Mars – The Xtreme – o – Philes

Grades: 6-8   Prep Time: ~30 Minutes   Lesson Time: Option #1 ~2.25 Hours
Option #2 ~4.25 Hours

WHAT STUDENTS DO: Conduct an investigation and construct explanations for the viability of extremophiles in specific Mars environments

In this lesson, students will use research to learn about the similarities and differences between Earth and Mars environments along with the different types of extremophiles that can be found on Earth. The class will continue their exploration through a matching activity to determine which extremophiles could potentially exist in specific environments on Mars because of their unique form of obtaining energy from their environments. Students will:

- Summarize information about Earth and Mars along with types of extremophiles;
- Recognize the difference between living and non-living objects;
- Infer the potential for life in extreme environments on Mars; and
- Explain which regions of Mars are the most likely candidates to find these extremophiles.

NRC FRAMEWORK/NGSS CORE & COMPONENT QUESTIONS	INSTRUCTIONAL OBJECTIVES
HOW AND WHY DO ORGANISMS INTERACT WITH THEIR ENVIRONMENT AND WHAT ARE THE EFFECTS OF THESE INTERACTIONS? *NGSS Core Question: LS2: Ecosystems: Interactions, Energy, and Dynamics* **How do organisms interact with the living and nonliving environments to obtain matter and energy?** *NGSS LS2.A: Interdependent Relationships in Ecosystems*	*Students will be able to* **IO1: Construct a justification using evidence for a plausible Mars location in the search for life, either past or present, assuming natural laws of the universe are constant, such as biotic and abiotic factors, but remaining open minded to the potential anomalies.**

1.0 Materials

Required Materials

Please Print Option #1:

From Student Guide:

(C)	Extremophile Selection	– 1 per student
(D)	Xtreme-o-phile and Mars Match	– 1 per student

From Teacher Guide:

(G)	Earth/Mars Comparisons Data Chart Sample	– 1 per pair
(H)	Extremophile Data Chart Sample	– 1 per pair

Please Print Option #2:

From Student Guide:

(A)	Earth/Mars Comparisons Data Chart	– 1 per pair
(B)	Extremophile Data Chart	– 1 per pair
(C)	Extremophile Selection	– 1 per student
(D)	Xtreme-o-phile and Mars Match	– 1 per student

Optional Materials

Print from Teacher Guide or post on projector:

(E)	Tanzania Volcano – Ol Doinyo Lengai
(F)	Meridiani Planum Hematite

Additional Materials

(G)	Earth/Mars Data Chart Sample
(H)	Extremophiles Data Chart Sample
(I)	Xtreme-o-phile and Mars Match Sample
(O - Q)	Mars – The Xtreme-o-philes Rubric
(R)	Placement of Instructional Objective and learning Outcomes in Taxonomy

Xtreme-o-phile and Mars Card set   – 1 per pair or group of 3 – 4

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2.0 Vocabulary

Abiotic   not made by or comes from living things

Biotic   made or caused by living organisms

Consumer   an organism in a community that feeds on plants or animals

Environment   the area where a plant or animal lives and affects its development and behavior

Extremophiles   a microorganism, that lives in conditions of extreme temperature, acidity, alkalinity, or chemical concentration

Living   a state defined by the capacity for metabolism, growth, reaction to stimuli, and reproduction

Metabolism   all of the chemical processes that occur in a living organism

Micrometer   a measurement equal to 1×10^{-6} meters (about the size of bacteria) or 0.000001 meters (symbol is μm)

Nanometer   a measurement equal to 1×10^{-9} meters (about the size of a DNA strand) or 0.000000001 meters (symbol is nm)

Organism   an individual able to carry out the activities of life

Producer   an organism, especially green plants, that builds up its own tissues from simple compounds in its environment

Stimuli   something causing a reaction or response

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STEP 1: ENGAGE (~20 minutes)
Conditions for Life and Extremophiles

A. Direct students to take out a scrap sheet of paper, dry erase board, or electronic tablet to record brainstorming ideas.

B. Ask students the following question: "*What are the conditions for life to survive?*"

C. Allow students a few minutes to brainstorm their ideas and/or share with others in their group.

D. Students will share their ideas to be recorded on the board by the teacher or displayed from dry erase boards or electronic tablets. Ask the students: *"Can we group these conditions into larger categories? What would those categories be?"*

E. Students should establish the categories as the WANTS (Water, Air, Nutrients, Temperature, Space) and probably a miscellaneous category of conditions that do not fit (probably not conditions for life).

   Teacher Tip: Students will most likely need the clarification between the conditions for life vs. characteristics of life. Conditions refer to their environment while characteristics refer to how we identify organisms as living/non-living.

F. Ask students to identify which of these conditions are considered normal for organisms on Earth. Students should identify Water, Oxygen, Plants and Animals, a reasonable Temperature Range, Space.

G. Ask students *"Does every organism follow these norms for WANTS or are there some that live in the extreme?"* Give examples*, such as Cacti are considered Xerophiles because they can live on very small amount of water, humans and other mammals are called Oxyphiles because they require Oxygen to live, which is a poisonous gas. (Oxygen is poisonous to many organisms, however mammals and many other organisms on Earth adapted to take advantage of this particular resource. Even at high levels, oxygen is poisonous to humans.)*

H. Explain to students that the organisms we find on Earth in the most extreme environments have the potential of being able to survive in some of the most extreme environments out in the Solar System and our Universe. This potential is tantalizing for many scientists and is the basis of Astrobiology.

STEP 2: EXPLORE (Option #1 – 15 minutes, Option #2 – 135 min)
Research Earth/Mars Comparisons and Extremophiles
Option #1:

A. Hand out *(G) Earth/Mars Data Chart Sample* sheet and *(H) Extremophile Data Chart Sample Answers* sheet.

B. Play "Optional" slideshow for students to gather more information about these topics.

Option #2:

-  **Teacher Tip:** Option #2 is provided for teachers desiring a heavy focus on Common Core requirements such as:

    o Reading in Science
        - Craft and Structure #4
        - Integration of Knowledge and Ideas #7, #8
    o Writing in Science
        - Text Types and Purposes #1a, 1b, 1c, 1d, 1e
        - Research to Build and Present Knowledge #8, 9
        - Range of Writing #10

A. Assign students to one of two teams: Earth/Mars comparisons team (abiotic) or the Extremophile team (biotic).

B. On each team, have students work in pairs to locate the information to complete the Data Chart *(A) Earth/Mars Comparisons Data Chart* or *(B) Extremophile Data Chart*.

C. Have team members collaborate to share information they were able to locate in their research and debate/correct any potential errors in their data collection.

D. Once teams and the facilitator have verified the information to be accurate, they will then create a PowerPoint ®, Prezi ©, or any other presentation application your school uses to communicate their findings to the remainder of the class.

 **Teacher Tip:** Remind students as they research to record locations of great images or video clips they could use or reference in their group presentation. It is recommended that these presentations be printed and distributed to the class as reference materials for the remainder of the lesson.

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STEP 3: EXPLAIN (~20 minutes)
Connecting Mars to Potential Extremophiles

A. Create student teams of 2-3 students.

B. Each team will complete *(C) Extremophile Selection* choosing one extremophile (biotic) found on Earth that could potentially survive on Mars (abiotic). Students will need to use information from presentations to complete this task. (~ 10 min)

C. Upon completion, teams will present their extremophile choice to the class and the justification for why they believe this organism could survive on Mars surface. (~10 min)

STEP 4: ELABORATE (~40 minutes)
Extremophile Matching

A. Explain to students that their selection for the potential presence of extremophiles on Mars was based on a very general description of the entire planet of Mars, but there could be potential for other types of extremophiles in small places on the planet. Just like Earth, Mars has very interesting geology that can be extremely unique and ultimately a singularity for that type of environment.

B. Share the following Earth example:

   a. Use *(E) Teacher Guide - Tanzania Volcano - Ol Doinyo Lengai* to show the location and image of the volcano.
   b. On Earth, there is an extremely rare rock type called carbonatite. Basically it is a volcanic rock made from carbonates (organic). There are only 330 examples of this type of volcano on Earth with this type of volcanic rock. The only active example of this type of volcano is located in Tanzania near the East African Rift. This type of lava typically has less than 10% silica and is extremely runny. In fact, so runny it looks like water flowing. (Videos at the site below demonstrate this runny lava):

   i. http://www.nsf.gov/news/news_images.jsp?cntn_id=114703

   The temperature of this lava is relatively cool in comparison to other lavas at 500-600° C compared to 650-950**°** C of higher silica lavas.

C. On Mars, an example of a singularity would be the abundance of hematite found in Meridiani Planum at the longitude and latitude of 0°E and 0°N. The entire planet

was mapped using the TES (Thermal Emission Spectrometer) system looking for hematite. Hematite is typically formed in the presence of water. When scientists found a literal "hot spot" of hematite, this was an extremely interesting and unique observation. This unique observation eventually led to landing of the Opportunity rover in this area to investigate the potential origin of this "hot spot." (For an image of the hematite "hot spot" use *(E) Teacher Guide - Meridiani Planum Hematite*.)

D. Since singularities exist on both Earth and Mars, then it is possible an environment *could potentially* be suitable to an extremophile. If that were the case, then these would be places scientists are very interested in researching. For this next exercise, students will match Extremophile (Biotic) Cards to potential habitable spots on the Mars (Abiotic) Cards.

   a. Hand out one set of Extremophile cards and Mars cards (8 of each) to a team.
   b. Ask the teams to match Extremophiles cards to Mars cards that could potentially have an environment suitable to the extremophile.

   🍎 **Teacher Tip:** Have students select 1 Mars Card to work with at a time. Then use the process of elimination with each Extremophile Card. This will reduce confusing, preventing the students from getting frustrated or overwhelmed with information.

   🍎 **Misconception Alert!!:** Remind students that life has never been found on Mars and that this is an exercise in critically thinking about the regions that could *potentially* harbor life based on observations of extremophiles made on Earth.

   c. Students may find an extremophile that could exist in a variety of locations. They should record all possible matches to Mars environments.
   d. Students will record their matches to *(D) Xtreme-o-phile and Mars Match.*

STEP 5: EVALUATE (~30 minutes)
Propose a Landing Site.

A. Upon completion of matching, ask students to individually write a one to three paragraph explanation (depending on your course writing requirements) where they choose a potential landing site for a future Mars mission based on the potential for extremophile habitation. Students should:

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a. justify the reasons for their selection including their understanding of life on Mars today;

b. include critical information such as the abiotic materials that can be used to support the biotic environment;

c. give examples of how the organism could potentially exist in that particular landing site specifically including limited access to resources; and

d. consider the potential for life not only in the present environment, but in past environments.

4.0 Extensions

Have students select extremophiles that could potentially live on Mars and be producers for other extremophiles, acting in primary succession

Use the Marsbound! activity found at http://marsed.asu.edu/lesson_plans/marsbound to have students plan a mission to Mars looking for extremophiles at their proposed landing site using Engineering Practices and the Iterative Design Cycle.

5.0 Evaluation/Assessment

Use the *(O - Q) Mars – The Xtreme-o-philes Rubric* as a formative and summative assessment, allowing students to improve their work and learn from mistakes during class. The rubrics evaluate the activities using the Next Generation Science Standards, Common Core State Standards, and 21st Century Skills.

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(A) Earth/Mars Comparisons Data Chart (Abiotic)

NAME:_____

Directions: Complete the following table to show the abiotic (non-living) similarities and differences between Earth and Mars.

Characteristic	Earth	Mars
Atmospheric Pressure		
Axis tilt		
Composition of the Atmosphere		
Days in a year		
Distance from the Sun (in AU)		
Gravity		
Length of day		
Surface Temperature		
Water abundance		

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(B) Extremophile Data Chart (Biotic)

NAME:_____

Directions: Complete the following table to define the types of Extremophiles (biotic – living) and describe the environment (abiotic – nonliving) they are typically found in.

Extremophile	Definition	Description of Typical Location
Acidophiles [uh-sid-uh-fahyl]		
Alkaliphiles [al-kuh-luh-fahyl]		
Endoliths [en-doh-lith]		
Halophiles [hal-uh-fahyl]		
Psychrophiles [sahy-kru-fahyl]		
Thermophiles or Hyperthermophiles [thur-muh-fahyl]		
Radioresistant [rey-dee-oh-ri-zis-tuhnt]		
Xerophile [zeer-uh-fahyl]		

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Student Guide

(C) Extremophile Selection

NAME:_____

Review *(A) Earth/Mars Comparisons Data Chart* and *(B) Extremophiles Data Chart* you completed in class. Look at the Mars info and choose one extremophile in the list that we could look for on Mars today. Circle that extremophile in the table below.

Acidophile [uh-sid-uh-fahyl]	**Alkaliphile** [al-kuh-luh-fahyl]	**Endoliths** [en-doh-lith]	**Halophile** [hal-uh-fahyl]
Psychrophile [sahy-kru-fahyl]	**Thermophile** [thur-muh-fahyl]	**Radioresistant** [rey-dee-oh-ri-zis-tuhnt]	**Xerophile** [zeer-uh-fahyl]

Justification: What evidence did you use to support your claim?

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(D) Xtreme-o-phile and Mars Match

Directions: Using the red and blue cards provided by your teacher, match the extremophile type to a region or regions (environment) on Mars that the extremophile could possibly live.

Extremophile (Biotic)	Mars Region (Abiotic Environment)
Acidophiles [uh-sid-uh-fahyl]	**Gale Crater**
Alkaliphiles [al-kuh-luh-fahyl]	**Home Plate**
Endoliths [en-doh-lith]	**Meridiani Planum**
Halophiles [hal-uh-fahyl]	**Pavonis Mons**
Psychrophiles [sahy-kru-fahyl]	**Vastitas Borealis**
Thermophiles or Hyperthermophiles [thur-muh-fahyl]	**Palikir Crater**
Radioresistant [rey-dee-oh-ri-zis-tuhnt]	**Utopia Planitia**
Xerophile [zeer-uh-fahyl]	**Terra Cimmeria**

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(E) Teacher Guide - Tanzania Volcano - Ol Doinyo Lengai (1 of 2)

Pronounced ol doyn-yo len-guy
Image Credit: Dan Sherrod, St. Lawrence University, 2010

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(E) Teacher Guide - Tanzania Volcano - Ol Doinyo Lengai (2 of 2)

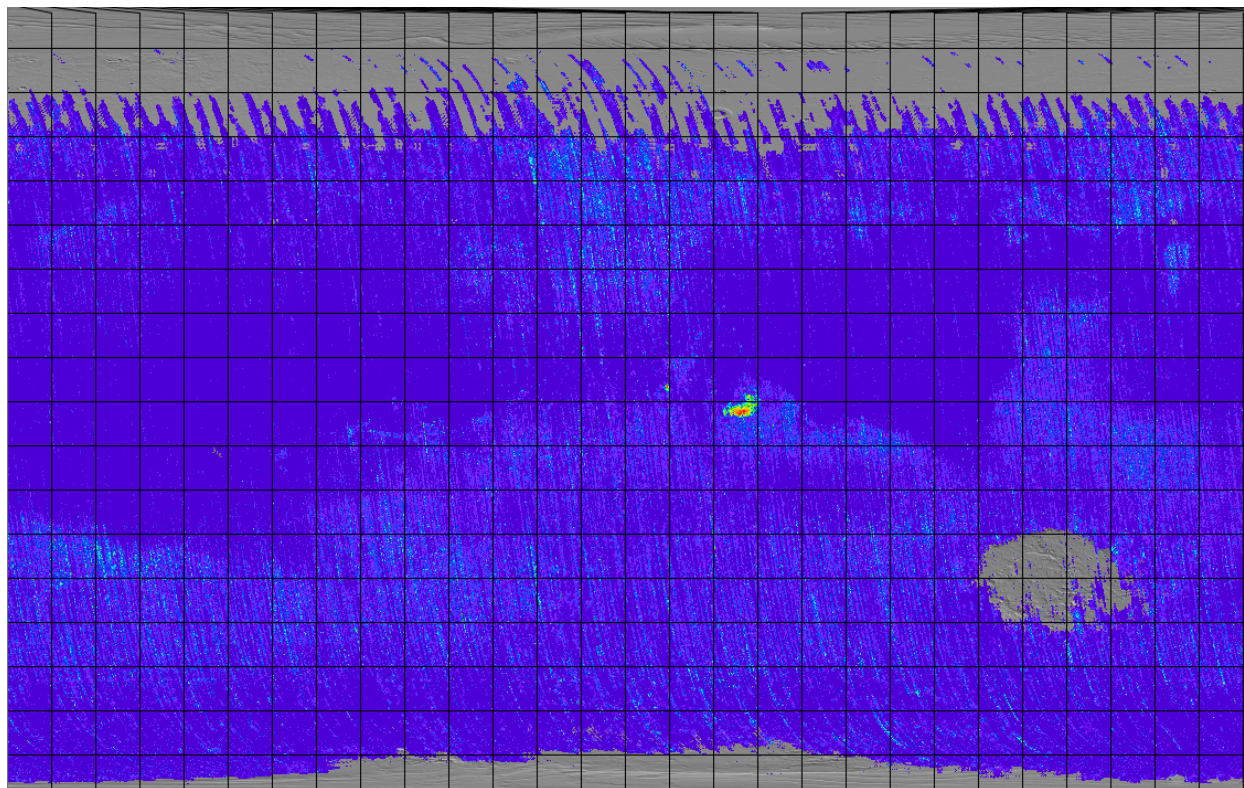Image Credit: "Tanzania." 2°44'15.83"S and 35°57'39.61". **Google Earth.** 2013. January 13, 2013.

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(F) Teacher Guide – Meridiani Planum Hematite (1 of 1)

Image Credit: Bandfield, J.L., Global Mineral Distributions on Mars, J. Geophys. Res., 107, 10.1029/2001JE001510, 2002., Bandfield, J. L., Martian Global Surface Mineralogy from the Thermal Emission Spectrometer: Surface Emissivity, Mineral Map, and Spectral Endmember Data Products, Abstracts for the 6th Annual International Mars Society Conference, 2003. Retrieved from JMARS, January 13, 2013.

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(G) Teacher Guide – Earth/Mars Data Chart Sample

Characteristic	Earth	Mars
Atmospheric Pressure	*1,013 millibars at sea level (1atm)*	*7.5 millibars (0.01atm)*
Axis tilt	*23.45 degrees*	*25 degrees*
Composition of the Atmosphere	*Nitrogen (77%) Oxygen (21%) Argon (1%) Carbon Dioxide (0.038%)*	*Carbon dioxide (95.32%) Nitrogen (2.7%) Argon (1.6%) Oxygen (0.13%) Water vapor (0.03%) Nitric oxide (0.01%)*
Days in a year	*365 days*	*687 Earth days*
Distance from the Sun (in AU)	*1 AU*	*1.54 AU*
Gravity	*2.66 times Mars*	*0.35 of Earth*
Length of day	*Just slightly under 24 hours*	*24 hours, 39 minutes*
Surface Temperature	*57 degrees F (14 degrees C)*	*-81 degrees F (-63 degrees C)*
Water abundance	*71%*	*???*

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(H) Teacher Guide – Extremophiles Data Chart Sample

Extremophile	Definition	Description of Typical Location
Acidophiles [uh-sid-uh-fahyl]	*Acid-loving microbes pH levels 3 or below*	*Sulfuric springs*
Alkaliphiles [al-kuh-luh-fahyl]	*Alkali-loving microbes pH levels 9 or above*	*Soda-Lake*
Endoliths [en-doh-lith]	*Rock-loving Make their own food using gas or dissolved nutrients from water moving through rock or dissolving surrounding rock and absorbing nutrients*	*Trans-Antarctic Mountains*
Halophiles [hal-uh-fahyl]	*Salt-loving microbes 0.2M concentration of NaCl (salt)*	*Salt Lake or Death Valley*
Psychrophiles [sahy-kru-fahyl]	*Cold-loving microbes Temperatures -15°C and lower*	*Sea ice*
Thermophiles or Hyperthermophiles [thur-muh-fahyl]	*Heat-loving microbes Temperatures between 45-122°C*	*Hydro-thermal vents*
Radioresistant [rey-dee-oh-ri-zis-tuhnt]	*Radiation resistant microbes Commonly UV radiation or even nuclear*	*Chernobyl locations*
Xerophile [zeer-uh-fahyl]	*Dry loving microbes In desiccating conditions*	*Desert*

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Teacher Guide

(I) Teacher Guide – Xtreme-o-phile and Mars Match Sample

Extremophile	Mars Region (Environment)
Acidophiles [uh-sid-uh-fahyl]	**Gale Crater**
Alkaliphiles [al-kuh-luh-fahyl]	**Home Plate**
Endoliths [en-doh-lith]	**Meridiani Planum**
Halophiles [hal-uh-fahyl]	**Pavonis Mons**
Psychrophiles [sahy-kru-fahyl]	**Vastitas Borealis**
Thermophiles or Hyperthermophiles [thur-muh-fahyl]	**Palikir Crater**
Radioresistant [rey-dee-oh-ri-zis-tuhnt]	**Utopia Planitia**
Xerophile [zeer-uh-fahyl]	**Terra Cimmeria**

 Teacher Tip: Key only represents Mars Environments that are a _direct match_ to extremophiles. If Question marks are present, it was omitted. Students will establish criteria and justification for their choices, therefore it is expected their matches would be different.

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