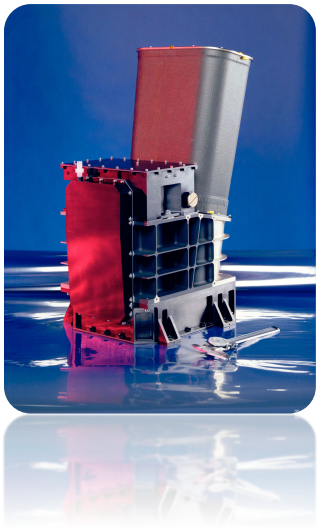
(A) Student Handout. Introduction

NAME:_____

All science begins with a question or an hypothesis. Some people refer to this as the "scientific method". The scientific method starts from questions or hypotheses we create based on our curiosity. We become curious about scientific observations we make. Professional scientists have questions about Mars they want to answer because they are curious, and so you will begin by investigating images from Mars. Keep in mind that it is a natural part of science to refine or even change your question as you research. The process of science continues with designing an experiment to answer that question and test your hypotheses. Your goals through this lesson are:

- Follow your curiosity about Mars and create research questions and hypotheses using scientific observations;
- Evaluate your questions, making sure you have met the criteria for a scientific question;
- Realize that there are different types of questions for research based on the branch of science you are conducting your research in;
- Realize that it's understandable to have "big picture" questions, but scientists (and you) need a specific focus or question to study; and
- Recognize that scientists contribute to a greater understanding of Mars through detailed research.



Photos Courtesy of NASA's Jet Propulsion Laboratory

See Section 4.0 and Teacher Guide at the end of this lesson for details on Instructional Objective(s), Learning Outcomes, Standards, & and Rubrics.

(B) Student Sheet #1. Questions and Hypotheses (1 of 4)

NAME:_____

Did you know that many times scientists start with a big question in mind before they even have a research question or hypothesis? This often occurs as a result of very specific scientific observation, such as the observations you made in Mars Image Analysis. These big questions often lead to possible explanations. We call these explanations hypotheses. You may even already have a big question and an hypothesis about your topic! Below you will find a description of what is meant by a "big picture question," an hypothesis, and a research question.

Big picture questions are the initial questions a scientist will ask while making observations. When researchers observe a feature that is interesting or unique, they will often ask themselves "What is that? How did it form? Why does it appear this way? or Why is this different from other examples?" One of these questions will be the guiding question for the remainder of their research or even possibly their career!

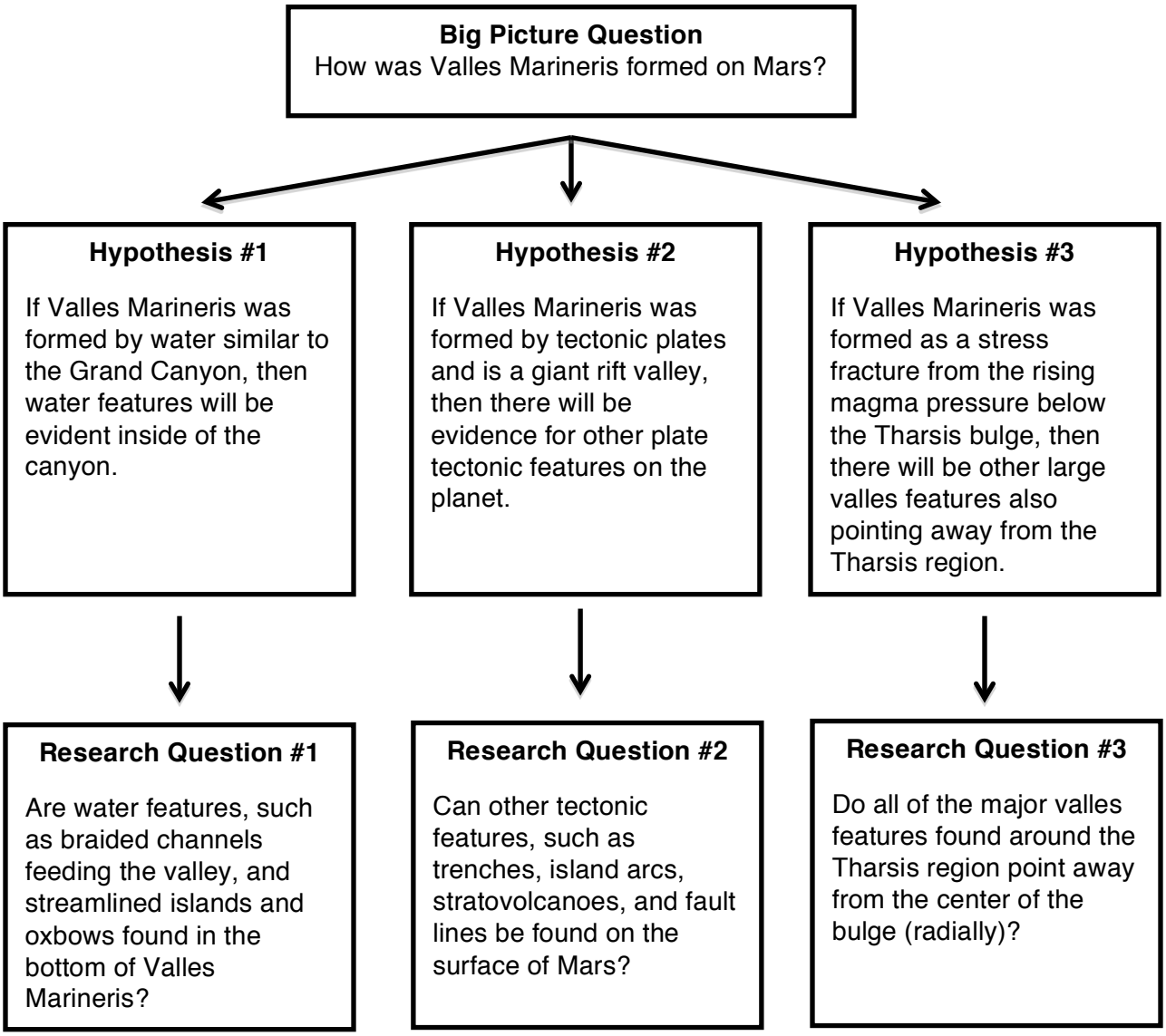
Hypotheses often result from these "big picture questions." These are in the form of potential answers or explanations for the observation. There can be many working hypotheses that are an attempt to answer the question. Each hypothesis is specific to the data that will be collected. The hypotheses must be testable and falsifiable. This means an answer can be found and the answer can either support or disprove the hypothesis.

Research questions are the best explanations to the big picture questions. Research questions are specific to the data that will be collected. Results from each research question can be pooled together to determine the best answer to the big picture question. Sometimes the hypothesis and research question are considered to be the same.

(B) Student Sheet #1. Question and Hypotheses (2 of 4)

NAME:_____

Formation of Valles Marineris Hypothesis Example



(B) Student Sheet #1. Question and Hypotheses (3 of 4)

NAME:_____

Below you will find 2 examples of stories from real research on Mars. These examples are stories about how the scientists came up with their questions for research. Read through each of these scenarios looking for the hypothesis and research question. The big picture question has been provided for you. Be prepared to share your findings with the class. Don't forget, sometimes the question may not be written in the form of a question, but more as a statement.

Gale Crater Landing Site of Curiosity (MSL) Rover

Whether life has existed on Mars is an open question that this mission, by itself, is not designed to answer. NASA's Mars Science Laboratory mission will study whether the Gale Crater area of Mars has evidence of past and present habitable environments. Curiosity will look for three conditions that are crucial for habitability; liquid water, a source of energy and other chemical ingredients utilized by life, such as carbon, amino acids, nitrogen, phosphorus, sulfur, and oxygen.

Big Picture Question: Is there evidence of a past or present habitable environment in Gale Crater?

Hypothesis:

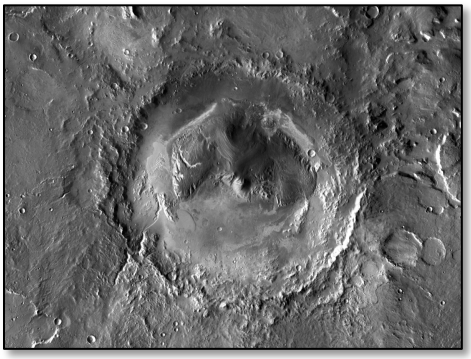
_____

_____

Research Question:

_____

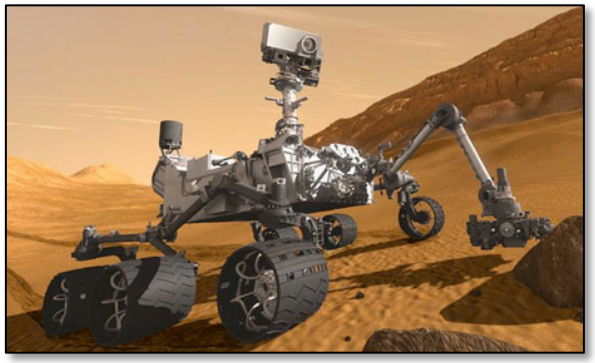
_____



Photos Courtesy of NASA's Jet Propulsion Laboratory

Image left: Gale Crater

Image right: Curiosity Rover (MSL)



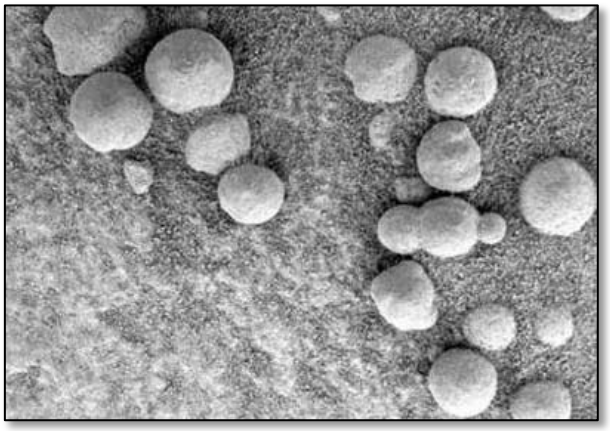
(B) Student Sheet #1. Question and Hypotheses (4 of 4)

NAME:_____

Meridiani Planum Landing Site of Opportunity (MER) Rover

Meridiani Planum interested scientists because it contains an ancient layer of hematite. This hematite was identified using Thermal Emission Spectrometer (TES) data. Hematite is an iron oxide that, on Earth, almost always forms in an area containing liquid water. So how did the hematite get there? There were five or six hypotheses to explain this hematite on Mars. For example, the hematite could have been produced directly from iron-rich lavas. This process would not require liquid water. But if water was involved, then the hematite either formed from the iron-rich waters of an ancient lake, or it formed when Martian groundwater bubbled up though layers of volcanic ash. Another idea was to look for minerals such as goethite and magnetite. If goethite were found among the hematite, which would mean that it was formed in watery conditions, but if magnetite were found instead, a watery past was not likely.

On the ground, Opportunity discovered the hematite is in BB-sized spheres, also called "blueberries" by scientists. These loose blueberries are all over the landing site, making what geologists call a lag deposit. It is thought the blueberries formed when strongly acidic groundwater soaked the basaltic sandstone. This sandstone was rich in goethite, another iron-bearing mineral. The water altered the goethite into hematite, forming spherules within the rocks. Then, over time, as the acid-rotted sandstones weathered away, the tougher spherules came free and collected on the surface.



Hematite spheres (blueberries) photographed by Opportunity Rover.
Photo Courtesy of NASA's Jet Propulsion Laboratory

Big Picture Question: Is there evidence for long standing water in Meridiani Planum?

Hypothesis:

_____

_____

Research Question:

_____

_____

(C) Student Sheet #2. Identifying the Big Picture Question (1 of 2)

NAME:_____

For this activity, you will need the observations and your team chosen topic from the Mars Image Analysis activity. Review the key observations your team used to pick your topic and discuss with your team what was unique and interesting about these observations. Work in a small group to brainstorm some of the big picture questions about your topic. Question prompts have been provided. You are not limited to the number of times you can use a prompt and you might not use all of the prompts. Additional space has been provided in case you want to use a prompt more than once.

What is _____?
(Should be a specific description of an interesting feature you are unable to identify)

How did _____ form?
(Should be a specific feature)

Why does _____ appear _____
_____?
(A specific feature and a description of the appearance)

Why is _____ different from _____
_____?

(C) Student Sheet #2. Identifying the Big Picture Question (2 of 2)

Now that you have a list of possible big picture questions, share your favorite one or two with the team. Explain why you are interested in answering this question and what observations were made that brought you to the question.

Top 2 Big Picture Questions to share:

#1:

_____

_____

_____

This question is interesting and important because:

_____

_____

_____

_____

#2:

_____

_____

_____

This question is interesting and important because:

_____

_____

_____

_____

(D) Student Sheet #3. Identifying the Explanations (1 of 3)

NAME:_____

As a team, you will now need to debate which Big Picture Question you would like to use. Once your team has selected a Big Picture Question, record it here:

Big Picture Question:

_____

_____

_____

With a big picture question in place, you are ready to start brainstorming possible explanations. Create a list of possible answers or explanations to the Big Picture Question. Work with your team to create this list.

(D) Student Sheet #3. Identifying the Explanations (2 of 3)

NAME:_____

Take some time with your team to see if there are tools available to test your explanations. An explanation cannot become an hypothesis if you do not have the appropriate tools available to test them. In this case, you can use the JMARS tool (http://jmars.asu.edu/download-jmars) to see what types of data can be collected. Take a few minutes to use the JMARS tool and record the layers that might be helpful in research of your topic. Record those layers below and explain what type of data they can help you research. An example has been provided for you.

JMARS Layer	What will be measured or recorded?
Ex: Lat/Lon Grid	***Ex: Measure distances of features in km or find the latitude/longitude of a feature***

(D) Student Sheet #3. Identifying the Explanations (3 of 3)

NAME:_____

With your understanding of what tools you have available, go back to your original brainstorming list and mark out the explanations you will be unable to research because you do not have the tools available. From the remaining list, choose two explanations you would like to share with the team as a possible explanation.

#1:

_____

_____

_____

#2:

_____

_____

_____

As a team you will need to debate among all of the possible explanations, which is the best. This will be your primary hypothesis. You may pick a second if it is closely related to the primary. We will revisit this hypothesis after writing our research question to ensure it is testable and falsifiable.

Primary Hypothesis (DRAFT):

_____

_____

_____

(E) Student Sheet #4. Writing a Research Question (1 of 3)

NAME:_____

In order to write a quality research question, you need to consider the information you need to prove or disprove your explanation (hypothesis). You will need to consider the variables you intend to collect data on. A variable is something that will be measured or observed in an experiment. Below you will find a list to get you started. This list does not contain all of the possible variables, but has a good amount to get you started. Create your own list of variables that are specific to your explanation in the area below.

Potential Variables			
Location	**Comparisons**	**Characteristics**	**Measurements**
Region	Similarities	Shape	Length
Distribution	Differences	Type	Diameter
Elevation	Relationships	Texture	Circumference
Lowlands/highlands	Patterns	Quantity	Height

(E) Student Sheet #4. Writing a Research Question (2 of 3)

NAME:_____

Using your list on the previous page, create at least 2 questions for your research on Mars. These questions should be related to your topic/primary hypothesis and be testable. Once you have written your questions, use the Evaluation Criteria in the box below to see if your question qualifies as a testable research question. If you can put a check (√) in all of the boxes, your question should be good enough for your team to consider for your research.

Question 1:

_____

_____

_____

Question 2:

_____

_____

_____

Question		Evaluation Criteria
1	2	
		Question can be answered using materials available and in the time allotted.
		Question focuses on specific features that can be observed using the JMARS tool and THEMIS images.
		Question does not focus on ***how*** the feature formed.
		Question includes observations or is similar to one of these: evidence, similarities, differences, relationship, patterns, etc.
		Question is not a ***why*** or ***how come***.

(E) Student Sheet #4. Writing a Research Question (3 of 3)

NAME:_____

Share your research questions with your team. As a team, debate which question would be the best potential question for your class to research. Decide which final question is the most interesting and answerable question using THEMIS images.

Try not to feel "possessive" of your own created question. Your creation and participation in the team discussions and decisions will help your team select the best and most interesting question to focus on for your research.

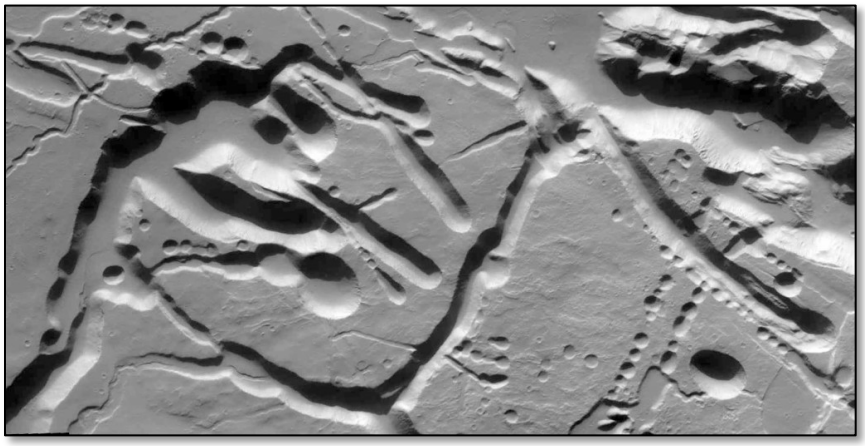
Why is this question the best? List the reasons here:

Final Science Question:

_____

_____

_____



Ascraeus Mons Southwest Flank
NASA/JPL/Arizona State University

(F) Student Sheet #5. Writing a Testable Hypothesis (1 of 2)

NAME:_____

Refer to your primary hypothesis written in Student Sheet #3 and your newly written team question. You will need to modify the hypothesis to more accurately reflect the research question your team has chosen. Once you have written your hypothesis, use the Evaluation Criteria in the box below to see if your hypothesis qualifies as a testable and falsifiable hypothesis. If you can put a check (√) in all of the boxes, your hypothesis should be good enough for your team to consider for your research.

Primary Hypothesis Draft:

_____

_____

Research Question:

_____

_____

_____

Research Hypothesis:

_____

_____

_____

✔	Evaluation Criteria
	Hypothesis can be answered using materials available and in the time allotted.
	Hypothesis focuses on specific features that can be observed using the THEMIS images and JMARS tool.
	Results of the experiment could support the hypothesis OR disprove it.
	Hypothesis includes observations or is similar to one of these: evidence, similarities, differences, relationship, patterns, etc.
	Hypothesis includes an 'If…then…" statement (*note* not always 100% true. Use if it makes sense.)

(F) Student Sheet #5. Writing a Testable Hypothesis (2 of 2)

NAME:_____

If it meets the criteria, share your hypothesis with your team. As a team, debate which hypothesis would be the best for your class to research. Decide which hypothesis is the most interesting and answerable question using THEMIS images.

Try not to feel "possessive" of your own created hypothesis. Your creation and participation in the team discussions and decisions will help your team select the best and most interesting hypothesis to focus on for your research.

Why is this hypothesis the best? List the reasons here:

Final Science Question:

_____

_____

_____

Final Research Hypothesis:

_____

_____

_____