EYE
Extreme Yellowstone Expedition

INVESTIGATING HOT SPRINGS

LESSON 5

Student Activity Book

MONTANA STATE UNIVERSITY
Thermal Biology Institute

BACKGROUND IMAGE: This Yellowstone thermal feature was unofficially nicknamed "Gabby's Spring" by Montana State University (MSU) researchers because Gabby Michel, a student at Lone Peak High School in Big Sky Montana, accompanied the MSU Extreme Yellowstone Expedition scientists and helped them gather data from the spring.

You will be using the data that she collected to learn more about Yellowstone's thermal features.

FACING PAGE: Gabby took the samples collected by the MSU team and helped examine them in a lab.

battery acid	pH 0
	pH 1
	pH 2
	pH 3
	pH 4
black coffee	pH 5
	pH 6
water	pH 7
	pH 8
	pH 9
	pH 10
	pH 11
bleach	pH 12
	pH 13
liquid drain cleaner	pH 14

A wild place to study

Yellowstone National Park is a beautiful but wild place. Of the millions of tourists who visit the Park each year, a few are injured or killed in rare incidents: being attacked by an animal, being struck by lightning, drowning, falling off cliffs or other accidents.

One of the most dangerous features of the Park are its hot springs. If you fall in one, you will be severely burned and it is likely that you will die. Therefore, when you visit the Park it is critical that you stay on the boardwalks and paths and never touch the hot springs. When scientists go to Yellowstone to research the hot springs, they have to get special permits from the National Park Service and receive training on how to gather samples.

A virtual research expedition

Since it's much too dangerous (and illegal) for anyone but fully trained and properly permitted individuals to gather data from a Yellowstone hot spring, today you are going to examine a virtual hot spring. Either your teacher or you and your classmates will put together the pieces of a virtual hot spring on your classroom floor.

The pieces will form a picture of a hot spring found in the Heart Lake region of Yellowstone National Park unofficially nicknamed "Gabby's Spring." Today you will be using the data from "Gabby's Spring" to learn more about Yellowstone's thermal features.

What organisms could live here?

You will be working with data on pH and temperature. These two variables impact what kind of organisms can live in a certain place. If you know the temperature and pH of an environment, then you can guess what kinds of organisms might be living there.

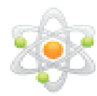
For example, the pH of water can vary slightly due to the minerals found in the soil and rocks around it because of pollution, the amount of plant growth and organic material found in the water and other factors.

The average pH of surface ocean water is around 8, whereas the average pH of clean rain (not polluted acid rain) is around 5.5. If the pH of water goes below 5, fish reproduction (breeding) is affected. If the pH of water goes below 4, fish die. So if you test water from a stream and it has a pH of 4 or lower, there will be no fish living that area.

What is pH?

pH is a measure of a measure of how many hydrogen ***ions*** are in a solution. The strength of an acid or base is measured on a scale called the pH scale.

- The scale ranges from 0 to 14 with the middle value (7) being neutral (neither acidic nor basic).
- Zero is the strongest acid and 14 is the strongest base.
- Every time you go *down* a number on the scale (e.g., from 7 to 6) there are 10 times more hydrogen ions.
- Every time you go *up* a number on the scale (e.g., from 7 to 8) there are 10 times fewer hydrogen ions



An *ion* is a charged atom or molecule. It is charged because the number of electrons do not equal the number of protons in the atom or molecule. An atom can acquire a positive charge or a negative charge depending on whether the number of electrons in an atom is greater or less then the number of protons in the atom.

This means that your stomach acid (pH 2) is *100,000 times more acidic than neutral water (pH 7),* not just five times more acidic, as you might assume.

In agriculture, pH is one of the most important single properties of the moisture associated with a soil, since that indication reveals what crops will grow readily in the soil and what adjustments must be made to adapt it for growing any other crops. For example, most agricultural crops will not grow in acidic soils and need alkaline soil, whereas some evergreen trees and shrubs like acidic soils.

Your teacher may have asked you to test the pH of samples you brought in from home or samples taken from around your school.

If you are testing pH, fill in the names of the liquids you tested and their pH values on the scale at left.

YOUR MISSION

Start your virtual research expedition to Yellowstone

Look at the photo of “Gabby’s Spring” pictured here or the large version of the hot spring which should be on your classroom floor. There are microbes that can live in very hot water living in the spring. The microbes and minerals cause the vivid colors of the hot spring.

In the green and orange areas, the microbes are so thick that they form mats and are visible to the naked eye. The white areas of the spring are mostly mineral deposits. The microbes living in the blue part and center clear channel of the spring are not visible to the naked eye.

Predict: Which part of “Gabby’s Spring” do you think will be hottest and which part will be coolest (the blue, the green, or the orange parts)? Mark your predictions in the table below.

Test: Take temperature readings of the liquid samples in your class, following your teacher’s directions, and write the results below. ***NOTE:*** *the temperatures you collect will not accurately reflect the temperatures of the hot spring. You will work with the real temperature data in the graphing activity.*

	Your prediction: Blue? Green? or Orange?	**Explain the reasons behind your prediction**	**Your results: (Blue, Green or Orange?)**	**Mark a ✓ if your prediction was correct, or an x if it was incorrect**
Hottest colored area				
Mid-range				
Coolest colored area				

Now measure the pH of “Gabby’s Spring.”

1. What pH did you measure? ___________________________

2. Add the pH of “Gabby’s Spring” to your pH chart on the previous page, as well as the pH values for surface ocean water, which is around 8, and clean rain (not polluted acid rain), which is around 5.5.

3. Is “Gabby’s Spring” acidic or alkaline? ____

4. What are some of the possible causes for water from different sources to have different pH values?

____

____

5. What are two important variables in this hot spring that change and impact the visible zones you see, and therefore the kind of organisms that live in those zones?

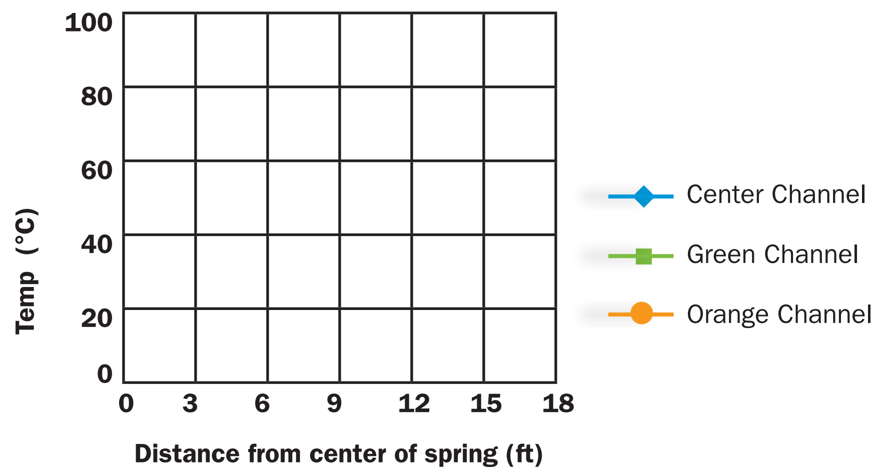
____

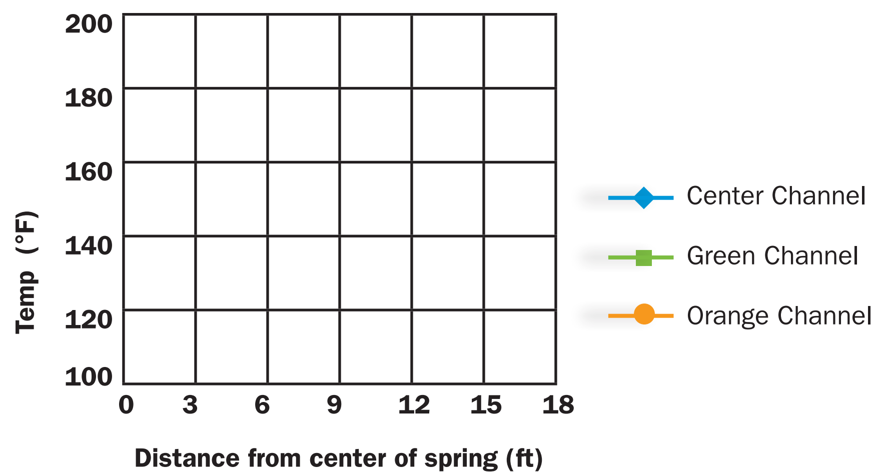
Center channel (clear)	
ft.*	Temp °F (°C)
0	______°F (______°C)
3	______°F (______°C)
6	______°F (______°C)
9	______°F (______°C)
12	______°F (______°C)
15	______°F (______°C)
18	______°F (______°C)
Green outer channel	
ft.*	Temp °F (°C)
0	–
3	–
6	______°F (______°C)
9	______°F (______°C)
12	______°F (______°C)
15	______°F (______°C)
18	______°F (______°C)
Orange outer channel	
ft.	Temp °F (°C)
0	–
3	–
6	–
9	______°F (______°C)
12	______°F (______°C)
15	______°F (______°C)
18	______°F (______°C)

* Distance from center of spring in ft.

Gather temperature data

Use the "Gabby's Spring" map on your classroom floor to virtually sample temperatures in the clear, green and orange channels at 3-foot intervals from the spring's center and mark them in the chart at left. *(Your teacher can tell you whether to fill in Fahrenheit or Celsius values.)*





Graph your temperature data

Now that you have gathered the temperature data, graph the distance on the X axis and the temperature on the Y axis above. Use a different color for each channel (ideally use ink that matches the color of each channel: blue, green and orange) and connect the data points of each channel when you have plotted them all. *(Your teacher can tell you whether to graph Fahrenheit or Celsius values.)* After you are finished, answer questions 1-5 (below and on the next page).

1. Almost all the data you graphed should illustrate a basic trend. What is that trend?

____

2. There is one data point that very visibly doesn't follow the same basic trend as the rest. On which channel line is the data point? Make some guesses as to why it is so different than the others?

____

____

3. When you look at the picture of the spring, why do you think the clear center channel gets so narrow?

____

____

4. What do you think happens to the spring's channels beyond the frame of the picture? Do the three zones go on for miles?

____

____

____

____

____

5. Looking at the graph you made on the previous page, what could you infer about the temperature zones where the organisms in the green and orange channels can live? Why?

____

____

____

____

____

Zones of life

The graphic on the next page illustrates some of the concepts we have been talking about. It depicts the temperature and pH niches where various organisms can live (in other words, the environmental conditions that are suitable for them to thrive). Answer the questions below by looking at the graphic.

NOTE:

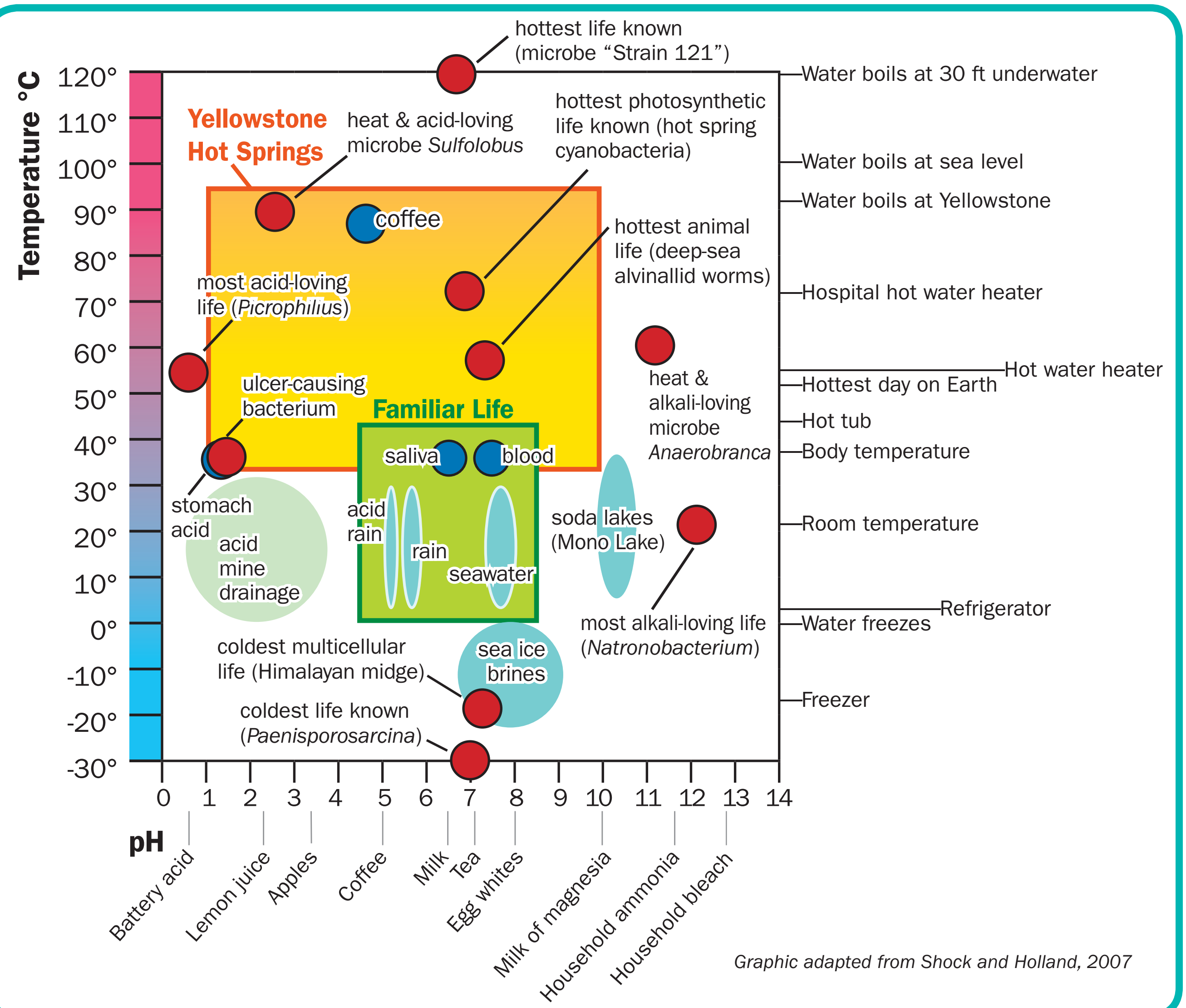
- The red dots are specific types of life.
- The blue dots are non-living things.
- The large shapes are niches or types of environments.

1. In what area of the graphic would you find a tree? ________________________________

2. According to the graphic, what kind of animal life can survive the hottest temperatures?

____

LIFE ON EARTH

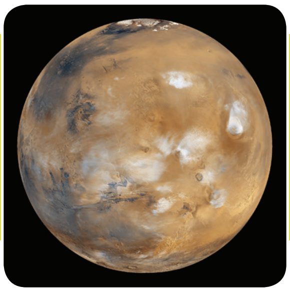
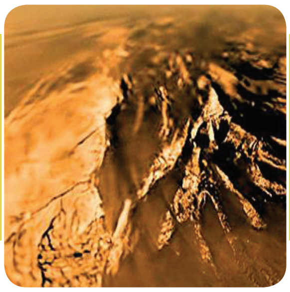


Graphic adapted from Shock and Holland, 2007

3. Which zone on the graphic is larger: The one representing life in Yellowstone hot springs, or the one representing familiar life?

4. Clearly illustrating scientific data so that it is easy to understand is very difficult. Does this graphic seem effective to you? In other words, does it help you understand and visualize how different forms of life inhabit different niches? Explain why you find the graphic helpful or unhelpful.

5. If you look at the types of life that survive in the hottest temperatures, the most alkaline conditions, the most acidic conditions, and the coldest temperatures, what kinds of life are they all, and therefore what kind of life is the most robust and able to survive what we consider to be extreme conditions?


Exploring for Life

Imagine that you have to advise NASA as to which of the following places to go look for alien life. If you want to rule out places to look for life, which variable (temperature or pH) do you think is the better one to use? In other words, if you had data for pH levels on other planets and temperatures on other planets, which data would be more helpful to use to tell NASA where not to go?

Mark in the chart below if you think NASA should look for life in any of the following places in our solar system.

Location in solar system	**Explore? (Yes or No)**
Mercury: temperature ranges from 800°F (430°C) to -280°F (-170°C)	
Venus: average temperature 864°F (462°C)	
Jupiter: average temperature in the clouds -234°F (-145°C)	
Europa (one of Jupiter's moons): -260°F at the equator's surface (-160°C), possible liquid water under the ice that could reach the boiling point in places 212°F (100°C)	
Neptune: average temperature of -328°F (-200°C)	

What about Mars?

The temperatures on Mars can range from -287°F (-177°C) to 86°F (30°C). Scientists think it is highly unlikely there is any life on Mars currently but that we might find signs of past life that existed when Mars had more of an atmosphere, less extreme temperatures, and liquid water on the surface.

Will we ever find aliens?

Even if we never find life on other planets or moons in our own solar system, there is probably life somewhere else in our giant universe. NASA's Kepler mission is constantly finding new planets. To learn more about the mission and find out how many planets have been discovered visit ***kepler.nasa.gov.***