# Explanation Phase Handout

**Search for Thermophiles in Yellowstone National Park**

**Purpose**: Students use multiple data sources to determine the most probable hydrothermal location for ten different thermophiles. Throughout the activity, students compare environmental data and physical resources for various hot springs in Yellowstone and compare it to the thermophiles that the Burnap lab may be interested in studying.

Nature of science is a way of knowing how scientific knowledge is generated based on empirical evidence. Science is also a human endeavor and therefore while it is durable in nature, it is also tentative. During the Explanation Phase, students make claims, provide evidence to support their claims, and engage in argumentation to defend their claims.

### Materials:

Materials for students:

Student handouts: *StudentExplanationHandout1-SearchForThermophiles\_StoryLine StudentExplanationHandout2-SearchForThermophiles\_Table1: DescriptiveData StudentExplanationHandout3-SearchForThermophiles\_ThermophileDataCards StudentExplanationHandout4-SearchForThermophiles\_Table2:ThermophileLocationsAnd SupportingEvidence*

3 x 3” Post-it notes

Materials for teacher:

Teacher Handout: *TeacherExplanationHandout2-SearchForThermophiles\_ThermophileInformation*

Giant Post-it note paper (25” x 30” or larger) or for a less expensive option we might suggest using butcher paper.

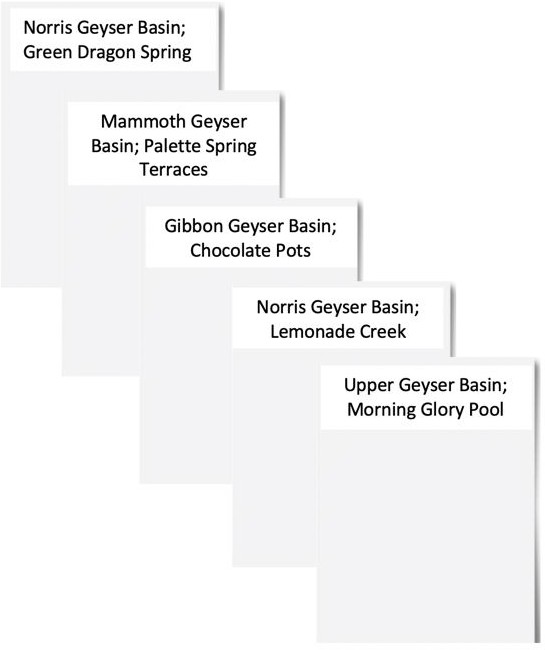
### Activity:

* 1. In teams, students are provided with a factitious story (*StudentExplanationHandout1\_StoryLine*) about how Dr. Burnap and his team of microbiologists are searching for hydrothermal features in Yellowstone National Park that could be potential environments for any of the ten thermophiles they are looking to work with in their NSF funded research project.
  2. Students are provided with descriptive data for five hot springs found in Yellowstone National park (*StudentExplanationHandout2\_Table1*). Data on this table include the name and description of each hot spring, the geyser basin where each hot spring is located, and the hot spring’s temperature and pH range.
  3. Students are also provided with a set of Thermophile Data Cards (*StudentExplanationHandout3\_ThermophileDataCards*). These are the microorganisms that students connect with one of the five hydrothermal environments (hot springs listed in Table 1). They investigate the environmental conditions of each hot spring, and compare these physical conditions to the environmental needs of ten different microorganisms.
  4. Students complete Table 2 (*StudentExplanationHandout4\_Table2*). Using multiple data sources, student draw conclusions for the probable location (hot spring and geyser basin) of ten different thermophiles, and provide a rationale for their selection.
  5. The culminating aspect of the Explanation Phase is when students engage in oral argumentation as they defend their claims for their decision to place each thermophile in a specific hot spring.

### The role of the teacher is to act as the moderator for students’ scientific discussions.

* Now that students have analyzed and interpreted data with their research team, it is time for each team to share their findings with other research teams, including Dr. Burnap. During the discussion, students compare and critique arguments made by their peers about the same topics. This allows students to analyze similarities and differences in student presentations that were based on the same available evidence but may have different interpretations of that evidence.

For Peer Review

* Write the name of one hot spring on a large piece of paper (11 x 16 or larger); repeat this for the other four hot springs. Print the image of the hot spring (found on TeacherExplanationHandout3\_SearchForThermophiles\_Images) and glue it to the paper. This provides students with a visual of the geothermal feature being discussed.
  + ***Norris Geyser Basin; Green Dragon Spring***. http://www.city- data.com/articles/Green-Dragon-Spring-Yellowstone-National.html
  + ***Mammoth Geyser Basin; Palette Spring Terraces***. https[://w](http://www.yellowstonepark.com/things-to-do/mammoth-hots-springs-inside-)ww[.yellow](http://www.yellowstonepark.com/things-to-do/mammoth-hots-springs-inside-)s[tonepark.com/things-to-do/mammoth-hots-springs-inside-](http://www.yellowstonepark.com/things-to-do/mammoth-hots-springs-inside-) cave
  + ***Gibbon Geyser Basin; Chocolate Pots***. <http://www.volcanic-springs.com/> index.php?section=USA&usasection

=gibbongeyserbasin&usasubsection=chocolatepots

* ***Norris Geyser Basin; Lemonade Creek***. https://epod.usra.edu/blog/2015/07/geothermal-features-in-yellowstone- national-park.html

***Upper Ge***

pool?medi

* Figure 1 ***yser Basin; Morning Glory Pool***. https[://w](http://www.gettyimages.com/photos/morning-glory-)ww[.gettyimag](http://www.gettyimages.com/photos/morning-glory-)e[s.com/photos/morning-glory-](http://www.gettyimages.com/photos/morning-glory-) atype=photography&phrase=morning%20glory%20pool&sort=mostpopular
* Place each piece of paper on the board or around the room; students will place Post-it notes on the piece of paper that corresponds with their selected extremophile (see Figure 1).
* Provide students with ten 3 x 3 inch Post-it notes (preferably a different color for each team. It is easier to keep track of teams when they have different color Post-its). Instruct students to write the following information on each Post-it:

1. The name of the Thermophile;
2. The geyser basin and hot spring where the team has evidence to support the thermophile location; and
3. On the back of each Post-it, have students write the name of their research team (team names and colored Post-it better position you to keep track of how each research team responds. This is beneficial when you facilitate discussion on each thermophile).
4. Instruct research teams to place Post-it notes (containing the name of each thermophile and its location), on the five large papers (each titled with one of the five hot spring – see Figure 1) where each thermophile is most likely to be found.
5. Explain to students that they will engage in a discussion and to prepare to provide evidence to support why they placed each thermophile in a specific hot spring. To bring authenticity into the group discussion, have students “present” to Dr. Burnap.

Rules for engaging in scientific discussions may need to be explained. Be sure that students understand that:

* 1. each team’s scientific claims are based on how they interpreted and analyzed the evidence;
  2. if there is disagreement across teams, it is important to disagree with the evidence and not the person (or team) presenting the evidence; and
  3. everyone has an equal voice and when one team is presenting their claims, the other teams are quite until it is time for a rebuttal.

1. As a class, location consensus should be reached for each of the ten thermophiles. The evidence that students provide to support their claims may vary but the evidence should parallel the range of the hot spring’s temperature and pH to the optimal environmental conditions of the corresponding thermophiles.

### Student Data Table 2 Answer Key.

|  |  |  |
| --- | --- | --- |
| Name of Thermophile | Geyser Basin and Hot Spring Location | Provide Evidence/Rationale to Support Your Claim |
| *Green nonsulfur bacteria, Chloroflexus* | Mammoth Hot Springs; Palette Spring Terraces | Supporting evidence may vary among research teams. |
| *Red algae, Cyanidioschyzon* | Norris Geyser Basin; Lemonade Creek | Supporting evidence may vary among research teams. |
| *Aquifex hydrogenobaculum* | Norris Geyser Basin; Green Dragon Springs | Supporting evidence may vary among research teams. |
| *Cyanobacteria, Oscillatoria* | Gibbon Geyser Basin; Chocolate Pots | Supporting evidence may vary among research teams. |
| *Thermus thermus* | Upper Geyser Basin; Morning Glory Pool | Supporting evidence may vary among research teams. |
| *Sulfolobus acidocaldarius* | Norris Geyser Basin; Lemonade Creek | Supporting evidence may vary among research teams. |
| *Cyanobacteria, Synechococcus* | Mammoth Hot Springs; Palette Spring Terraces | Supporting evidence may vary among research teams. |
| *Green algae, zygogonium* | Norris Geyser Basin; Lemonade Creek | Supporting evidence may vary among research teams. |
| *Cyanobacteria, Calothrix* | Norris Geyser Basin; Lemonade Creek | Supporting evidence may vary among research teams. |

|  |  |  |
| --- | --- | --- |
| *Cyanobacteria, Phormidium* | Norris Geyser Basin; Lemonade Creek | Supporting evidence may vary among research teams. |

TeacherExplanationHandout2-SearchForThermophiles\_ThermophileInformation

# Search for Thermophiles Thermophile Information

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Microorganism** | **Location** | **Color** | **Metabolism** | **Temp (°C)** | **pH** |
| *Green nonsulfur* | Mammoth Hot Springs, Upper, | Green mats | Anoxygenic photosynthesis | 35-85**°**C |  |
| *chloroflexus* | Midway, and Lower Geyser Basins |  |  | 95-185**°**F | 7-9 |
| *Red algae* | Norris Geyser Basin, Lemonade | Bright green | Photosynthesis | 40-55**°**C |  |
| *Cyanidioschyzon* | Creek, Nymph Creek |  |  | 104-131**°**F | 0-4 |
| *Aquifex* | Norris Geyser Basin and | Yellow and | Uses hydrogen, hydrogen sulfide, | 55-72**°**C |  |
| *hydrogenobaculum* | Amphitheater Springs | white  streamers | and carbon dioxide as energy  sources; can use arsenic in place of | 131-162**°**F | 3-5.5 |
|  |  |  | hydrogen sulfide |  |  |
| *Cyanobacteria* | Mammoth Hot Springs, Chocolate | Orange mats | Photosynthesis; oscillating moves it | 36-45**°**C | 6-8 |
| *oscillatoria* | Pots |  | closer to or away from light | 97-113**°**F |  |
| *Thermus thermus* | Lower and Upper Geyser Basins | Bright red or | Chemosynthesis; can obtain energy | 40-79**°**C |  |
|  |  | orange streamers | for growth from nearby photosynthetic organisms | 104-174**°**F | 5-9 |
| *Sulfolobus* | Norris Geyser Basin, Lemonade | Dark Green | Chemosynthesis | 40-55**°**C |  |
| *acidocaldarius* | Creek, Nymph Creek |  |  | 104-131**°**F | 0-4 |
| *Cyanobacteria* | Mammoth Hot Springs, Upper, | Green mats | Photosynthesis by day; | 52-74**°**C |  |
| *synechococcus* | Midway, and Lower Geyser Basins |  | fermentation by night | 126-165**°**F | 7-9 |
| *Green algae* | Norris Geyser Basin, Lemonade | Appears black | Photosynthesis | 32-55**°**C | 0-4 |
| *zygogonium* | Creek, Nymph Creek | or dark purple in sunlight |  | 90-131**°**F |  |

TeacherExplanationHandout2-SearchForThermophiles\_ThermophileInformation

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| *Cyanobacteria* | Mammoth Hot Springs, Upper, | Dark brown | Photosynthesis by day; | 30-45**°**C | 6-9 |
| *calothrix* | Midway, and Lower Geyser Basins | mats | fermentation by night | 97-113**°**F |  |
| *Cyanobacteria* | Mammoth Hot Springs, Upper, | Orange mats | Photosynthesis | 35-57**°**C | 6-8 |
| *phormidium* | Midway, and Lower Geyser Basins |  |  | 86-113**°**F |  |
| *Sulfolobus* | Norris Geyser Basin, Lemonade | Dark Green | Chemosynthesis | 40-55**°**C | 0-4 |
| *acidocaldarius* | Creek, Nymph Creek |  |  | 104-131**°**F |  |
| *Red algae* | Norris Geyser Basin, Lemonade | Bright green | Photosynthesis | 40-55**°**C | 0-4 |
| *Cyanidioschyzon* | Creek, Nymph Creek |  |  | 104-13**°**F |  |
| *Green algae* | Norris Geyser Basin, Lemonade | Appears black | Photosynthesis | 32-55**°**C | 0-4 |
| *zygogonium* | Creek, Nymph Creek | or dark purple in sunlight |  | 90-131**°**F |  |

Science Scope

StudentExplanationHandout1\_SearchForThermophiles\_StoryLine

# Search for Thermophiles Yellowstone National Park Story Line

**Background Information**: Dr. Rob Buranp is a microbiologist from Oklahoma State University and he has just received a large grant from the National Science Foundation (NSF) to study mechanisms that Cyanobacteria and other thermophiles use to obtain life sustaining energy. Dr. Burnap and his research team have identified potential locations in Yellowstone National Park where these thermophiles may be living, and is seeking student researchers to assist them in their pursuit of knowledge about the photosynthetic mechanisms of Cyanobacteria and other thermophiles.

**Directions**: To assist Dr. Burnap in his research endeavor, you will use information found in *Table 1: Descriptive Data from Yellowstone’s Hot Springs* to learn about the environmental conditions of five different hot springs, which are located in four of Yellowstone’s eight geyser basins. Then, you will use data provided on the *Extremophile Data Cards* to learn about optimal living conditions of ten different thermophiles.

Using information obtained from your Thermophile Lab, *Table 1: Descriptive Data from Yellowstone’s Hot Springs,* and from the Thermophile Data Cards, determine potential locations of the ten different extremophiles that Dr. Burnap team might be interested in investigating. Record your information in *Table 2*, and then on a Post-it note, write the following information:

1. The name of the thermophile;
2. The geyser basin where the thermophile could be located;
3. The name of the hot spring where the thermophile could be located;
4. On the back of the Post-it, put the name of your research team.

Because science is based on experimental evidence, Dr. Burnap asks that once your team has identified a potential thermophile-location match, that you provide sound scientific evidence to support your claim. Write your supporting evidence for your claim in *Table 2*. Be prepared to defend your claims during your presentation to the class and the Burnap team.

StudentExplanationHandout2\_SearchForThermophiles\_Table1\_DescriptiveDataForYellowstone’sHotSprings

# Search for Thermophiles

**Descriptive Data for Five (Hydrothermal features) Hot Springs in Yellowstone National Park**

## Table 1. Descriptive data for five hot springs in Yellowstone National Park

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Geyser Basin Location** | **Name of Hot Spring** | **Description of Hot Spring** | **Temperature (**° **C and F)** | **pH** |
| Norris Geyser Basin | Green Dragon Spring | Highly acidic sulfate- chloride spring | 66-73°C  151-163**°**F | ~3 |
| Mammoth Hot Springs | Palette Spring Terraces | Outside the caldera boundary. Water comes from Norris Geyser Basin | 70-73°C  158-163**°**F | 6-8 |
| Gibbon Geyser Basin | Chocolate Pots | An exemplary model for iron-depositing hot springs | 40-55°C  104-131**°**F | 6-8 |
| Norris Geyser Basin | Lemonade Creek | Warm-water creek that empties into Norris Geyser Basin | 40-55°C  104-131**°**F | 0-4 |
| Upper Geyser Basin | Morning Glory Pool | Distinct blue color in center of pool | 68-70°C  154-158**°**F | 5-6 |

StudentExplanationHandout3- SearchForThermophiles\_ThermophileDataCards

# Search for Thermophiles: Data Cards

|  |  |
| --- | --- |
| *Thermus thermus*  Optimal Temperature: 40-79**°**C (104-174**°**F) Optimal pH: 5-9  Metabolism: Chemosynthesis  Mat Color: Bright red or orange | *Aquifex hydrogenabaculum* Optimal Temperature: 55-72**°**C (131-162**°**F) Optimal pH: 3-5.5  Metabolism: Chemosynthesis  Mat Color: Yellow and white |
| *Red algae, Cyanidioschyzon* Optimal Temperature: 40-55**°**C (104-131**°**F) Optimal pH: 0-4  Metabolism: photosynthesis  Mat Color: Bright Green | *Sulfolobus acidocaldarius* Optimal Temperature: 40-55**°**C (104-131**°**F) Optimal pH: 0-3  Metabolism: Chemosynthesis  Mat Color: Gray |
| *Cyanobacteria, Synechococcus* Optimal Temperature: 52-74**°**C (126-165**°**F) Optimal pH: 7-9  Metabolism: Photosynthesis  Mat Color: Orange | *Green nonsulfur bacteria, Chloroflexus* Optimal Temperature: 35-85**°**C (95-185**°**F) Optimal pH: 7-9  Metabolism: Photosynthesis  Mat Color: Orange in summer; green in winter |
| *Cyanobacteria, Oscillatoria* Optimal Temperature: 36-45**°**C (97-113**°**F) Optimal pH: 6-8  Metabolism: Photosynthesis  Mat Color: Orange | *Green algae, zygogonium* Optimal Temperature: 32-55**°**C (90-13**°**F) Optimal pH: 0-4  Metabolism: Photosynthesis  Mat Color: appears black or dark purple in sunlight |
| *Cyanobacteria, Calothrix* Optimal Temperature: 30-45**°**C (86-113**°**F) Optimal pH: 6-9  Metabolism: Photosynthesis  Mat Color: Dark Brown | *Cyanobacteria, Phormidium* Optimal Temperature: 35-57**°**C (95-135**°**F) Optimal pH: 6-8  Metabolism: Photosynthesis  Mat Color: Orange |

**Search for Thermophiles**

## Name of each group member: Table 2. Thermophile Location and Supporting Evidence

|  |  |  |
| --- | --- | --- |
| **Name of Thermophile** | **Name of Hot Spring and Geyser Basin Location** | **Provide Evidence/Rationale to Support Your Claim** |
| *Green nonsulfur bacteria, Chloroflexus* |  |  |
| *Red algae, Cyanidioschyzon* |  |  |
| *Aquifex hydrogenobaculum* |  |  |
| *Cyanobacteria, Oscillatoria* |  |  |

StudentExplanationHandout4\_SearchForThermophiles\_Table2:ThermophileLocationAndSupportingEvidence

|  |  |  |
| --- | --- | --- |
| *Thermus thermus* |  |  |
| *Sulfolobus acidocaldarius* |  |  |
| *Cyanobacteria, Synechococcus* |  |  |
| *Green algae, Zygogonium* |  |  |
| *Cyanobacteria, Calothrix* |  |  |
| *Cyanobacteria, Phormidium* |  |  |

# Concluding Arguments

Read through the writing prompts with your research team, then designate one member as the scientific writer. While someone writes, the rest of the team provides the writer with information to address each writing prompt.

### Writing Prompts.

1. Notice there is a difference in the pH of the water in hot springs located in different geyser basins. In a written response, explain how pH could determine which thermophiles could live in each geyser basin. Provide examples of thermophiles that live in different geyser basins as evidence to support your claim. (minimum of 4-sentences)
2. If the Burnap team is specifically looking for thermophiles that thrive in an acidic environment, which geyser basin would you recommend they explore and why? (minimum of 3-sentences)
3. If the Burnap team is specifically looking for thermophiles that thrive in a more neutral pH, which geyser basin(s) would you recommend they explore and why? (minimum of 3-sentences)