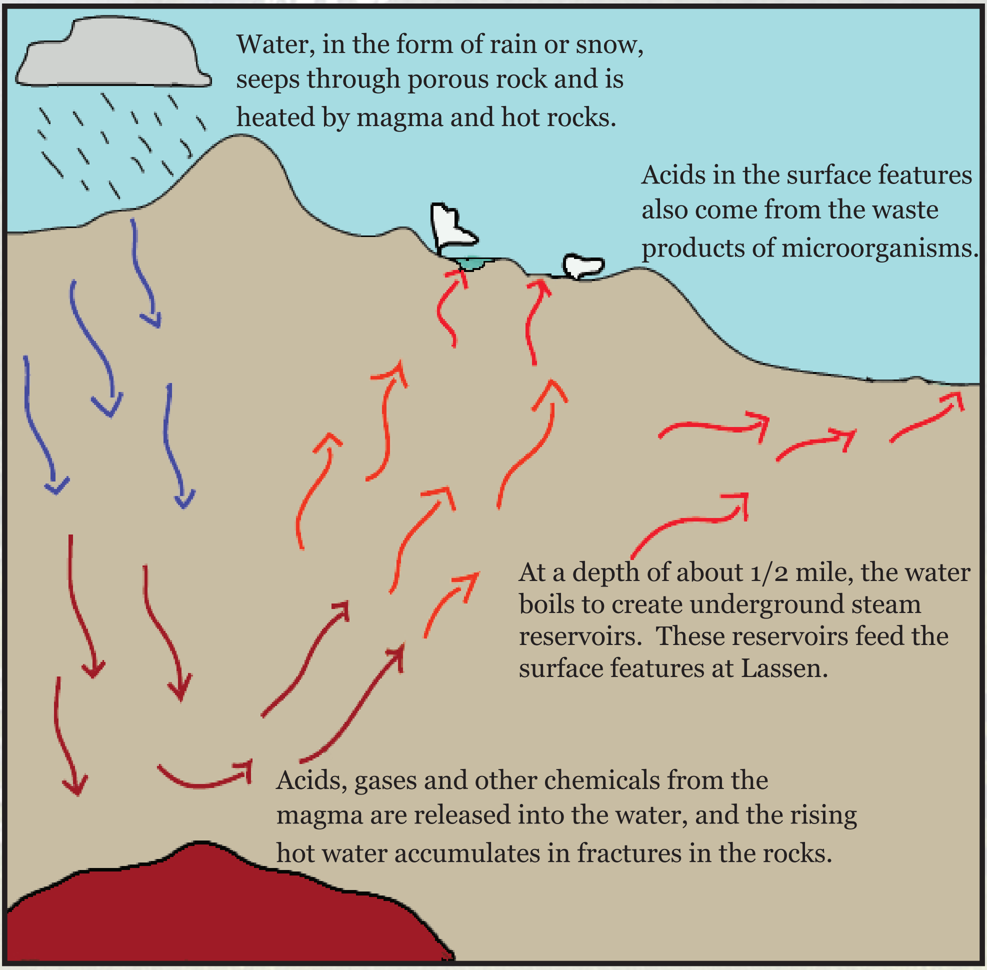
Lassen is a volcanically active area. The volcanism is caused by the oceanic Juan de Fuca Plate plunging beneath the continental North American Plate. The region where these plates collide is called the Cascadia Subduction Zone. The downward-plunging rocks of the Juan de Fuca Plate are melted by the hot shell surrounding the center of the earth.

Since it is less dense than the surrounding rock, the hot molten rock (magma) rises. The rising magma flows up through the crust of the earth, creating volcanoes. This magma is also the heat source for the boiling lakes, steam vents and other hydrothermal features of Lassen Volcanic National Park. Despite these volatile geologic forces there is abundant life here.



Where is the boiling acid coming from?

Hydrothermal systems often have surface features such as boiling lakes and steam vents. There are three necessary requirements for these features to occur: (1) a heat source, (2) porous rock, and (3) plentiful ground water. All three of these criteria are present in Lassen Volcanic National Park.



The Research:
Discovering life in boiling acid

In a place seemingly devoid of life, scientists are discovering new forms of life in abundance! Take a closer look at the discoveries being made here in Lassen Volcanic National Park.

Microorganisms have important roles in Earth's ecosystems as producers and decomposers. These small life forms are amazingly diverse and shockingly abundant. This world of microbes reaches high into the clouds and extends well below land surface. Despite their abundance, less than 1% of Earth's microscopic life has been identified and studied.

Boiling Springs Lake is pictured below

This limited knowledge led the National Science Foundation (NSF) to form a program called Microbial Observatories. This program is intended to increase our understanding of the diversity and importance of microorganisms in our planet. This NSF program brings groups of researchers together to unravel the microscopic web of life that underlies all ecosystems on Earth. At Microbial Observatories all around the world, thousands of scientists and students work together to understand these important and interesting life forms.

Remember to stay on trails at all times

Boiling Springs Lake in Lassen Volcanic National Park became a NSF-funded Microbial Observatory in January of 2008 under the direction of scientists at Humboldt State University, Portland State University, and California State University at Chico.

Exploring in the acid

A special National Park Service research permit allows students and researchers to sample and collect in the park. A Remotely Operated Vehicle (ROV) allows researchers to safely obtain samples from the center of the lake. Prior to using the ROV, researchers could only sample around the lake by using 16 foot painter's poles.

This vehicle was designed and constructed by undergraduate engineering students at Portland State University. The Lassen ROV made its maiden voyage in Boiling Springs Lake on July 1st 2007.

Remember to stay on trails at all times

Students from three universities and local high schools will be studying life in boiling acid for years to come! Over 600 students will be involved in the five year study. Students will have the chance to collect, study, and interpret data from multiple disciplines.

Discoveries in boiling acid

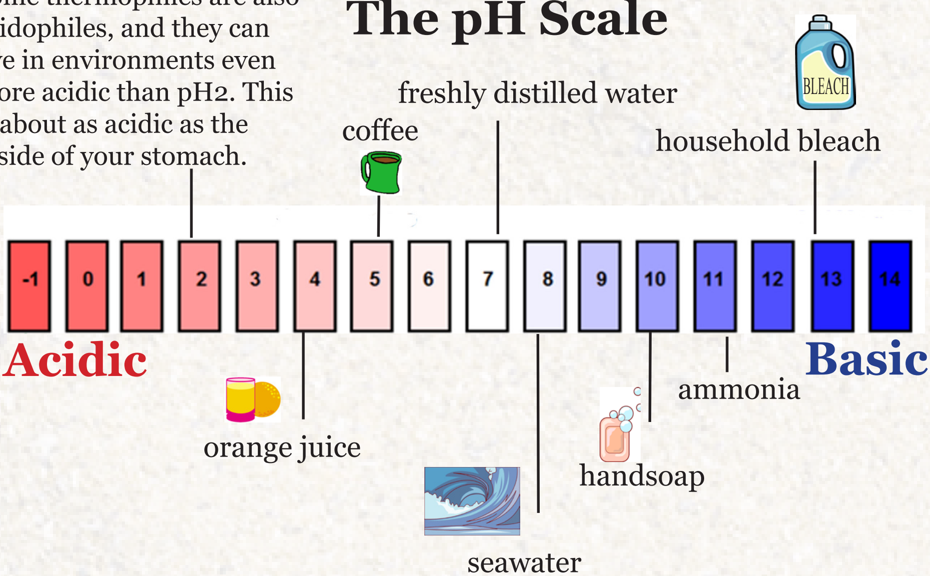
Thermophiles have several adaptations to assist them to thrive in the heat and acid of Lassen Volcanic National Park. Some of these adaptations are changes in their membranes, proteins, and genetic material.

Thriving in the acid

Thermophiles have proteins in their cell membrane allowing cells to maintain a near neutral interior even in very acidic surroundings (pH2). The pH of the cell interior is much closer to that of pure water (pH7) to prevent proteins and other molecules in the cell from falling apart.

Some thermophiles are also acidophiles, and they can live in environments even more acidic than pH2. This is about as acidic as the inside of your stomach.

The pH Scale

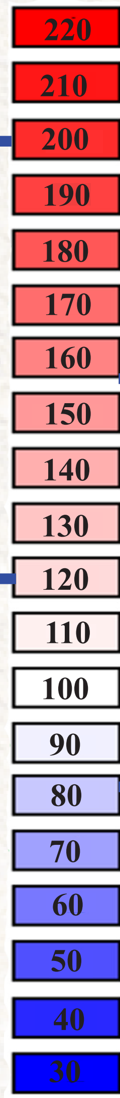


Thermophiles must protect their genetic material (DNA) from decomposing. The two strands of DNA in a cell are linked together by hydrogen bonds, and the DNA is wound into tight coils and mixed with proteins while supercoiling. Although all organisms supercoil their DNA, thermophiles often coil their DNA in an opposite direction so the intense heat does not break the relatively weak hydrogen bonds.

If you can't take the heat... get out of the boiling acid

Cell membranes of all organisms on the planet are composed of lipids (fats) and proteins. This fatty layer is like a fireman's jacket; it won't break down under very hot temperatures. The most extreme thermophile known can maintain the structure of its proteins and fatty membrane layer at temperatures up to 268° F (131° C).

Thermometer (F)



More than 1 billion microbes per liter of hot water, with many previously unknown species, have been found in LVNP hot springs at 200 $^{\circ}$F (93 $^{\circ}$C)

Eukaryotes in LVNP have been found in environments up to 155° F (68 $^{\circ}$C)

Mojave desert in the summer reaches 120° F (49° C)

Lassen Volcanic National Park average high temperature in July 84° F (29° C)

Water freezes 32° F (0° C)

Keeping it together

Saturated fats (common in meat) are solid at room temperature and more resistant to breaking down at high temperatures. Thermophilic organisms increase the amount of saturated fats in their membranes. This prevents the membrane from melting under high temperatures. In addition, Archaea use a different type of fat to construct their membranes, resulting in higher heat stability than we usually see in Bacterial membranes.

Meet the microorganisms of boiling acid

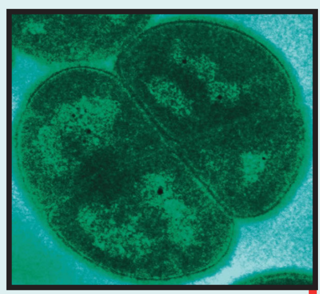
Species unseen to the naked eye thrive in waters hot enough to melt your skin and as acidic as the liquid in your car battery.

Bacteria

Bacteria are single-celled organisms that are still largely unexplored. Many species thrive in boiling acid. In and on every human there are 10 times as many bacterial cells as human cells.

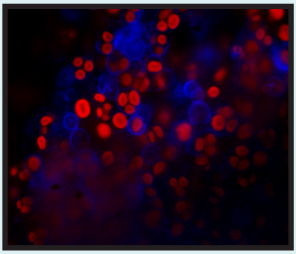
Archaea

The most extreme of all high temperature and acid loving extremophiles are Archaea. Anytime you see a hot, muddy, acidic spring, you are probably seeing a thriving community of Archaea, including *Sulfolobus*. *Sulfolobus* and many other Archaea use sulfur for energy and carbon dioxide for growth. They produce sulfuric acid as a waste. This is part of the reason why these springs have acid in them.

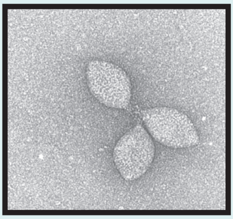


Bacteria and Archaea are microscopic, single-celled organisms that are found everywhere on Earth where we find liquid water. In one 8 ounce cup of hot spring water, there can be up to 25 billion Bacteria and Archaea.

Eukarya



Eukarya are single or multi-celled organisms whose cells contain a distinct membrane around their genetic material. Most Eukarya are single-celled organisms, such as algae and fungi. Did you know that we are a form of Eukarya as well? All other animals and plants on Earth are Eukarya too because they have membranes around their genetic material. When you see mudpots and hot springs in LVNP, chances are there are microscopic Eukarya in the cooler areas surrounding them.

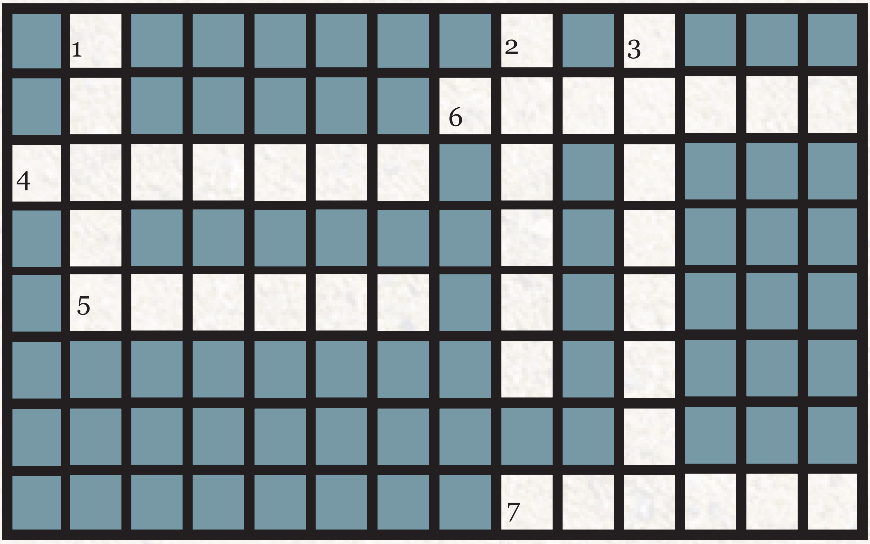


Viruses

A virus is an infectious agent that is unable to grow or reproduce outside a host cell. These viruses may play an important role in controlling the abundance and diversity of life in boiling acid. Most environments on Earth have 10 times as many viruses than Bacteria and Archaea. In LVNP hot acid lakes, viruses appear to be present in much smaller numbers.

Remember to stay on trails at all times

Kids Fun Page



Down

1. Infectious agent that cannot live outside a host cell.
2. Brown, boiling, stinky, and muddy
3. There are 10 times as many of these cells in your body than human cells.

Across

4. These are considered to be some of the most extreme thermophiles.
5. Used as an energy source of many microbes that live in boiling acid.
6. These organisms include everything from fungi to plants and animals.
7. It is important to stay on these when exploring wilderness and thermal areas.

Kids Fun Page Answers!
Crossword Answers: 1. virus 2. mudpot 3. Bacteria 4. Archaea
5. sulfur 6. Eukarya 7. trails
Word Scramble Answers: 1. park 2. science 3. bacteria 4. lassen

Archaea Maze

Find your way through the Archaea!

Q: What do you get when you cross a thermometer and a filing cabinet?

A) A thermo-file!

Q: How do bacteria say hello?

A) Micro-waves!

Q: What do you get when you cross a hen and a science kit?

A) An egg-speriment!

mudpot in LVNP

Word Scramble

k p r a   c e i s c n e

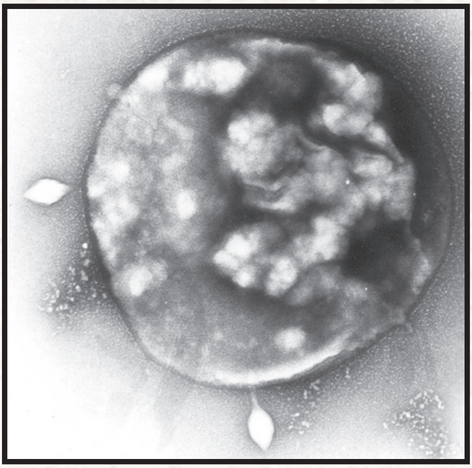
_ _ _ _   _ _ _ _ _ _ _

a a b c e r i t   n l s a s e

_ _ _ _ _ _ _ _   _ _ _ _ _ _

Remember to stay on trails at all times

These incredible microscopic life forms are still largely unexplored, and researchers are uncovering new insights each day. Bringing this wondrous world into light may bring exciting new understanding to the limits of life on the planet, and the role of microorganisms in shaping the world around us.



This is a highly magnified image of a virus attacking the archaeon *Sulfolobus*. This image was magnified over 100,000 times!

This project is supported by National Science Foundation grant MCB-0702018. Participants include researchers and students from the following institutions:

* Humboldt State University - Dr. Patricia Siering and Dr. Mark Wilson.
* Portland State University - Dr. Kenneth Stedman
* California State University, Chico - Dr. Gordon Wolfe

For more information, contact:
Patricia Siering, Dept. of Biological Sciences
1 Harpst St. Humboldt State University Arcata, CA 95521
707-826-3120 pls13@humboldt.edu

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Designed by Humboldt State University undergraduate students Amy Estrada, Richard Muñoz and Sarah Vellutini under the direction of Drs. Patricia Siering, Mark Wilson and Carolyn Ward.