Probability of Life Elsewhere - Student Materials

Unit 2	Earth and Space Science

Student Materials Table of Contents

Performance Task Organizer

Unit 2 Probability of Life Elsewhere	**Earth and Space Science**
Student Name:	

Tell the Story

Evolution of Life on Earth

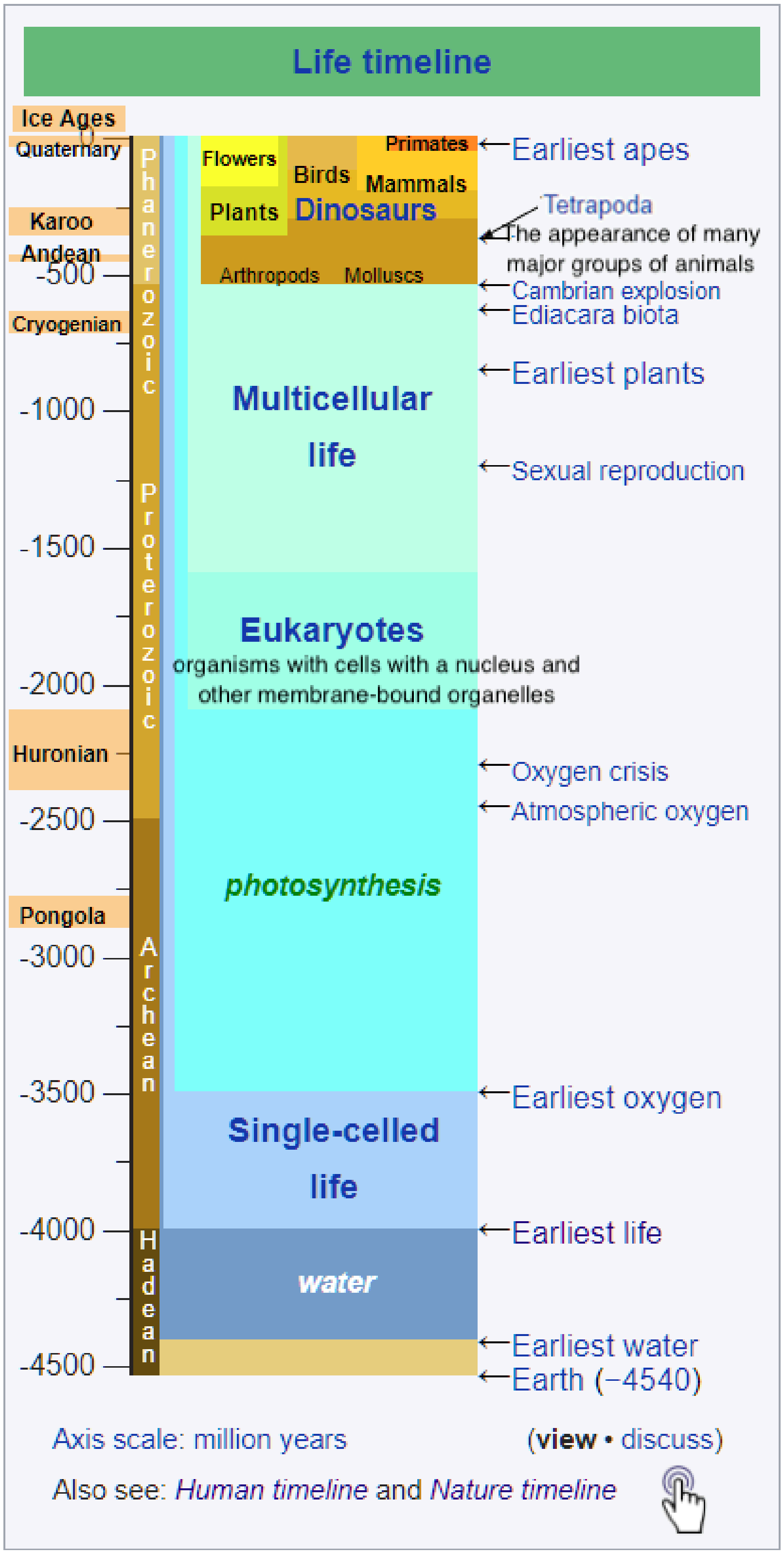
Directions:

1. Silently read or watch the “text” provided to you.
2. Record or annotate three details that are most important to the phenomenon being described for each text.
3. Share with your group. Each person should identify the details that they circled.
4. Discuss as a group, and determine the overall story. What is the phenomenon?

Text 1: The History of Life on Earth

1. ______________________________
2. ______________________________
3. ______________________________

Text #2: Visual Representation of the History of Life on Earth



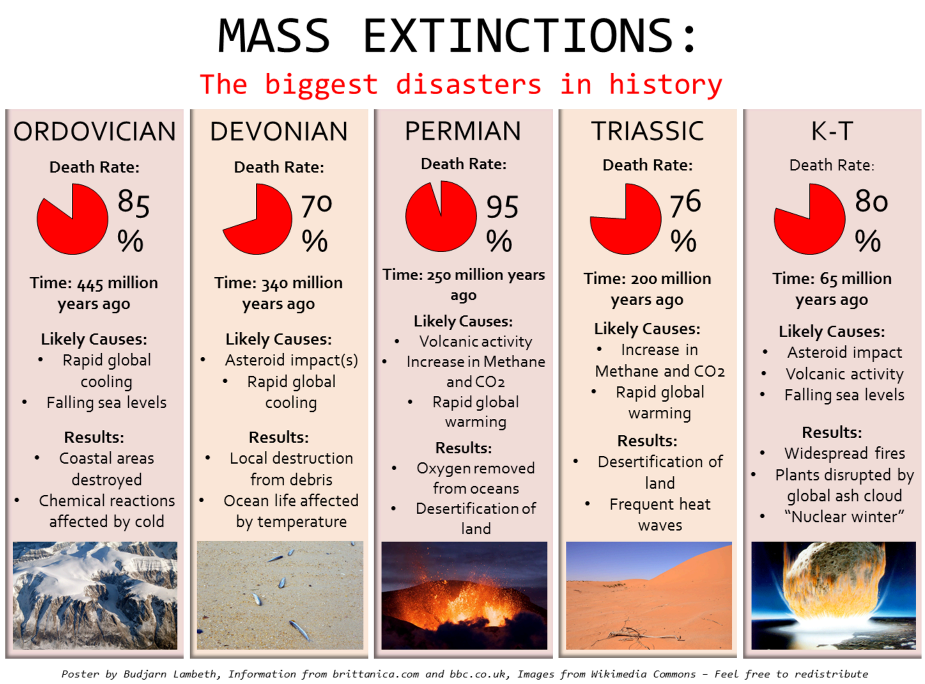
Evolution of Life Timeline

1.

2.

3.

Text #3: Mass Extinction throughout Earth's History



Mass Extinctions

1.

2.

3.

Important details our group surfaced (provide at least 5):

1. ______________________________

2. ______________________________

3. ______________________________

4. ______________________________

5. ______________________________

Overall Story of the Phenomenon (based on group discussion):

Introduction to the Unit Performance Task

Are We Alone?

Does life exist somewhere outside of Earth? What about life that has technology and can communicate like humans?

4.5 billion years passed and 5 mass extinctions occurred before humans appeared on Earth. So far we have yet to come in contact with any other beings from another planet or even find evidence that proves any sort of life exists elsewhere.

So are we alone?

Your task in this unit is to work with classmates to investigate some factors that influence the evolution of life on Earth and explain why modern human's emergence on Earth required nearly 4.5 billion years. Then use your findings to make and defend an argument about the probability of intelligent life existing somewhere outside Earth.

Developing an Initial Explanation

What set of conditions allowed for the evolution of humans on Earth, and why did it take so long?

Your first step in this investigation is to consider details from the Tell the Story texts and work with classmates to develop an initial model that illustrates your group's ideas about why it took so long for humans to appear on Earth.

Initial Explanation

Directions

1. Review the important details from the Tell the Story texts.
2. In your group, identify the following:
    - Factors that support the existence and evolution of life
    - Factors that prevent or limit the existence and evolution of life.
3. Explain what combination of supportive and limiting factors could resulted in the evolution of intelligent life on Earth

You can represent your ideas in words or drawings

What set of conditions allowed for the evolution of humans on Earth, and why did it take so long?

Scientists think that one reason life may not have appeared until approximately 3.5 billion years ago is that it could not evolve during a time of instability in the solar system. Despite Earth having relatively few asteroid impact craters, scientists believe that it was constantly being bombarded by asteroids about 4 billion years ago. Use the evidence from this 5E to explain why scientists believe that to be true.

In your explanation, be sure to include:

1. The evidence for the late heavy bombardment and the time it occurred
2. An explanation of why Earth has relatively few impact craters, including citing evidence from the activities you completed in this 5E
3. The evidence that life appeared after the time of the late heavy bombardment
4. A discussion of the strength or limitations of this evidence in supporting this explanation

For each component of your explanation, you should be citing evidence from the activities in this 5E and linking the evidence to the claim using logical reasoning and scientific concepts to link the evidence to the claim

Claim: Life did not appear until 3.5 billion years ago because the Earth was undergoing a period of heavy asteroid bombardment 4 billion years ago.

Reflection on your Explanation:

For each piece of evidence you used in your explanation, describe the scientific concept and/or logical reasoning you used to link the data to the claim.

What set of conditions allowed for the evolution of humans on Earth, and why did it take so long?

Scientists think that the pace of evolution increased, resulting in much more complex life including humans, in the past billion years as a result of oxygen increasing above a certain threshold. Use what you've learned in this 5E about the dynamics of Earth's systems to explain the complex interactions that had to occur in order to result in the evolution of intelligent life.

In your explanation, be sure to include:

1. At least two examples of an organism that led to changes in the amount of oxygen in one of Earth's systems. Include your evidence and reasoning.
2. At least three examples of a time that a change in oxygen in one of Earth's spheres led to the evolution of more complex life. Include your evidence and reasoning

Claim: Earth's systems and life coevolved over 3.5 billion years, resulting in the evolution of humans, with oxygen playing a central role.

Reflection on your Explanation:

For each piece of evidence you used in your explanation, describe the scientific concept and/or logical reasoning you used to link the data to the claim.

Could life-supporting conditions exist elsewhere?

Given that the universe started as one single mass and expanded outward in every direction, and we know that the processes that formed galaxies and solar systems were the same everywhere, scientists think it is likely that other Earth-like planets exist. Use what you've learned in this 5E to explain how scientists are confident that the big bang theory is correct and why that would result in a universe with similar types of planets and stars throughout.

In your explanation, be sure to include:

1. Evidence that supports the expansion of the universe, called the big bang theory
2. Evidence that supports stars and planets being similar throughout the universe
3. Include your scientific reasoning that links the evidence to the claim

Claim: The way the universe has formed resulted in a universe with similar stars and galaxies throughout.

Reflection on your Explanation:

For each piece of evidence you used in your explanation, describe the scientific concept and/or logical reasoning you used to link the data to the claim.

Given that all the stars and solar systems throughout the universe are similar to what we see in our own galaxy, how likely do you think it is that one of them has intelligent life?

Revisiting the Performance Task: Asteroid Orbits 5E

In order to have a civilization that is able to communicate with other forms of intelligent life in the universe, that civilization needs to exist for long enough to develop the technology to make contact with and receive messages from other advanced societies. As you've learned, asteroid impacts can have devastating effects on species, potentially extinguishing a civilization before it reaches that technological point.

However, as you've also learned, an advanced society can use a piece of technology called a gravity tractor to redirect an asteroid that is on a path to impact a planet.

Use what you've learned in this 5E to explain how a gravity tractor works to protect a planet from impact.

In your explanation, be sure to include:

1. How scientists can predict where an asteroid will be
2. How a gravity tractor works to change the trajectory of an asteroid if it were on a path to hit Earth
3. Include your scientific reasoning that links the evidence to the claim

Claim: scientists can pinpoint where an asteroid is and will be, and then use a gravity tractor to deflect it

Reflection on your Explanation:

For each piece of evidence you used in your explanation, describe the scientific concept and/or logical reasoning you used to link the data to the claim.

Why haven't we found life outside Earth?

In 1961, a scientist named Frank Drake created an equation to predict the likelihood of intelligent life capable of communicating with humans on Earth existing on other planets in the Milky Way.

This equation cannot be solved definitively, because scientists do not yet know what numbers to assign to each factor in the equation.

Given this equation and everything you have learned in this unit, construct an argument about whether or not it is likely that there is intelligent life somewhere else in the Milky Way or in the Universe, and whether or not we will make contact with it.

In your argument, consider the likelihoods following points:

1. There being stars with planetary systems similar to Earth
2. Other planets being stable enough to support life
3. Other planets having the right conditions to produce life and sustain evolution
4. Evolution occurring for long enough on those planets to produce intelligent life
5. Those societies surviving long enough to develop interstellar communication
6. Those societies overlapping with our society such that our signals would be detectable to each other

Stability of the Solar System 5E

Unit 2 Probability of Life Elsewhere	Earth and Space Science
Student Name:	

Craters in the Solar System

Phenomenon: On Earth, the number of impact craters discovered is around 128. On Mars, the number is more than 300,000. On the Moon, the number is more than one million![1]

Directions:

- Look at the surfaces of the Mars, Moon and Earth in Google Maps:
  - Mars
  - Moon Google Maps
  - Earth’s Barringer Crater in Google Earth - this is a link to the best preserved crater on Earth. You can look at it, and then try to find other crater sites, and zoom around the Earth.
- Explore different areas of each world and what the surfaces look like.
- Are there different patterns for the relationship between meteor impacts across the surface of Earth, Mars and the Moon? Write your noticings below, and come up with some ideas for what may be happening here, drawing upon what you know about meteors.

See-Think-Wonder

Use the graphic organizer below to record your ideas from the investigation.

See What patterns did you observe?	**Think** What do those observations make you think about?	**Wonder** What questions do you have?

[1] https://www.science.org/content/article/earths-colossal-crater-count-complete

Early Solar System Investigation

Part 1: Investigating Radioactive Decay and Absolute Dating

Part 1a: Decay Rate Tab

1. Play around with the Radioactive Dating Game - Radiometric Dating | Carbon Dating | Half Life - PhET Interactive Simulations simulation for a few minutes.

2. Click on the tab for Decay Rates. Check Carbon-14.

3. Click on the bucket and add some nuclei to the simulation, observe what happens and note your observations below.

4. What do the red dots represent?

5. What do the blue dots represent?

6. Use the stop and play buttons to control how fast the decay occurs. What is the half life of C14?

7. Explain or draw what the pie graph looks like at one half life.

8. Explain or draw what the pie graph looks like at 2 half lives, then 3 half lives.

9. What happens to the Carbon-14 by the end of the simulation?

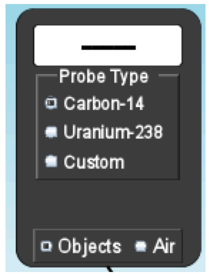
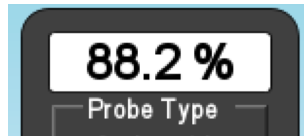
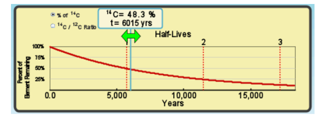
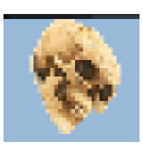
10. Repeat #6-9 for Uranium-238. What is similar between the way Carbon-14 changes and in Uranium-238 changes? What is different?

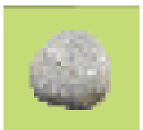
See-Think-Wonder

See	Think	Wonder
What patterns did you notice in how fast Carbon-14 changed? Was it always the same?	In what ways is Carbon-14 stable? In what ways is Carbon-14 not stable?	
What patterns did you notice in how fast Uranium-238 changed? Was it always the same?	In what ways is Uranium-238 stable? In what ways is Uranium-238 not stable?	
What did you notice was different about how fast the two isotopes changed?		

Part 1b: Dating Game

1. Explore the Dating Game tab and collect data to complete the table below.

Layer	Object	**What isotope gives a reading above 0% for this object?** Write one of the choices below for each object. 	**What percent of the isotope was remaining?** 	**What do you estimate the age of the object is?** 
Surface		Carbon -14	98.2%	134 years
				
Layer 1				
				
				
Layer 2				
				

Layer 3				
				
				
Layer 4				
				
Bottom layer				
				
				

2. Complete the See-Think-Wonder chart based on the data you collected.

See	**Think**	**Wonder**
What pattern did you notice in the age of the fossils within the same rock layer?		
What pattern did you notice in the age of objects as you go into lower rock layers?		
What did you notice about the isotope needed to age each object?	In what way does the isotope you chose relate to its stability?	

Part 2: The Age of Rocks in the Solar system

1. To better understand how to use the composition of rocks to determine the age of those rocks, complete Tables 1 and 2 using the information in the Geologically Important Radioactive Elements Used for Radiometric Dating table below. .

Geologically Important Radioactive Elements Used for Radiometric Dating

Parent Isotope	**Daughter Decay Product**	**Half-life** (years)	**Useful Dating Range** (years)	**Datable Materials**
Samarium-147	Neodymium-143	106 billion	10 million - 4.6 billion	Garnets, micas
Rubidium-87	Strontium-87	48.8 billion	10 million - 4.6 billion	Potassium-bearing minerals (mica, feldspar, hornblende),whole igneous or metamorphic rock
Uranium-238	Lead-206	4.5 billion	10 million - 4.6 billion	Uranium-bearing minerals (zircon, apatite, uraninite)
Uranium-235	Lead-207	713 million	10 million - 4.6 billion	Uranium-bearing minerals (zircon, apatite, uraninite)
Potassium-40	Argon-40	1.3 billion	100,000 - 4.6 billion	Potassium-bearing minerals (mica, feldspar, hornblende), igneous or volcanic rock (tuff and/or lava flows)
Carbon-14	Nitrogen-14	5730	100 - 70,000	Organic materials, glacial ice containing carbon dioxide, groundwater, and ocean water

Table 1. Absolute Dating using Uranium-238

Half-Life	**Original Uranium-238 Remaining (%)**	**Number of Years**
0	100	0
1		4.5 billion
2	25	
3		13.4 billion

Table 2. Absolute Dating using Carbon-14

Half-Life	**Original Carbon-14 Remaining (%)**	**Number of Years**
0	100	0

1		5,730
2	25	
3		17,190

a. Based on the information above, under what conditions would you choose to use Uranium-328 over Carbon-14?

b. Based on the information above, under what conditions would you choose to use Carbon-14 over Uranium-238?

2. Use the graph from the "Dating Game' to help you determine the age of the solar system objects below based on their composition.

Table 2. Radiometric Ages of Minerals from Solar System Rocks

Object	Original Uranium-238 Remaining (%)	Age
Oldest Earth mineral	50.5	
Oldest Mars mineral	50.1	
Oldest Moon mineral	50.5	
Oldest meteorite mineral	49.0	

3. When an asteroid impacts the surface of a planet or moon, the intense heat from the impact produces what scientists call 'impact melt rocks'. These rocks can be dated in order to determine when asteroids struck.

Below you will find composition data from rocks that are representative of the large majority of impact melt rocks found in craters on the moon. Scientists have used these samples to figure out when the majority of asteroids struck the moon and other inner solar system objects.

Use the graph from the "Dating Game' to help you determine when the large majority of asteroids struck the moon.

Table 3. Radiometric Ages of Impact Melt Rocks

Object	Original Uranium-238 Remaining (%)	Age
Impact Melt Rock Sample 1	55.7	

Impact Melt Rock Sample 2	55.4	
Impact Melt Rock Sample 3	53.7	
Impact Melt Rock Sample 4	54.9	

Making Sense of the Early Solar System Investigation
See-Think-Wonder
Use the graphic organizer below to record your ideas from the investigation.

See What did you observe?	**Think** What does each observation make you think?	**Wonder** What questions do you have about each observation?
What do you notice about the age of minerals found in different rocks in our solar system?	What does this make you think about the formation of our solar system?	
What is the range in age in impact melt rocks from craters that represent the large majority of craters on the moon?	What does this make you think about when the majority of asteroid impacts on the moon and on other inner solar system objects like the Earth and Mars occurred?	

Explaining the Craters in the Inner Solar System

Based on the explore phase,

1. How old are the oldest rocks on Earth?

2. How does that age compare to rocks from the moon and Mars?

3. Based on that, how old do you think the planets in our solar system are?

4. Based on the melt rocks from the moon, how old long ago did the asteroids impact the moon?

5. If asteroids were bombarding the moon at that time, do you think asteroids were hitting other nearby objects in the solar system?

6. What evidence would support that prediction?

The Late Heavy Bombardment Hypothesis
From PBS

Read the text below and then respond to the two prompts:

It is hypothesized that about 4 billion years ago, 500 million years after the formation of the Sun, all the planets and moons in the solar system were pummeled by asteroids and comets. This period, called the Late Heavy Bombardment (LHB), would have been caused by an instability in the solar system. According to one popular computer model, the four gas giant planets and the icy objects of the Kuiper Belt used to be closer to the Sun than they are now. The orbits of Jupiter and Saturn changed so that Jupiter completed two orbits in the time that Saturn orbited the Sun once. The resulting interaction between Jupiter and Saturn created an enhanced gravitational force, which destabilized the orbits of Neptune and Uranus and flung them into the Kuiper Belt, causing the small objects in the belt to scatter. Some asteroids were ejected from the solar system while others collided with other objects in their paths. Impact craters on the Moon, Earth, and other moons and planets may be evidence of this period of heavy bombardment.

Such a period of heavy impacts would have had a significant effect on the evolution of the planets and the development of life on Earth. It is possible that asteroids delivered basic ingredients for life, like water and other key molecules, to Earth during this period. It is also possible that life had already developed on Earth before the LHB.

Think-Talk-Open Exchange

Think - Respond to the prompt individually, in the space below.

1. How does the evidence you saw in the Dating Investigation support the Late Heavy Bombardment hypothesis?

2. What implications might that have had for life on Earth?

Discuss your ideas with your group, using Think-Talk-Open Exchange, and then write down any new ideas you have here.

Summary Task

Today we completed a class consensus discussion! How did it go?

1. One thing that went well in the discussion:

2. One thing we can improve the next time we have a discussion:

3. One person who helped me learn today:

What did you learn from this person?

4. One idea that I contributed to my group or my class:

Explain what you know about the following questions, based on what we discussed today:

1. Describe how the process of radioactive decay provides evidence for the stability or change of celestial bodies.

2. Use scientific reasoning to explain how the geologic processes on Earth contribute to the changing visual appearance of craters on Earth compared to other celestial bodies.

The Role of Water Investigation

In the previous activity, you established that asteroids likely hit Earth with the same frequency and at the same time as they hit the moon and Mars. However, as you saw, Earth has much less evidence of this asteroid activity than the moon and Mars do.

In this activity, you will investigate how water on Earth might have contributed to the lack of visible craters on Earth's surface compared to other celestial bodies.

Part 1. Chemical Weathering
In this part of the investigation, you will perform an experiment to test how water affects Earth's materials and through the processes of chemical weathering

Materials:

- Two pieces of chalk
- White vinegar
- Clear cups
- Electronic balance
- Masking tape
- Water
- Stopwatch
- Goggles
- forceps

Procedure:

1. Using the masking tape, label one cup "water" and one cup "vinegar"
2. Measure and mass of each piece of chalk and record it in the data table
3. Place one piece of chalk in each cup
4. Pour water and vinegar over the pieces of chalk in the corresponding cup
5. Set the timer for 5 minutes and begin timing
6. While the timer is running, record your observations in the data table
7. After 5 minutes, measure the mass of each piece of chalk and record it in the data table
8. Calculate the change in mass of each piece of chalk and record that number in the data table

1. State the independent variable in this investigation:

____

2. State the dependent variable in this investigation:

____

3. Write a prediction of how your dependent variable will be affected in this investigation:

____

____

Perform the experiment according to the steps above and record your data in the Data Table

Data Table

Liquid	Initial Mass	Mass after 5 Minutes	Change in Mass	Qualitative Observations
Water				
Vinegar				

4. Analyze the results. What was the relationship between your independent and dependent variables?

5. Based on these results, how do you think acidified rain would affect rock formations on Earth over time?

Part 2. Erosion and Deposition
In this part of the investigation, you will design and perform an experiment to test how water affects Earth's materials and the processes of erosion and deposition.

Possible materials:
- Stream table
- 2L soda bottle with the bottom cut off and a hole in the top or plastic cup with holes in the bottom
- Wet fine sand
- Wet coarse sand
- Wet gravel
- Ring stand and clamp(s)
- Spray bottle
- Stream table dividers
- Stopwatch
- Water
- ruler/meter stick/measuring tape
- A round object, like a ball, for creating craters in the sediment/gravel

1. State the independent variable in this investigation:

2. State the dependent variable in this investigation:

3. Write a prediction of how your dependent variable will be affected in this investigation:

4. Write the step by step instructions you will follow for your investigation

5. Draw how you plan to set up your experiment:

6. Construct a data table for your results, then conduct your experiment and fill in the data table

7. Analyze the results. What was the relationship between your independent and dependent variables?

8. Did your data support or refute your hypothesis?

9. Based on both investigations, how could the processes of erosion and deposition affect rocks that had already experienced chemical weathering?

Making Sense of the Role of Water Investigation

See-Think-Wonder

See	Think	Wonder
What do you notice about how acidic liquid affects the minerals in chalk?	How do you think that relates to the lack of visible craters on Earth?	
What do you notice about how the movement of water affects soils and rocks?	How do you think that relates to the lack of visible craters on Earth?	

The Role of Water

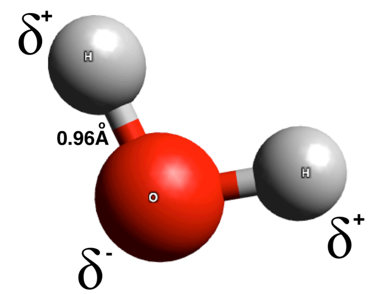
The Role of Water

Guiding question: Why is water such an important part of weathering, erosion, and deposition?

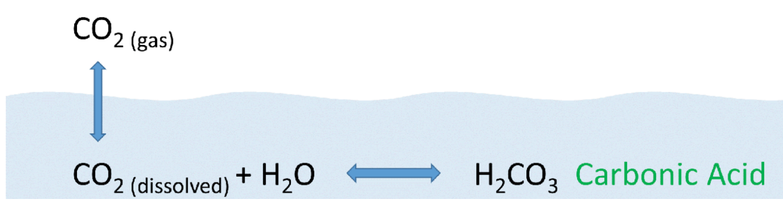
Water possesses a unique ability to dissolve a wide range of substances, including gasses like carbon dioxide. This remarkable property is crucial for various natural processes and the functioning of living organisms.

Water's ability to dissolve substances stems from its polar nature. The water molecule consists of two hydrogen atoms and one oxygen atom, with the oxygen atom being slightly negative and the hydrogen atoms slightly positive. This polarity creates an electrically charged environment within the water molecule.

When carbon dioxide (CO_2) encounters water, it undergoes a dissolution process. The polar water molecules surround the CO_2 molecules and form weak hydrogen bonds with them. These interactions disrupt the intermolecular forces within the CO_2 gas, causing it to dissolve in the water. The dissolved CO_2 forms carbonic acid (H_2CO_3), which chemically weathers rocks and contributes to erosion and deposition.



Polar Water Molecule



This ability of water to dissolve carbon dioxide, convert it to carbonic acid, and weather rocks is crucial for the carbon cycle and the regulation of carbon dioxide levels in the atmosphere and bodies of water. It facilitates the exchange of CO_2 between the atmosphere and oceans, influencing climate patterns and supporting marine life.

Water's capability to dissolve a diverse array of substances, including carbon dioxide, is a testament to its importance as a universal solvent, and its role in the movement of Earth's sediments.

Part 2. The Presence of Water in the Inner Solar System

Read the table below and answer the questions that follow.

Planet / object	Water
Earth	71% of the Earth's surface is water 96.5% of all the Earth's water is contained within the oceans as salt water 3.5% is freshwater lakes and frozen water locked up in glaciers and the polar ice caps.
Mercury	Very small traces of water vapor in its atmosphere
Mars	Almost exclusively ice at the poles. Small amount present in the atmosphere as vapor Some transient liquid water on the Martian surface
The Moon	The Moon has water, although it exists in limited quantities and mostly in the form of ice.

Based on the levels of water in each location, would you expect Earth-like levels of weathering, erosion, and deposition on Mercury, Mars, or the moon? Why or why not?

Part 3: Constructing a Scientific Explanation for Differences in the Number of Craters on the Moon, Mars, and Earth

Using evidence you have gathered so far, write a scientific explanation in response to the following question:

Question
Why is there a tremendous difference in the number of craters found on the Moon, Mars, and Earth?

Scientific Explanation

Evaluate Your Explanation

An important part of writing scientific explanations is evaluating the extent to which reasoning and data support an explanation.

1. Evaluate your explanation by naming each piece of evidence you used to support your claim and explicitly citing the scientific reasoning that links each piece of evidence to your claim.

Claim:	
What pieces of evidence do you have?	**What scientific reasoning links the evidence to your claim? How?**

Summary Task

Today we completed a class consensus discussion! How did it go?

1. One thing that went well in the discussion:

2. One thing we can improve the next time we have a discussion:

3. One person who helped me learn today:

What did you learn from this person?

4. One idea that I contributed to my group or my class:

Explain what you know about the following questions, based on what we discussed today:

1. What have you learned about the strength of scientific explanations?

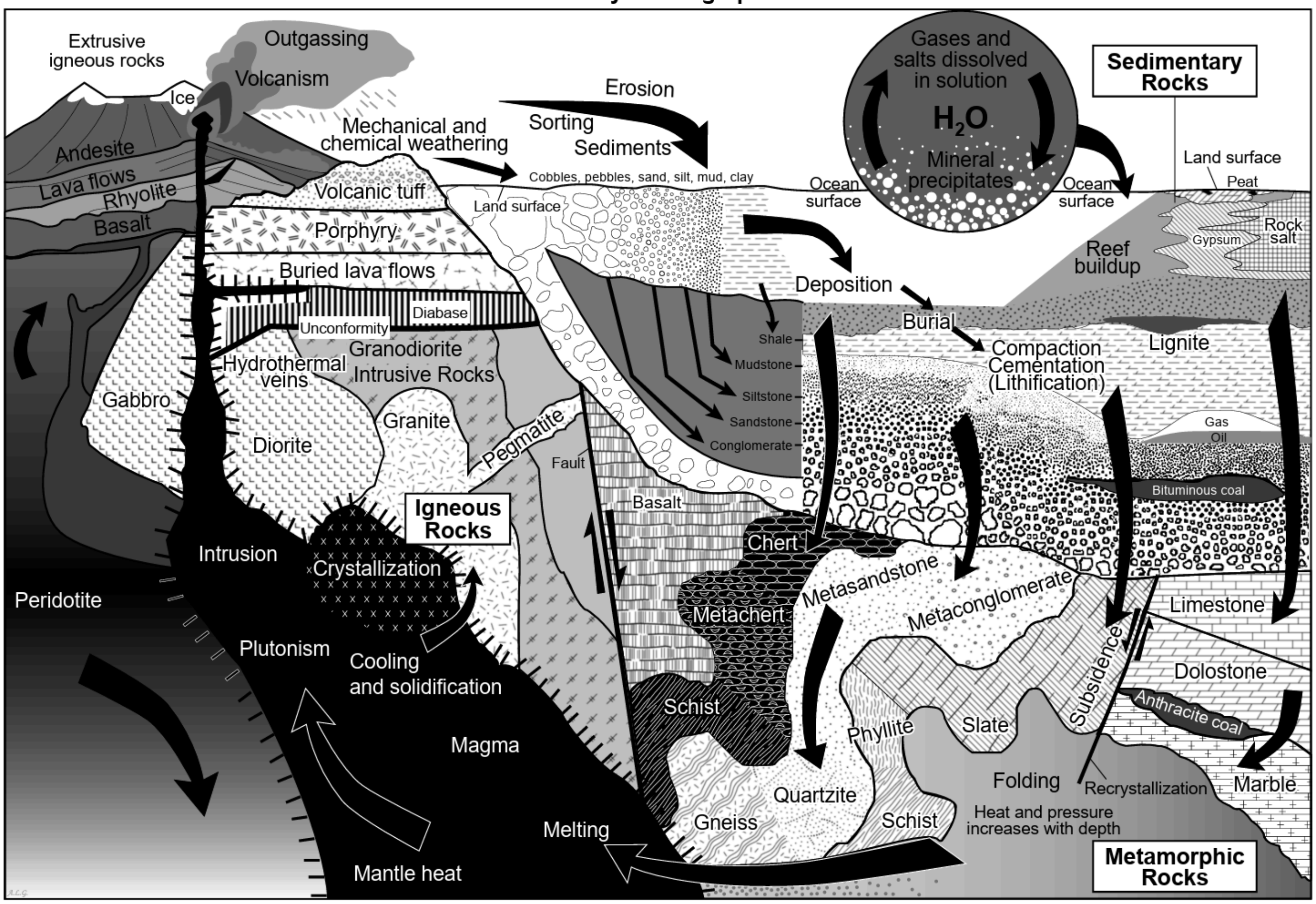
2. What have you learned about the stability of the solar system?

The Rock Cycle

As you learned in the Role of Water Investigation, the amount of water present on Earth is unique, and its properties influence the processes of erosion, deposition, and chemical weathering of rocks. These processes are all part of the rock cycle.

Analyze the diagram below and answer the questions that follow:

Rock Cycle Infographic



1. Which processes in the diagram rely on water in the atmosphere? Explain the role of water in those processes

2. Using a blue marker or colored pencil, outline the section of the diagram that illustrates sedimentary rocks and the processes that create them
3. Sedimentary rocks form in layers. On the diagram, draw stripes where you see indications of layers forming in the sedimentary rocks.
4. Think back to the layers you observed in the Dating Game activity. How does this rock cycle diagram explain why deeper layers had older dates?

5. Look at the directions of the arrows overall, throughout the diagram. Explain how this image is showing a cycle.

6. What does this cycle demonstrate about the stability of rock formations across Earth's history? Support your answer.

7. The straight lines with double arrows on the diagram indicate fault lines where plate tectonics are creating movement. How do you think this motion contributes to the stability or change of rock formations across Earth's history? Support your answer.

As you've already learned, Earth is unique in how much liquid water it has, which contributes to its active rock cycle. Use the table below to compare the tectonic activity of Earth to the other celestial bodies we have been learning about, and then answer the final question below.

Planet / object	Water
Earth	Undergoes extensive tectonic activity, shaping the planet's surface.
Mercury	Does not have active plate tectonics. However, Mercury does show signs of past tectonic activity, with scarps and cliffs indicating crustal compression and contraction as the planet cooled and shrank over time.
Mars	Does not currently display active plate tectonics either. While there is evidence of ancient tectonic activity on Mars, such as large rift valleys and volcanic features, these processes seem to have ceased long ago.
The Moon	Not known to have active plate tectonics. Although it has experienced tectonic activity in the past, particularly during its early history, the Moon lacks the same level of geologic activity as Earth.

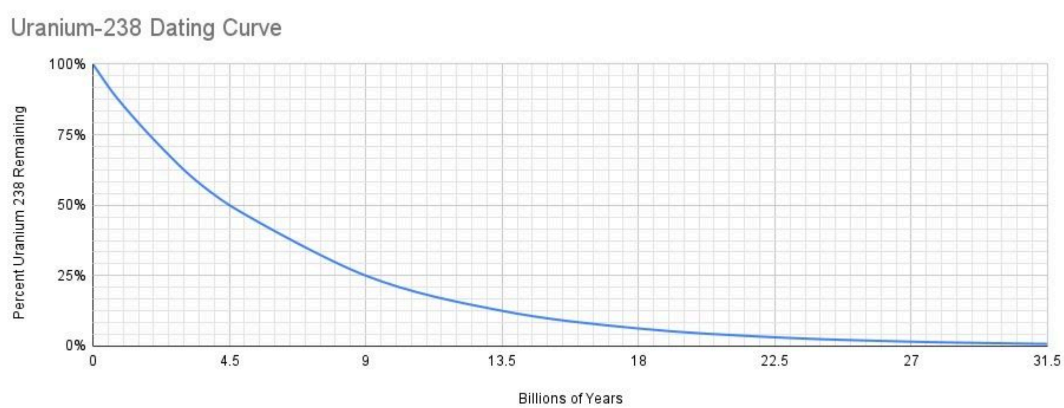
Conclusion:

8. Looking at the diagram as a whole, explain both how the rock cycle contributed to the evolution of life and how it (and tectonic activity) disrupted the record of craters on Earth compared to those of other planets.

The Beginning of Life on Earth

This image shows the oldest rock that contains evidence of life. Its striped pattern defines it as a stromatolite formation, a type of rock formation created by microscopic organisms living in colonies. It comes from an ancient ocean, and has been determined to have 59% of Uranium-238 remaining.

Use the Uranium-238 Dating Curve below to determine the age of this rock.



How old is the sample, based on this curve?

Using this sample alone, can you rule out the possibility of life evolving before 3.5 billion years ago? What are the strengths and limitations of this sample in drawing conclusions in support of the claim that life evolved 3.5 billion years ago?

Stability of the Solar System Performance Task Rubric

<table>
<tr><th>Stability of the Solar System</th><th>Proficient</th><th>Developing</th></tr>
<tr><td>Explanation Rubric</td><td>Claim and Evidence

Effectively and clearly provides evidence in support of the claim that includes all of the elements below:
At least 3 sources of relevant evidence are provided, including evidence:
of when the solar system formed
of when the great bombardment occurred
that accounts for the differences in the number of craters on other celestial bodies and Earth
Evidence is data from an investigation or resource in the learning cycle
Scientific Reasoning & Logic

Effectively and clearly provides scientific reasoning and logic that includes all of the elements below:
An accurate explanation of radiometric dating and surface processes on Earth
Includes a logic statement that links the evidence to the claim (including words such as because and therefore)
A discussion about the strengths and limitations of the data in support of the claim</td><td>Claim and Evidence

Provides evidence in support of the claim that includes some of the elements below:
At least 2 sources of relevant evidence are provided, including evidence:
of when the solar system formed
of when the great bombardment occurred
that accounts for the differences in the number of craters on other celestial bodies and Earth
Evidence is data from an investigation or resource in the learning cycle
Scientific Reasoning & Logic

Effectively and clearly provides scientific reasoning and logic that includes some of the elements below:
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</table>

Student Self- Score	**Circle One** **Proficient** **Developing**	**Glow**: **Grow**:
Teacher Score	**Circle One** **Proficient** **Developing**	**Glow**: **Grow**:

Relevance to your life: Think about everything that you have learned throughout this unit so far.

1. What is one idea and/or skill you learned that you think is important to teach someone in your family or community?

___

___

2. To whom do you intend to teach this idea and/or skill? Why do you think it is important for this person to learn this idea and/or skill?

___

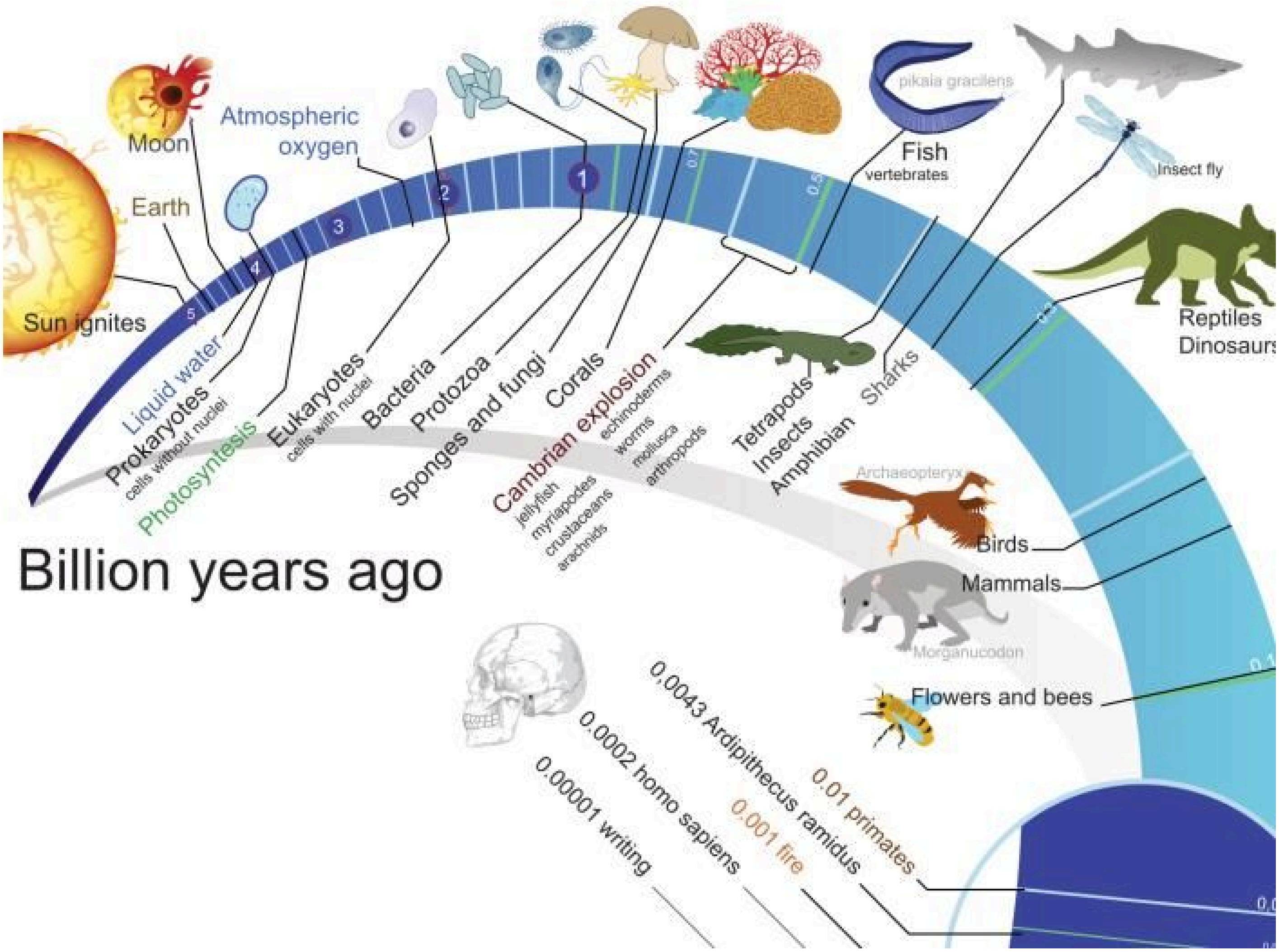
___

Coevolution of Earth and Life 5E

Unit 2 Probability of Life Elsewhere	**Earth and Space Science**
Student Name:	

The Pace of Evolution

Phenomenon:
The pace of evolution has increased over the past 4.6 billion years. Use the diagram to answer the prompts below, and then follow instructions to brainstorm about evolution below.



Based on the diagram:

1. When did the Earth form?

2. How long did it take for the first signs of life to appear?

3. After simple cells appeared, how long did it take for complex cells (with nuclei) to evolve?

4. After complex cells appeared, how long did it take for cells that live clustered together to appear?

5. After clustered cells appeared, how long did it take for different animals like jellyfish and worms to evolve?

6. How much change has occurred in the last billion years?

After reading about the phenomenon described above, brainstorm ideas about:

1. What changes might have occurred that allowed life to evolve on Earth
2. What factors may have changed to allow life to become more complex
3. What may have allowed evolution to progress faster as time passed

In order to brainstorm those ideas:

- Think about what you have learned about the history of the solar system and the formation of Earth so far
- Consider what you know about our Earth and what is necessary for life
- Brainstorm 2-5 ideas for how changing conditions on Earth may have influenced the speed of evolution of complex life
- Explain your thinking in the column on the right.

What are your ideas for what may have influenced the speed of evolution of complex life	What evidence and / or scientific ideas support this?

Beginnings of Life Investigation

Introduction: In this activity, you will investigate the fossil record, which has been formed over billions of years as layers of sediment have been deposited by the rock cycle. By investigating the fossil record, you will uncover events related to life on Earth (biological events) and events related to other Earth systems (geological events). Analysing these events and their connections will help you to gain a better understanding of how life evolved on Earth.

Part 1. Reconstructing Earth's Geological and Evolutionary History

Directions: follow the steps below to construct a timeline of Earth's Geological and Biological Evolutionary Histories. When you are done, answer the questions below and then complete the See-Think-Wonder chart.

1. On a piece of chart paper, draw a line across the middle of the page and set it up as a timeline from 4 billion years ago to now.
2. Label the top half of the page as "Life on Earth" and label the bottom half of the page as "Other Earth's Systems".
3. Sort the cards along the timeline, placing the cards according to their moment in time and impacted system.

Analysis Questions:

1. Based on the timeline, which events do you think impacted other events? Add lines on the timeline to represent those relationships and add written predictions about how they might have affected each other.
2. Based on the timeline, how do Earth's systems seem to affect life on Earth?

3. Based on the timeline,how does life on Earth seem to affect Earth's systems?

4. Looking at the images of the rock and fossil samples, how easy is it to determine what the fossils are showing (you if you didn't have captions)?

5. What evidence do you have to support your conclusions? Is that evidence correlative or causative? What additional information would you need to strengthen those conclusions?

6. Based on what you know about the rock cycle and the movement of tectonic plates, why might it be challenging to create a complete timeline of all the changes to the geosphere and the biosphere?

Part 2. Dating Fossil Layers

Introduction: The dates on the fossils in the last part were determined using radioactive dating, just like were used to date the rocks and craters from the earliest phases of the solar system. When looking at the whole length of Earth's history and fossil record, different isotopes are used depending on the age and composition of the samples. In this activity, you will use information about the properties of different radioactive isotopes to determine which isotopes would be most useful in different scenarios based on their half lives.

Directions: Use the chart below to answer the questions that follow.

Geologically Important Radioactive Elements Used for Radiometric Dating

Parent Isotope	Daughter Decay Product	Half-life (years)	Useful Dating Range (years)	Datable Materials
Samarium-147	Neodymium-143	106 billion	10 million - 4.6 billion	Garnets, micas
Rubidium-87	Strontium-87	48.8 billion	10 million - 4.6 billion	Potassium-bearing minerals (mica, feldspar, hornblende),whole igneous or metamorphic rock
Uranium-238	Lead-206	4.5 billion	10 million - 4.6 billion	Uranium-bearing minerals (zircon, apatite, uraninite)
Uranium-235	Lead-207	713 million	10 million - 4.6 billion	Uranium-bearing minerals (zircon, apatite, uraninite)
Potassium-40	Argon-40	1.3 billion	100,000 - 4.6 billion	Potassium-bearing minerals (mica, feldspar, hornblende), igneous or volcanic rock (tuff and/or lava flows)
Carbon-14	Nitrogen-14	5730	100 - 70,000	Organic materials, glacial ice containing carbon dioxide, groundwater, and ocean water

1. Dating of the iron band formations has been established using both Uranium-235 and Rubidium-87 dating. Using the information above, complete the tables below comparing the half lives of each isotope.

Half-Life	Original Uranium-235 Remaining (%)	Number of Years
0	100%	0
1		
2		
3		
4	6.25%	

Half-Life	Original Rubidium-87 Remaining (%)	Number of Years
0	100%	0
1		
2		
3		
4	6.25%	

2. The iron band formations were found to be approximately 2.5 billion years old.
   a. Approximately how much of the original Uranium-235 would be remaining in a sample of that age?

b. Why would it be more challenging to determine how much of the original Rubidium-87 would remain in the 2.5 billion year old sample?

c. Based on those answers, what is an advantage of using an isotope with a shorter half life?

3. Early humans emerged about 200,000 years ago. Based on the information in the chart above, which isotope would be useful for dating fossils of early humans and our ancestors? Support your answer with evidence from the chart.

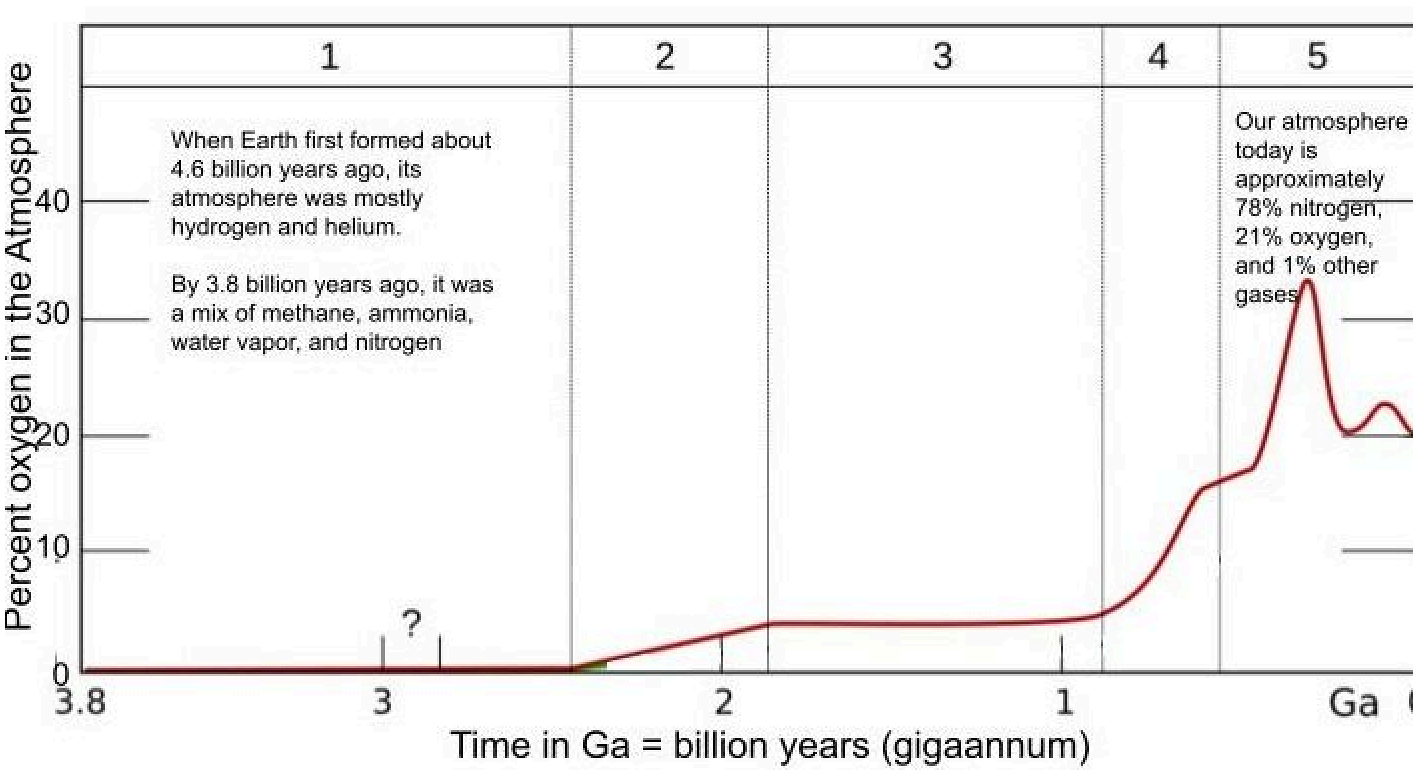
4. For whichever isotope you selected in question 3, complete the half life table below:

Half-Life	**Original __________ Remaining (%)**	**Number of Years**
0	100%	0
1		
2		
3		
4	6.25%	

Part 3. Oxygen in Earth's History

Introduction: Using a collection of data, including isotope information, fossils, and the presence of oxidized rocks and minerals, scientists have reconstructed the levels of oxygen in the atmosphere over Earth's history. In this activity, you will compare this graph of oxygen levels to the timeline that you created in order to better understand the relationships that have shaped the evolution of humans.

Stages of Atmospheric Oxygen in Earth's History



1. Based on the graph above, when did oxygen start to increase from nearly 0%.

2. Based on the graph above, when did oxygen start to increase sharply?

3. Based on the graph above, when did oxygen reach its highest levels?

4. How does this graph compare to the timeline you made?

5. Based on your timeline, why do you think oxygen concentration in the atmosphere increased so sharply about 2.1 - 2.4 billion years ago?

6. Using the timeline and this graph, how do you think that rise in oxygen impacted the evolution of complex organisms?

7. Using your timeline and this graph, how do you think the rise in complex organisms impacted the planet?

Making Sense of the Beginnings of Life Investigation
See-Think-Wonder

Use the graphic organizer below to record your ideas from the investigation.

See What do you observe?	**Think** What do those observations make you think about?	**Wonder** What questions do you have?
What do you notice about how geological factors on Earth have changed over time?		
What do you notice about how biological factors on Earth have changed over time?		
What patterns or relationships between changes in geologic factors and biological factors do you observe?		
What do you notice about the role of different radioactive isotopes in the reconstruction of the fossil record?		

What do you notice about how your reconstruction of the fossil record aligns with the graph of oxygen levels throughout time?		

Arguing for Coevolutions of Earth and Life

Introduction: Coevolution means evolving together. In this case, the evolution of the planet Earth happened together with the evolution of life on this planet. Using the information you learned in the Beginnings of Life Investigation, you will provide evidence for claims relating to the relationships between geological and biological changes on Earth.

The Role of Oxygen in Earth's History: as you watch the video, record the ways in which oxygen changed the surface of Earth:

- ______________________________
- ______________________________
- ______________________________
- ______________________________
- ______________________________
- ______________________________
- ______________________________

Part 1. Evidence of Coevolution

Instructions: After watching the video, use evidence from your timeline, and the oxygen graph, and the video, to add evidence and scientific reasoning in support of the claims below.

Claim	Evidence (what is actually seen in the fossil/geological record)	Reasoning (what we know about the processes that would have resulted in the evidence found in the geological record)
Claim: Early life forms influenced oxygen levels in the oceans		
Claim: increasing oxygen levels in the ocean and atmosphere influenced geological formations and processes, both in the ocean and on land		
Claim: Increasing oxygen in the oceans and atmosphere influenced biological evolution in the ocean and on land		

Part 2. Constructing an Argument from Evidence

Using the claim and evidence cards from Part 1, construct an argument in response to the prompt below:

Claim: The evolution of complex organisms relied on the interactions and co-evolution of the biosphere and Earth's systems

In your response, be sure to include the following:

- Information about the composition of the Earth's atmosphere when it formed and today
- At least one piece of evidence for the emergence of photosynthetic organisms
- At least one piece of evidence for how oxygen impacted Earth's systems
- At least one piece of evidence for how oxygen impacted the biosphere
- A description of causal links and feedback mechanisms between the biosphere and Earth's system

As you determined during the investigation, the evidence used to reconstruct early life is challenging to find and use.

Read the text below, and then write a reflection in response to the prompt that follows

Signals in the Sands of Time

The oldest species on our planet were microscopic, nothing more than itty-bitty specks. Detecting them, and verifying their identity, is a complicated task that often relies not only on hunting down tiny remains but also on chemistry and perceiving how those microorganisms modified their environments.

Picking out the evidence of Earth's earliest life is more than a needle-in-a-haystack problem. The entire planet is the metaphorical haystack, while the needles are no more than microscopic cells or faint chemical traces. Even when scientists can pin down possible candidates, it can be hard to know for sure when something is a signature of ancient life rather than a plain-old geologic phenomenon.

The search for the signs of early life, what experts call biosignatures, often focuses on four different lines of evidence, says University of New South Wales astrobiologist Tara Djokic. The first kind of evidence is relatively large and can be seen with the naked eye, such as stromatolites or other fossilized structures. Other traces are much harder to find, and that group includes chemical traces of fossils, degraded biological compounds, and fossils of microorganisms themselves. In addition, some non-biological processes and phenomena can mimic the shape and chemical signatures of microbial life.

Finding any one of the four markers is a good hint. But, Djokic says, “finding more than one of these together would of course strengthen the argument.” That’s because it’s not always easy to tell what’s a real sign of early life and what’s a trick from deep time. Sometimes folds in rock or other non-living features can look like stromatolites. What might look like a group of tiny cells could be some kind of sedimentary structure. Billions of years have passed since the time Earth’s first life originated. The rocks containing signs of early life, Djokic says, “have been deformed, and metamorphosed by heat, stress, and hydrothermal alteration and then subject to billions of years of weathering processes” such as erosion. And there aren’t many of them left exposed. “Thanks to billions of years of the rock cycle, there are not so many rocks which are even suitable to search in for signs of early life,” Olcott says. Searching for early life requires understanding—and correcting for—the factors that may obscure the truth. “It’s like coming to a crime scene and having to piece together what has happened and who was involved,” Djokic says.

Such clues tell us what to look for as we search other planets for life. “These studies have given us an idea of *how* to search other planets,” Olcott says, helping to refine what lines of evidence to look for and collect. Those plans are already underway, to be launched with the Mars 2020 Perseverance rover this year. “Decades of fighting over evidence and interpretations on Earth have hopefully prepared us to mount a search for potential signs of life elsewhere,” Olcott says.

Reflect on the evidence you used in your argument.

How does the variation or uncertainty in the data affect its usefulness? Support your answer with specific examples.

How helpful is the data for determining causal or correlational relationships between events in your timeline? Support your answer with specific examples.

Summary Task

Today we completed the first class consensus discussion of the unit! How did it go?

1. One thing that went well in the discussion:

2. One thing we can improve the next time we have a discussion:

3. One person who helped me learn today:

What did you learn from this person?

4. One idea that I contributed to my group or my class:

Explain what you know about the following questions, based on what we discussed today:

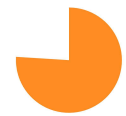
1. Consider oxygen levels in the atmosphere and oceans. How does the stability of Earth's systems or changes to Earth's systems impact life?

2. Consider the following statement: much of science deals with constructing explanations of how things change and how they remain stable. Use examples from this investigation, the previous investigation, or previous units to support this statement.

3. When writing an argument, why would it be important to discuss the factors that affect the quality of your data and evidence? Name at least one example of a factor in this activity that impacted the quality of your data and evidence.

Summary of Mass Extinction Events

When we think about the likelihood of finding intelligent life on other planets, not only do we have to consider the conditions that would have made its evolution possible, but we also have to consider how long that civilization may have existed. On Earth, there have been several major extinction events that have eradicated most species, both destroying their evolutionary lines and also paving the way for new species to take over.

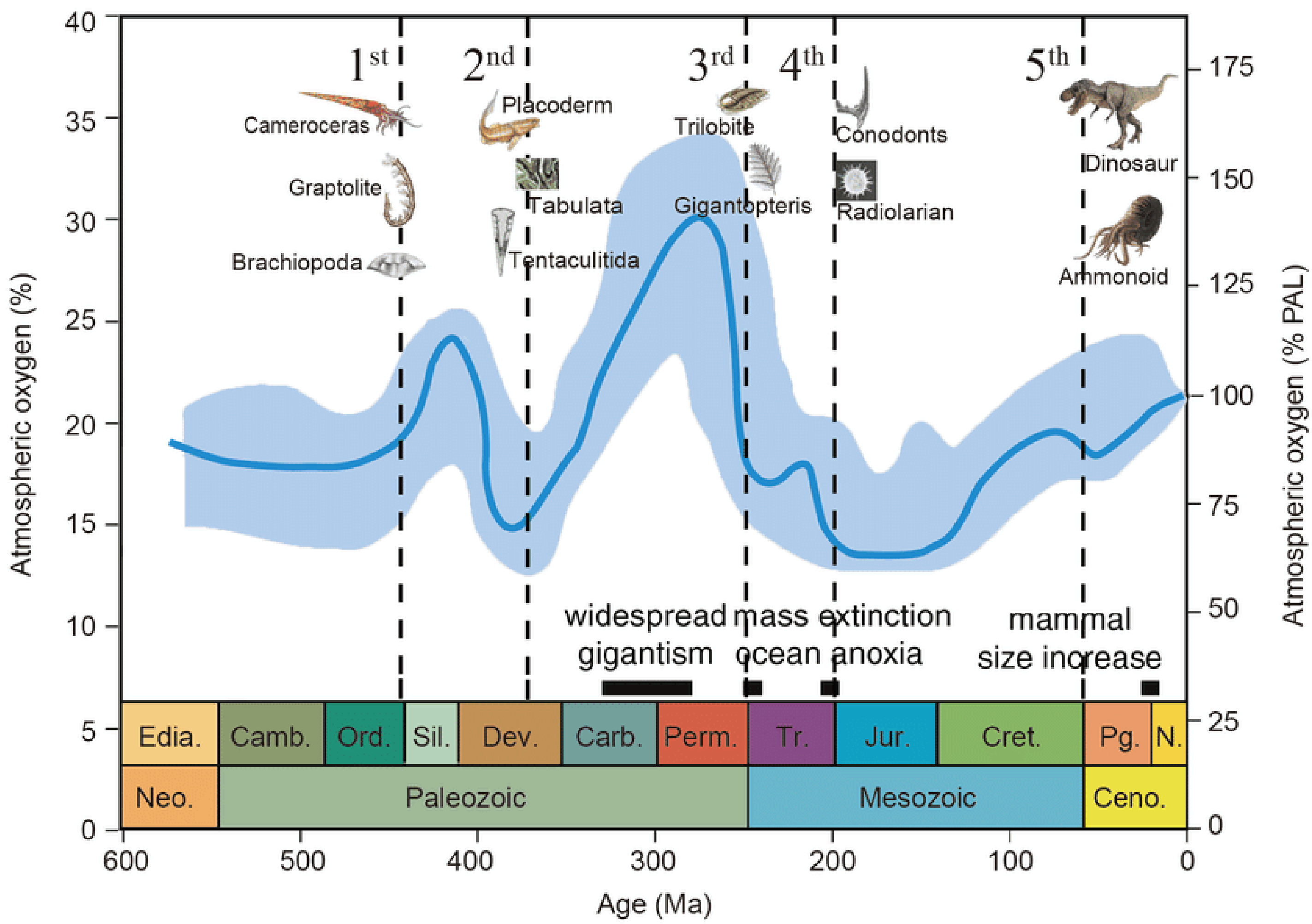
Extinction Event	Ordovician	Devonian	Permian	Triassic	Cretaceous– Paleogene (K–Pg)
Extinction Rate	 85% of all species	 75% of all species	 90% of all species	 76% of all species	 75% of all species
Date	**444 million years ago**	**360 million years ago**	**252 million years ago**	**201 million years ago**	**66 million years ago**
Earth's Systems Contributing Factors *Note: in many of these instances, scientists are still working out the exact causes of each extinction event. Changes related to temperature and atmospheric and ocean chemistry have been found through isotopes and fossil records	• Movement of the supercontinent Gondwana into Earth's southern hemisphere. • Repeated rises and falls in sea levels over millions of years. • Start of an ice age during the late Ordovician period • Changes in water chemistry, such as oxygen depletion	• Significant global cooling and glaciation (ice ages). • Repeated rises and falls in sea levels over millions of years • Widespread oxygen depletion in the oceans • Volcanic activity released gases that disrupted the climate and ocean chemistry.	• Massive volcanic eruptions • Significant increases in methane and CO_2 • Rapid global warming • Ocean acidification caused by increased levels of carbon dioxide.	• Massive volcanic activity. • Significant increase in methane CO_2 • Severe global warming. • Ocean acidification caused by increased levels of carbon dioxide.	• Massive asteroid impact. • Dramatic drop in global temperatures. • Massive volcanic activity

Immediate Biological Impacts *Note: these impacts are determined by shifts in the fossil record correlating with this time period	• Significant habitat loss for marine species • Extinction of many marine invertebrates.	• Collapse of reef ecosystems and the extinction of reef-building organisms like corals. • Extinction of many marine species, including many corals and lobe-finned fish.	• Extinction of a vast majority of life in the oceans and on land. • Major victims included marine invertebrates as well as many land animals and plants.	• Significant habitat loss and environmental changes • Collapse of many ecosystems • Disappearance of a variety of marine and terrestrial species	• Collapse of food chains due to disrupted photosynthesis. • Significant loss of biodiversity • End of the reign of the dinosaurs
Later Biological Impacts *Note: these impacts are determined by shifts in the fossil record correlating with this time period	Marine vertebrates, like fish, took over spaces that had been occupied by the invertebrates that became extinct.	In the millions of years after the extinction event, four-legged land animals, ray-finned fish, and cartilaginous fish exploded in number.	In the millions of years after the extinction event, **new plants** and animals evolved, including dinosaurs	Species including turtles, crocodiles, mammals, fishes, and **many plants** filled the available niches after the extinction event, and ushered in the age of dinosaurs	Mammals took over ecological niches that had been occupied by dinosaurs. Frogs, lizards, snakes, and **flowering plants** also increased.

Mass Extinctions and Oxygen

Extinction Events and Oxygen:

Each major extinction event has coincided with a decrease in atmospheric oxygen.



Reconstructed O 2 content during the Phanerozoic Eon. The dashed vertical lines show the timing of the five mass extinctions.

After each extinction event, the levels increased again.

Based on what you have learned about the interactions between living things and Earth's systems, what impact could organism recovery after an extinction event have on the oxygen levels in the atmosphere?

Arguing from Evidence

Arguing from Evidence

Using the evidence presented in the table along with what you've learned throughout this unit, construct an argument about how Earth's systems factors had both positive and negative impacts on the evolution of life on Earth.

In your argument, be sure to:

- Clearly state your claim
- Use evidence to support a negative impact of geological events on the evolution of life on Earth
- Use evidence to support a positive impact of geological events on the evolution of life on Earth
- Describe how the recovery of organisms after an extinction event could have impacted oxygen levels in the atmosphere
- Describe the reliability of the evidence used to draw these conclusions, based on what you know about isotope dating and the availability of the fossil record

Coevolution of Earth and Life Performance Task Rubric

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At least 2 sources of relevant evidence about organisms that changed the amount of oxygen in Earth's systems are provided
At least 3 sources of relevant evidence about oxygen levels in Earth's systems impacting the evolution of complex organisms are provided
Evidence is data from an investigation or resource in the learning cycle
Scientific Reasoning & Logic

Effectively and clearly provides scientific reasoning and logic that includes all of the elements below:
An accurate explanation of how photosynthesis, cellular respiration, and oxidation link the evidence to the claim
Includes a logic statement that links the evidence to the claim (including words such as because and therefore)
A discussion about the strengths and limitations of the data in support of the claim</td><td>Claim and Evidence

Provides evidence in support of the claim that includes some of the elements below:
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At least 2 sources of relevant evidence about oxygen levels in Earth's systems impacting the evolution of complex organisms are provided
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Student Self-Score	**Circle One** **Proficient** **Developing**	**Glow**: **Grow**:
Teacher Score	**Circle One** **Proficient** **Developing**	**Glow**: **Grow**:

Relevance to your life: Think about everything that you have learned throughout this unit so far.

1. What is one idea and/or skill you learned that you think is important to teach someone in your family or community?

2. To whom do you intend to teach this idea and/or skill? Why do you think it is important for this person to learn this idea and/or skill?

Origin of the Universe 5E

Unit 2 Probability of Life Elsewhere	Earth and Space Science
Student Name:	

How did the universe form?

Phenomenon: There are more stars in the universe than there are grains of sand on Earth and scientists predict each one of those stars hosts several planets.

Directions:
- Consider what you know about the universe
- Brainstorm 2-5 ideas for how all the stars and planets in the universe came into existence in the left column below.
- Explain your thinking in the column on the right.

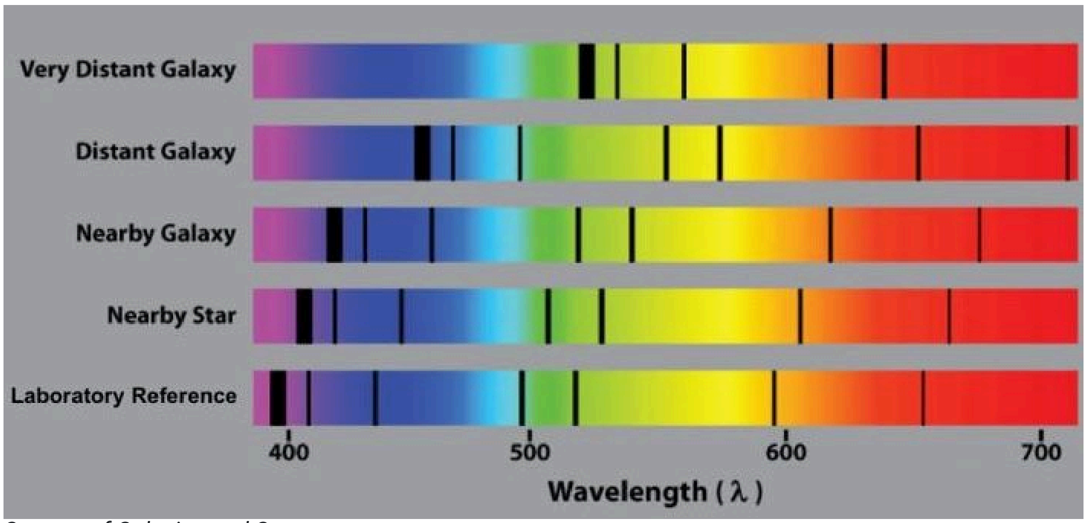
What are your ideas about how all the stars and planets in the universe came into existence?	What makes you think this? What is your evidence?

Investigating Light Spectra from Other Galaxies

In the 1920s, Dr. Edwin Hubble made a discovery that profoundly changed our understanding of the universe and its origin. He showed that some of the numerous distant, faint clouds of light in the universe were actually entire galaxies—much like our own Milky Way. The realization that the Milky Way is only one of many galaxies forever changed the way astronomers viewed our place in the universe.

Hubble wanted to learn more about these galaxies beyond our own, and began to closely examine their light spectra. This spectra is like the spectra from stars within our galaxy that we analyzed and interpreted as part of our stars investigation, but it comes from the light of an entire galaxy, not just one star.

Analyze the light spectra from other galaxies, a nearby star, and a laboratory reference of hydrogen and helium gas, then answer the questions that follow.



Spectra of Galaxies and Stars

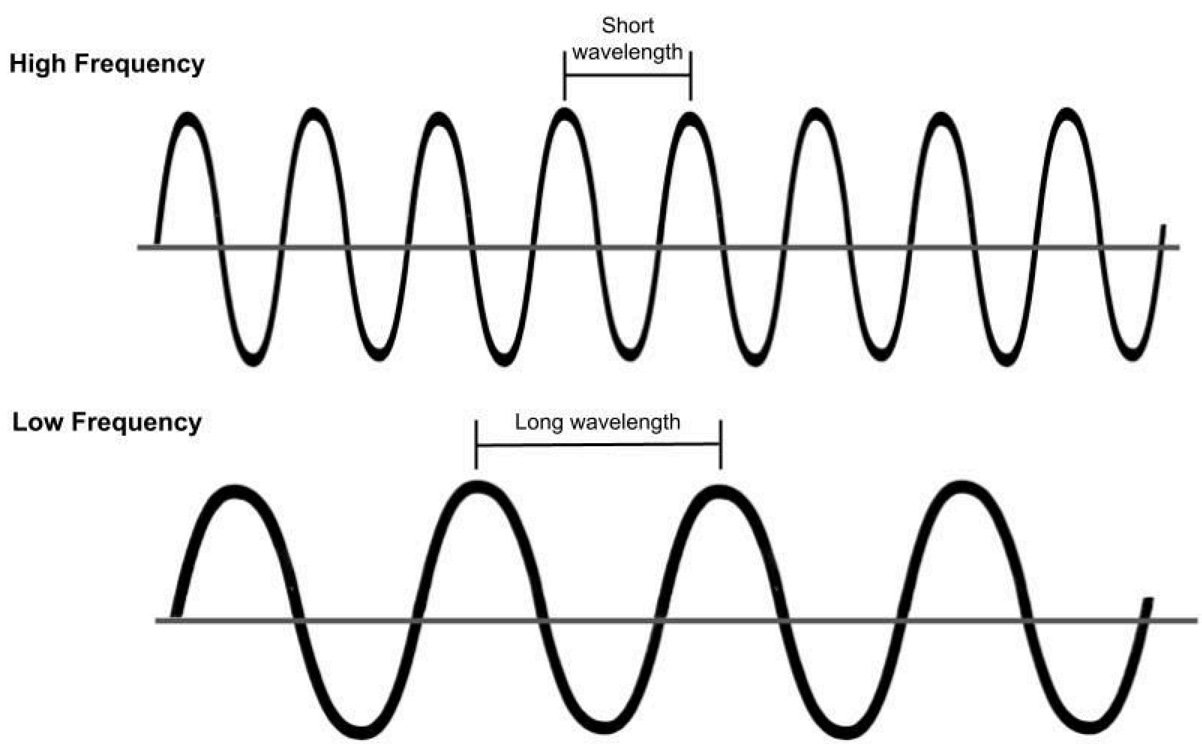
1. What similarities or patterns do you notice for individual wavelengths of light across all the spectra?

2. What is different about each spectra?

3. Is there a relationship between the absorption line wavelengths and the distance of the galaxies from Earth? If so, what is it?

What happens to sound and light waves when they travel from their source to an observer?

Light is a type of energy, which travels from a source, like a star, to an observer, like us! There are many ways energy moves between a source and an observer, including in the forms of light and sound. Both light and sound travel in waves. The energy of those waves can be measured by how close its peaks are to each other, called its wavelength. Its wavelength determines how many peaks are observed within a given time, called the wave's frequency.



High and Low Frequency Wavelengths

1. Based on the image above, how are frequency and wavelength related?

2. Looking back at the image of the spectra from different galaxies above, how does the distance of the galaxy relate to the frequency of the light coming from it?

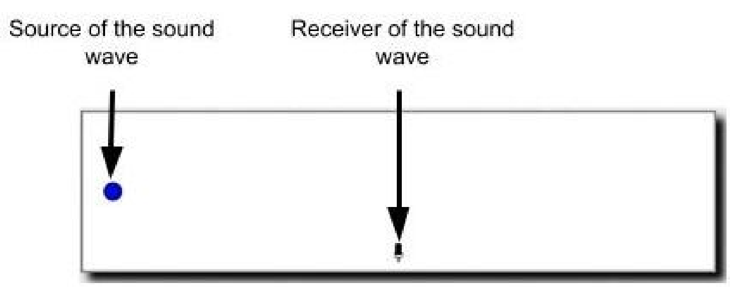
In order to make sense of the shift of absorption lines we noticed in the spectra of other galaxies, you will conduct an investigation into sound and light waves as they travel from their source to an observer.

We'll start with some scenarios here on Earth that are related and may help us make sense of the strange shift in the galaxy light spectra. The first scenario is related to sound waves, which behave very similarly to light waves, and are easier to detect changes in.

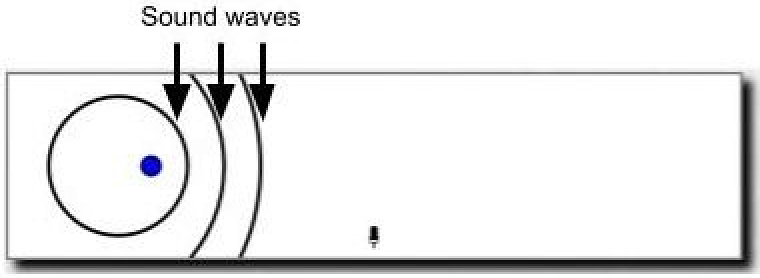
1. Listen to the sound of a siren in Siren Doppler Effect . What do you notice happens to the sound over the course of the video?

2. What are your initial ideas for what might explain what you heard?

Model 1: What happens to sound waves when they travel from their source to an observer?
Open Model 1: Doppler Effect #1 . It shows sound waves being emitted from a source (the blue dot) that is moving from left to right, and a receiver that detects those waves.



The circles that come out of the source (blue dot) are sound waves.

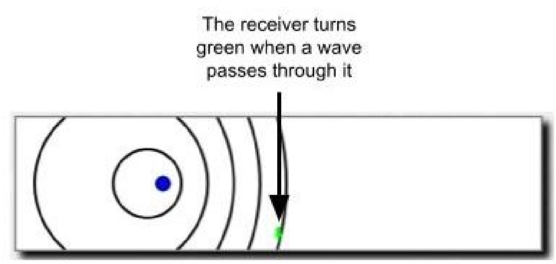


1. Sound waves are a type of energy in the system. What happens to the energy in the sound wave over time?

2. Mute (uncheck) the Snare drum sound. Try snapping your fingers every time a sound wave is produced by the blue dot.

    a. How often is a sound wave produced by the source (how often do you snap your fingers)? Does the way you snap your fingers get faster, slower, or is it constant as the source moves along the screen?

Now let's focus on the receiver. Unmute (check) the Snare drum sound. Every time a wave passes through the receiver, it turns green and a sound is produced.



Observe the simulation for a few minutes and use your observations to answer these prompts and compete the See-Think-Wonder

1. What do you observe about how often the sound waves are coming out of the blue dot?

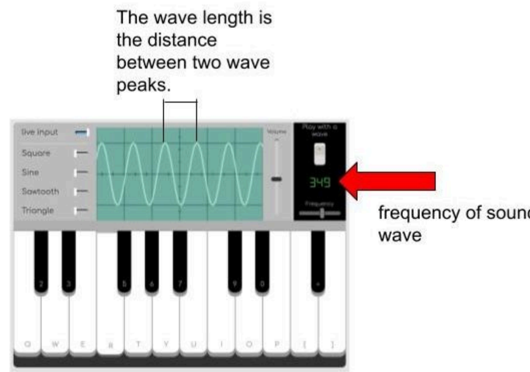
2. How does the sound picked up by the microphone change as the blue dot moves?

3. Why do you think the sound changes in that way?

Model 2: What is the relationship between the pitch of a sound and its wavelength?

Open Model 2: Piano . Use the simulator to study the relationship between the sound (pitch) and the characteristics of the wave. Play with the keys and take notes about what you observe in the graph. Use the concepts of frequency and wavelength (highlighted in the image below) to describe the patterns in the relationship between pitch and wave characteristics.

1. What happens to the sound you hear as the frequency increases?



2. What happens to the wavelength as the frequency increases?

How can we explain our observations of the siren sound?

Now you are ready to explain why the sound of the siren changes as it moves! Let's try to connect what you observed from Model 1 with what you observed from Model 2.

Just to review:

How does the ***frequency* of waves perceived by the observer** in model 1 change as the source moves? (Include the evidence that supports your statement)

From model 2 you observed that different sounds have different frequencies. How, then, would you explain the change in the sound of the siren?

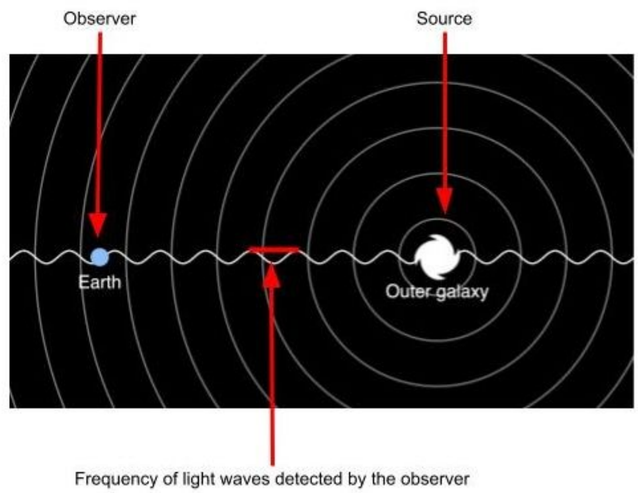
Challenge activity:
How would you hear the sound of the siren if you were the driver of the ambulance/police car? That is, would you experience the doppler effect if you were inside the source of the sound waves?

Model 3: What happens to light waves when they travel from their source to an observer?

Goal of this activity: Now that we understand how wavelengths and frequency affect our perception of sound waves, we will apply that same set of principles to light waves traveling from distant galaxies to Earth.

Open Model 3: Doppler Effect #2 . This model shows what happens with the light emitted by a galaxy as it travels millions of kilometers through space. Similar to sound, light is a type of energy in a system.

1. Where does this energy come from?



2. Where does this energy go?

3. After the energy leaves the space shown in Model 3, where do you think it goes?

Use the model to move the galaxy in different directions and make observations about the change in frequency in each of the situations in the table below. Also record the change of color perceived by the observer as the galaxy moves.

Situation	Is there a change in frequency of the light waves perceived by the observer on Earth? (increase, decrease, or no change?)	Change of color perceived by the observer on Earth? (shift toward red, blue or no shift?)
The galaxy is not moving.		
The galaxy is moving toward Earth.		
The galaxy is moving away from Earth.		

Model 4: Why does the model represent these changes in frequency as either red, white, or blue light?
Open Model 4: Electromagnetic Spectrum . Use the simulator to study the relationship between the color of the light and its wavelength and frequency.

1. What happens to the color of the light as the frequency increases and the wavelength decreases?

2. How does that color change explain why light from galaxies moving closer to Earth appears blue in Model 3?

3. What happens to the color of the light as the frequency decreases and the wavelength increases?

4. How does that color change explain why light from galaxies moving further from Earth appears blue in Model 3?

See What patterns do you see in the data?	**Think** What do those patterns make you think?	**Wonder** What questions do you have about the patterns you observed?
What do you notice about the relationship between the sound heard by the observer and the sound emitted by the source as the source moves?		
What patterns do you notice about the relationship between sound, wavelength, and frequency?		
What do you notice about the difference in how light is emitted by the source and how it is perceived by the observer?		
What patterns do you notice about color, wavelength, and frequency?		

What does the light spectra of galaxies tell us?

At this point you should understand that studying the light coming from an object in the universe can allow us to know whether this object is moving away from us, toward us, or not moving at all. You will now apply this understanding to the light spectra of galaxies we examined at the beginning of this investigation in order to determine whether the galaxies of the universe are moving away from us, moving closer to us, or not moving at all.

Make the following predictions about what you would expect to see for each of these alternative scenarios. A prediction is not a guess. You need to use your understanding about the doppler effect in order to justify them.

For example, if the universe were expanding, what kind of change in the light waves wavelength and frequency would you observe? Would the light observed shift toward the red or the blue side of the spectrum?

The universe is expanding (other galaxies are moving away from us) :

Claim	Evidence	Reasoning
If the universe is expanding, I'd expect the light to shift towards the _________ (red/blue) spectra	because the source is moving away from earth, resulting in _______ (longer/shorter) wavelengths and ______ (higher/lower) frequency light	and light with ______ (longer/shorter) wavelengths appears _________ (red/blue)

The universe is contracting (other galaxies are moving toward us) :

Claim	Evidence	Reasoning

The universe is static (other galaxies are not moving):

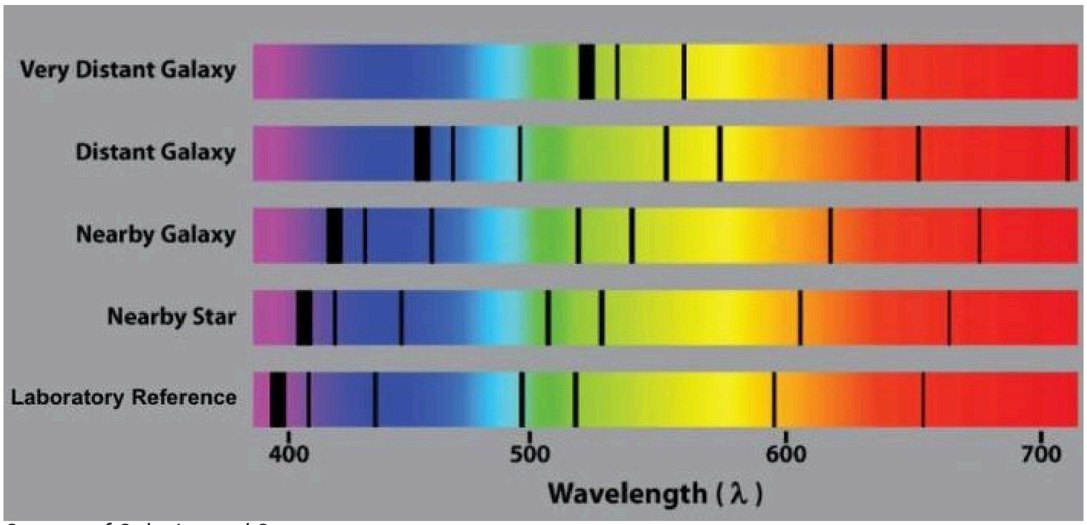
Claim	Evidence	Reasoning

Read - Generate - Sort - Solve

Read - Read and complete the text below by filling in the blanks, then examine the evidence for whether the universe is changing or not.

Universe: Static, Contracting, or Expanding?

If galaxies were moving away from us, the wavelengths would become (hint: shorter or longer?)________________. If this was the case, then the absorption lines would move toward the __________ color (hint: red or blue?). Take a look at the light spectra of galaxies you observed at the beginning of this investigation, then with your group members generate and sort ideas that will help you respond to the question: Is the universe static, contracting, or expanding?



Spectra of Galaxies and Stars

Generate - Brainstorm all ideas that you think might help you make a claim based on evidence

Name: _____________	Name: _____________	Name: _____________

Sort - Star the Ideas that are Most Useful

Solve - Construct an argument about whether the universe is static, contracting, or expanding based on the evidence provided.

Using evidence from the galaxy light spectra, make a claim about whether the universe is expanding, contracting, or static.

Claim	Evidence	Reasoning
The universe is……	My evidence for this is……	The scientific concept that links my evidence to my claim is……

Summary Task

Today we completed the first class consensus discussion of the unit! How did it go?

1. One thing that went well in the discussion:

2. One thing we can improve the next time we have a discussion:

3. One person who helped me learn today:

What did you learn from this person?

4. One idea that I contributed to my group or my class:

Explain what you know about the following questions, based on what we discussed today:

1. Models can be used to simulate systems and interactions— including energy flow —within and between systems. Revisit models 1 and 3 from the Explore phase and describe how they are both examples of this type of model.

2. Based on your observations from models 1 and 3, was the energy (sound and light waves) within the systems in those models ever destroyed? Explain your thinking.

How did it all start?

Part 1. If the universe is expanding, what did it look like in the past?
The universe is expanding! What a fascinating discovery! But what does this mean about what the universe was like early in its history? In this activity you will be using a model for universe expansion in order to answer this question.

1. Use the balloon provided by your teacher to represent space in the universe. Blow it up to a medium size, and hold it closed instead of tying a knot.
2. Using markers provided by your teacher, as one partner holds the balloon closed, the other partner should sketch about 15-20 galaxies spread out over the balloon. Draw a few wave lines coming from each galaxy to represent the light waves coming from them.
3. Inflate the balloon to a larger size, but still hold it instead of tying it closed.
   a. What happened to the distances between the galaxies?

   b. Does that match your predictions from the previous activities?

4. Observe the changes in the light waves as the balloon expands.
   a. What happened to the light waves around each galaxy?

   b. How would that influence how light is perceived by an observer looking at the galaxy?

   c. Does that match your predictions from the previous activities?

5. The universe has been expanding since the beginning of time, approximately 13.7 billion years ago. What do you think the universe looked like 5 billion years ago? Decide with your classmates how you

can use the balloon model to represent this. Describe what you will do with the model below.

6. Change your model as discussed with your group. Based on your model of the universe 5 billion years ago, how was the universe different from the universe today?

7. What do you think the universe could have looked like 10 billion years ago? Represent this in your model and explain how the universe 10 billion years ago was different from the universe today and the universe 5 billion years ago.

8. Based on your observations of the balloon model so far, what do you think the universe could have looked like when it initially formed (at the beginning of time)? Describe the distribution of galaxies in your model.

Part 2. What Were the Conditions of the Early Universe?

1. Remember that galaxies are composed of stars, planets, and other celestial bodies. How do you think the early universe would have looked and felt with all of those components tightly compressed (hint: think about pushing lots of stars together)?

2. As the universe began to expand, how do you think how it looked and felt would have changed?

3. How do you think the amount of energy and matter changed as the universe began to expand?

Astronomers predict that the early universe was so extremely dense and hot that no elements were able to exist, just subatomic particles, as if all the elements were melted apart. But as you just determined, when it began to expand, it started cooling down.

If that is true, as the universe expanded, it would have cooled to a temperature where elements could start to form because subatomic particles could start to fuse, like tiny water droplets forming from steam. That opportunity for elements to form would have been short, because particles were quickly moving apart from each other and getting too cold to fuse into elements.

Based on computational models, astronomers have calculated that, in the amount of time that the universe would have spent at the right temperature, it would have behaved similarly to the core of a star, where production of light elements takes place. Subatomic particles collided and fused, forming the first atoms: hydrogen and helium. Using computational models, astronomers have made two additional conclusions about the early universe.

Claim 1

- **When matter formed into elements, only hydrogen and helium formed. The result was 75% hydrogen and 25% helium by mass.**

Claim 2:

- **Like the core of a hot star made of hydrogen and helium, the early universe emitted a huge amount of energy as visible light.**

Part 3. How are we confident in this explanation??
Astronomers, like all scientists, always test their hypotheses, and can only consider something a theory if it stands up to repeated testing.

In the case of the big bang theory:

- Astronomers first used observations of the expanding universe to predict that the universe must have started off very small and then begun expanding.
- Then they used computational models to predict the conditions of the early universe, and create a model based on that.
- Then they used their understanding of how energy and matter work to predict what they should observe in the universe today if their previous models were true.
- Finally, they compare what they observe in the universe today and see if it matches their predicted models.

You have already done the first two parts of their process: you've determined that the universe is expanding, that it must have started off very small, and learned about the predicted conditions of the early universe.

Now you will predict what should be observed in the universe today if your understanding of the big bang is correct, and then you will examine evidence of the current universe to determine if it matches your predictions.

Predict what the universe would look like if the big bang theory is correct:

1. On an un-inflated balloon, draw:
    - several hydrogen and helium atoms in at a ratio of 3 hydrogens for every 1 helium
    - visible light waves
2. Read the law of conservation of matter and energy below

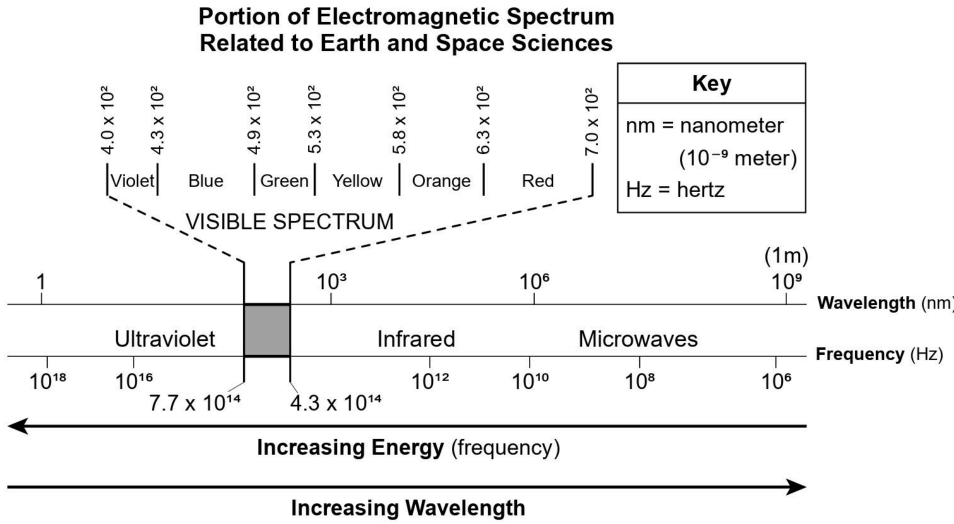
Law of Conservation of Matter and Energy
The law of conservation of matter and energy states that within a closed system, matter and energy can change form, but the total amount of matter and energy is constant.

3. Based on that law, if the big bang produced 75% hydrogen and 25% helium, what evidence of that matter would you expect to find today? Inflate the balloon to help you visualize these elements as the universe expands.

4. Based on that law, if the big bang produced a huge amount of light energy, what evidence of that energy would you expect to find today?

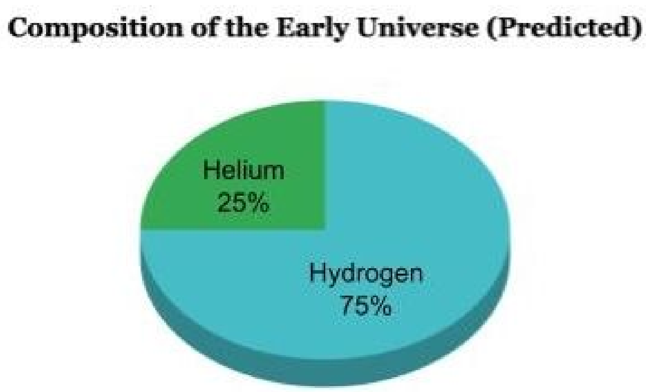
5. Using what you learned in the Light Spectra from Other Galaxies Investigation, If the big bang produced a large amount of light energy, and then the universe expanded, how would the light observed in the expanded universe change compared to the light at the time of the big bang? Inflate the balloon to help you visualize changes to the light waves as the universe expands.

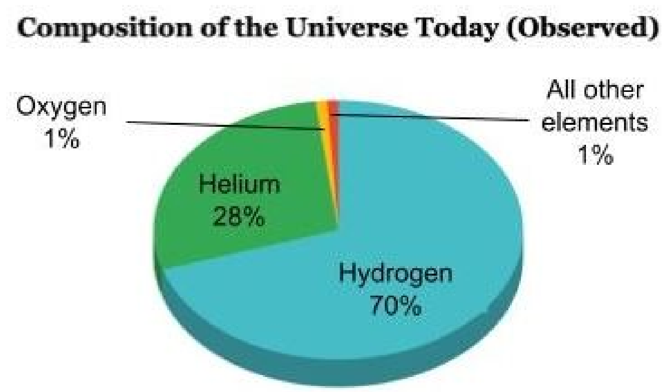
6. We know that we do not observe bright, visible light coming from all around the universe all the time. Using the diagram below and what you have learned about the ways that light waves change as the universe expands, what could explain the lack of visible light appearing all around the universe at this moment in time?



Part 4. Compare Your Predictions to Observations of the Universe Today

1. Using absorption spectra of stars, astronomers have observed that across the universe, matter is slightly less than 75% hydrogen, slightly less than 25% helium, and about 2% other elements by mass.



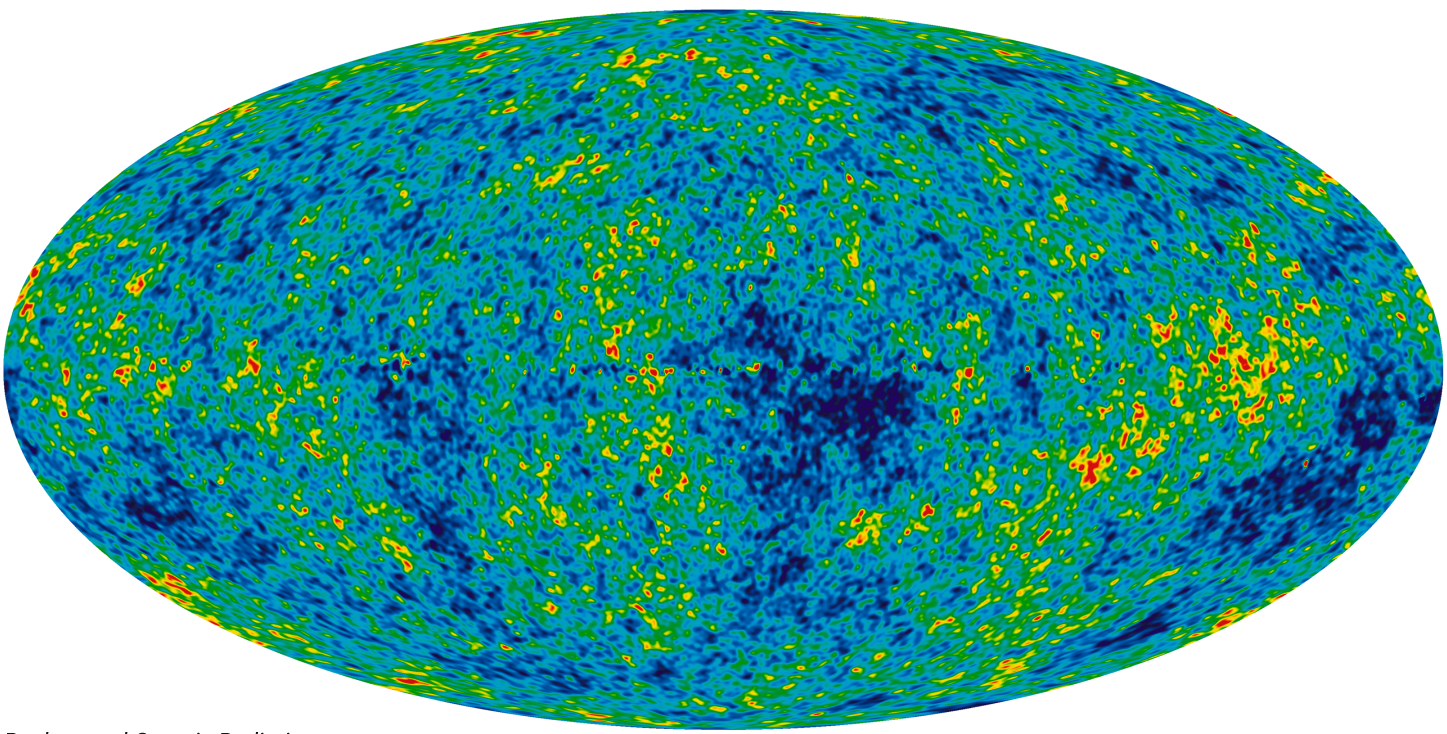


How does this observation support or refute your predictions?

What processes could account for the change in percentages of hydrogen and helium, and the addition of new elements present in the universe today?

2. Scientists had been making predictions about what happened to the energy from the early universe since the1940's, then finally, a breakthrough. Read the text, Murmur of a Bang , and compare your predictions about the early universe and how it has changed to what scientists predicted and found.
    - Underline ideas that confirm your thinking
    - Circle ideas that add to your thinking
    - Box ideas that cause you to change your thinking

3. In the past 50 years, scientists have created images of the microwave background radiation present throughout the universe.



Background Cosmic Radiation

How do the microwaves compare to the visible light waves that emitted from the early universe? Does this match what you predicted would happen to visible light waves as the universe expanded?

4. How do these observations support or refute the idea that matter and energy are never created or destroyed, but may change and move?

Bringing all the evidence together
Use what you have learned so far to connect observational evidence from today to an extremely dense and hot early universe that has expanded and cooled over time.

Evidence	Claim	Reasoning
Redshift in the spectra of galaxies	At the beginning of time, the universe was extremely small, hot, and dense but has been expanding ever since.	This evidence supports the claim because....
The detection of microwave background radiation all over the universe	At the beginning of time, the universe was extremely small, hot, and dense but has been expanding ever since.	
The composition of stars and interstellar gases is about 74 hydrogen and 25 % helium, while heavier elements make up less than 2% of the universe.	At the beginning of time, the universe was extremely small, hot, and dense but has been expanding ever since.	

Could there be other Earth-like planets?

How many stars are there in the Universe?

1. According to the video, how many stars are there in our universe?

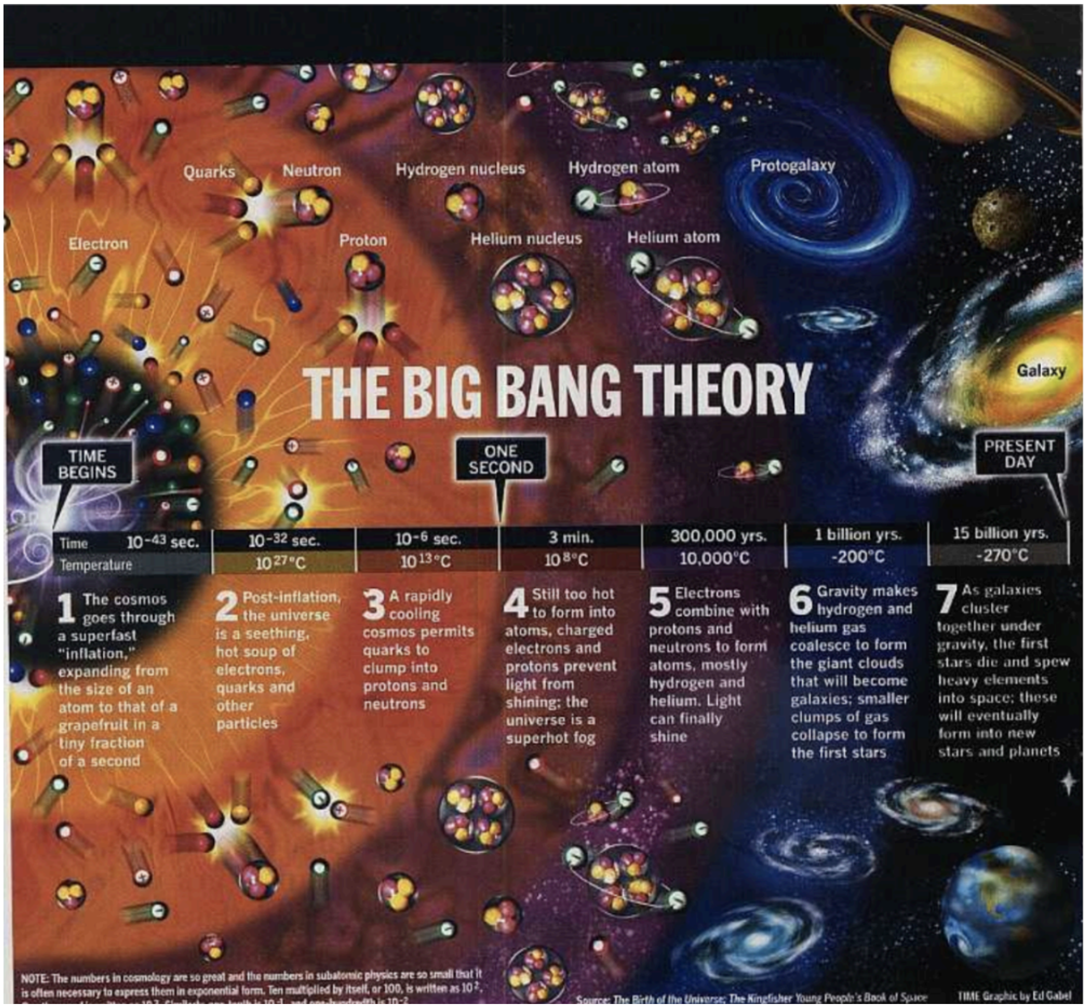
Based on the fact that our solar system has 8 planets and that we have detected multiple planets in the large majority of other solar systems we have discovered, astronomers believe that most stars in the universe have multiple planets revolving around them.

On the following page you can find a model of the expansion of the universe and how it led to the formation of all the galaxies, each potentially containing billions or even trillions of solar systems.

1. Examine the sequence of events associated with the formation of the universe depicted by the model. Were the processes that led up to the formation of galaxies the same everywhere in the universe?

2. What do you think the model tells us about whether other galaxies and solar systems in the universe are similar to ours? Be sure to provide evidence and reasoning for your response.

Model of the Formation of the Universe



THE BIG BANG THEORY
Quarks
Neutron
Hydrogen nucleus
Hydrogen atom
Protogalaxy
Electron
Proton
Helium nucleus
Helium atom
Galaxy
TIME BEGINS
ONE SECOND
PRESENT DAY
Time
Temperature
10-43 sec.
10-32 sec.
10 27 °C
10-6 sec.
10 13 °C
3 min.
10 8 °C
300,000 yrs.
10,000°C
1 billion yrs.
-200°C
15 billion yrs.
-270°C
1 The cosmos goes through a superfast "inflation," expanding from the size of an atom to that of a grapefruit in a tiny fraction of a second
2 Post-inflation, the universe is a seething, hot soup of electrons, quarks and other particles
3 A rapidly cooling cosmos permits quarks to clump into protons and neutrons
4 Still too hot to form into atoms, charged electrons and protons prevent light from shining; the universe is a superhot fog
5 Electrons combine with protons and neutrons to form atoms, mostly hydrogen and helium. Light can finally shine
6 Gravity makes hydrogen and helium gas coalesce to form the giant clouds that will become galaxies; smaller clumps of gas collapse to form the first stars
7 As galaxies cluster together under gravity, the first stars die and spew heavy elements into space; these will eventually form into new stars and planets
NOTE: The numbers in cosmology are so great and the numbers in subatomic physics are so small that it is often necessary to express them in exponential form. Ten multiplied by itself, or 100, is written as 10 2.
Source: The Birth of the Universe; The Kingfisher Young People's Book of Space
TIME Graphic by Ed Gabel

Origins of the Universe Performance Task Rubric

Origins of the Universe	Proficient	Developing
Explanation Rubric	**Claim and Evidence** Effectively and clearly provides a evidence in support of the claim that includes **all** of the elements below: • At least 3 sources of relevant evidence for the expansion of the universe and the similarity of planets and stars throughout the universe • Evidence is data from an investigation or resource in the learning cycle **Scientific Reasoning & Logic** Effectively and clearly provides scientific reasoning and logic that includes **all** of the elements below: • An accurate explanation of how the behavior of waves and matter changes or remains the same due to the expansion of the universe • Includes a logic statement that links the evidence to the claim (including words such as because and therefore)	**Claim and Evidence** Provides evidence in support of the claim that includes **some** of the elements below: • Relevant evidence for the expansion of the universe and the similarity of planets and stars throughout the universe • Evidence is data from an investigation or resource in the learning cycle **Scientific Reasoning & Logic** Effectively and clearly provides scientific reasoning and logic that includes **some** of the elements below: • An explanation of how the behavior of waves and matter changes or remains the same due to the expansion of the universe • Includes a logic statement that links the evidence to the claim (including words such as because and therefore)
Energy and Matter	Explanation includes a discussion of how the evidence of the big bang relies on the fact that energy cannot be created or destroyed, only moved between places, objects, or systems	Explanation does not include a discussion of how the evidence of the big bang relies on the fact that energy cannot be created or destroyed, only moved between places, objects, or systems
Student Self- Score	**Circle One** **Proficient** **Developing**	**Glow**: **Grow**:

Teacher Score	Circle One **Proficient** **Developing**	**Glow**: **Grow**:

Relevance to your life: Think about everything that you have learned throughout this unit so far.

1. What is one idea and/or skill you learned that you think is important to teach someone in your family or community?

2. To whom do you intend to teach this idea and/or skill? Why do you think it is important for this person to learn this idea and/or skill?

Asteroid Orbits 5E

Unit 2 Probability of Life Elsewhere	**Earth and Space Science**
Student Name:	

Asteroids in the Solar System

During the Driving Question Board launch and at the end of the last 5E, one category of questions that emerged was related to where the asteroids that caused mass extinctions came from, how many asteroids like it still exist in the solar system, and whether another large asteroid can hit the Earth in the future.

Part 1
Watch the video, Meet the NASA Scientist Who Tracks Dangerous Asteroids in Earth's Orbit , and respond to the prompts below.

1. What information from the video relates to the questions:
    a. Where do asteroids in our solar system come from?
    b. How many large asteroids are there in our solar system?
    c. Will another large asteroid ever strike Earth again?

2. What questions do you have about what you learned from the video?

Part 2
Watch the video, Apophis, and complete the See-Think-Wonder that follows based on your observations.

See-Think-Wonder

Use the graphic organizer below to record your ideas from the investigation.

See What do you observe?	**Think** What do those observations make you think about?	**Wonder** What questions do you have?

Asteroid Paths and Velocities Investigation

Different objects in space have orbits that look different. For instance, the shape of the orbit of Pluto was one of the reasons that it was downgraded from a planet to a dwarf planet in 2006. By understanding the different paths that objects take, we can understand how we predict the possible impact (or near miss) of different asteroids on Earth.

Part 1 will reintroduce **Kepler's 1st Law of Planetary Motion**, which is a mathematical model that describes the shape of orbits. Part 1 will build on this mathematical model by exploring new relationships between orbital variables that can be helpful in describing and explaining the stable patterns we see in planetary motions.

Part 2 of the investigation will allow you to further refine your understanding of how and why we can predict the trajectory of asteroids and other objects by introducing the force of gravity as part of a causal mechanism for the motion of planets and objects described by Kepler's Second Laws.

Part 1: Motion of Asteroids and Comets

All objects in the solar system move in shapes called ellipses. For planets, the ellipses are nearly circular. However, other objects have much different orbital shapes. Let's take a look:

Open the simulation Kepler's Second Law , and click "Kepler's 2nd Law"

1. In the slider on the right, change "eccentricity" - what happens?

2. What shape is an orbit with an eccentricity of 0.0? This eccentricity is not far from the eccentricity that most planets have.

3. What shape is an orbit with an eccentricity of 0.7? Does the planet always travel at the same distance from the Sun?

Keep the eccentricity at .7, and change the average distance from the Sun (the semimajor axis) to around 3 AU. If you press the button "start sweep", it will color an area of the model that equals the amount of time it takes for the planet to cover 1/16 of its orbit.

Do multiple sweeps, especially when it is close to and far away from the sun.

1. What do you notice?

2. What does this tell you about the speed of the object when it is close and far away from the Sun?

Part 2: The Force of Gravity

Use the following simulation to try to answer the questions below:
Gravity

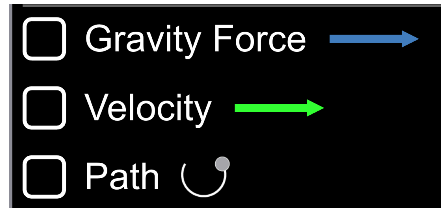
1. This simulation mimics the force of gravity one object has on another. You can change the mass of either object, or the distance. Holding the distance constant, what happens when you change the mass?

2. Holding the mass of the two objects constant, what happens when you change the distance?

Use the following simulation to continue to work on how gravity helps explain the patterns you found in the *Explore*.

Gravity and Orbits (choose model)

This simulation allows you to move the Sun and Earth and change their relative masses. After you move things around, you can press “play” at the bottom. Make sure that, for your experiments, you keep the following fields checked:



3. What happens when you increase the mass of the Earth or Sun? How does it change the gravity force?

4. When you change the mass and the orbit becomes elliptical, describe what happens to:

The change in gravity over the course of the ellipse:

The change in velocity over the course of the ellipse:

See-Think-Wonder

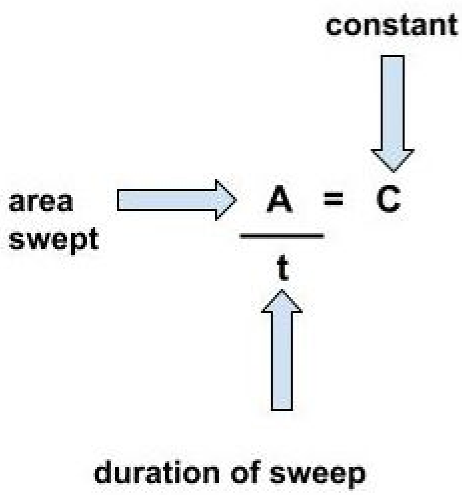
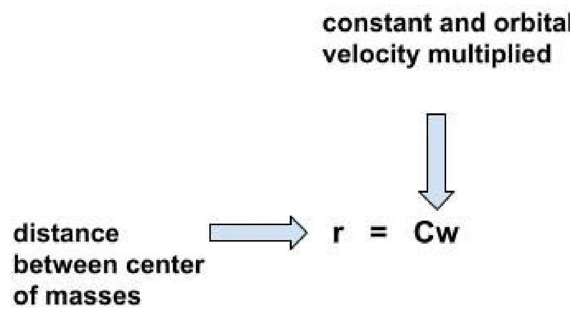
Use the graphic organizer below to record your ideas from the investigation.

See What patterns do you observe?	**Think** What do those observations make you think about?	**Wonder** What questions do you have?

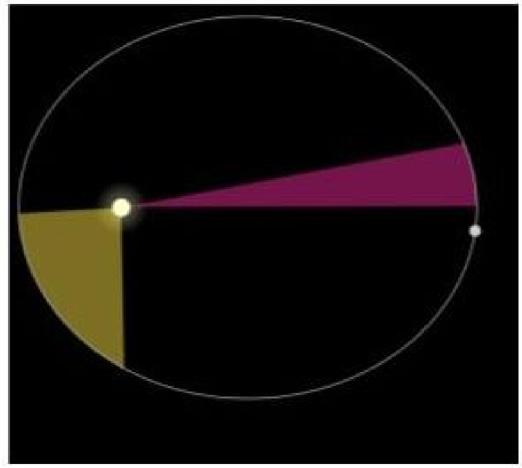
Part 1: Describing and Explaining Orbital Motion with Mathematical Models

1. The equations below are mathematical models that describe the speed of an object in relation to its distance from its star, or **Kepler's 2nd Law of Planetary Motion**. Analyze the mathematical models and think about what you observed to verbally describe the relationships they represent in your own words, then answer the question that follows.

Kepler's Second Law of Planetary Motion

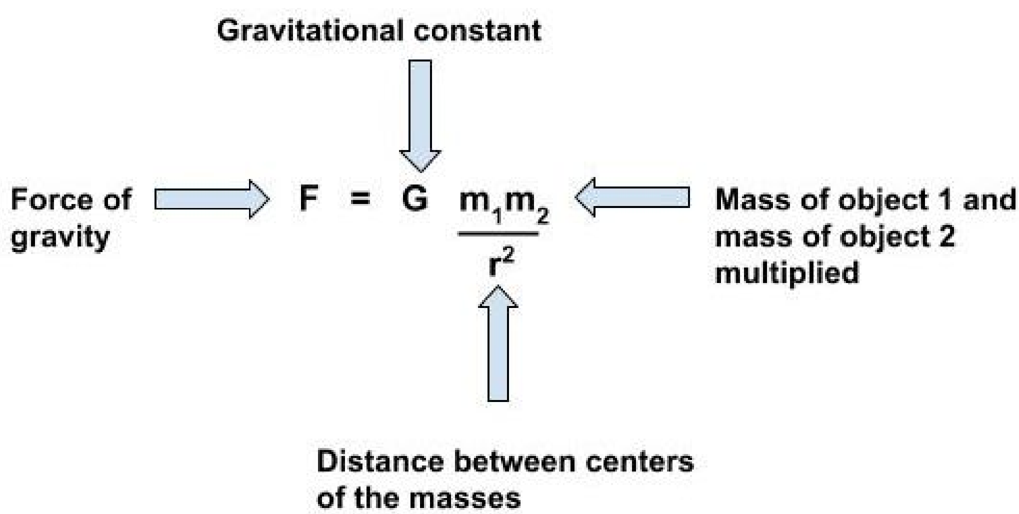
Mathematical Model		
Verbal Model		

2. How does the relationship represented by the mathematical model on the right help us explain why planets take an equal amount of time to travel a longer distance along their orbits when they are closer to the Sun?

	 • both sweeps had a duration of 0.0479 years • both sweeps covered an area of 0.104 AU^2

3. The equation below is a mathematical model that describes the gravitational force between two objects in relation to the distance between their centers and their masses, or **Newton's Law of Gravitational Force**. Analyze the mathematical model and think about what you observed to verbally describe the relationships they represent in your own words, then answer the question that follows.

Newton's Law of Gravitational Force

Mathematical Model	

Verbal Model	

4. How does the relationship represented by Newton's mathematical model help us explain why planets and objects move faster when they are closer to the star they orbit around?

Part 2: Predicting Orbital Motion with Mathematical Models

Putting all of these laws together, respond to the following questions about predicting orbits:

1. How can we predict how long it takes for an object to travel around the Sun?

2. How can we predict how fast an object is traveling?

3. How can we predict the path an object takes?

4. Finally, what is missing? Even though we know what is happening, do we know why?

Thinking about Kepler's Laws and the influence of gravity on orbits, develop a model explaining the ways in which we can predict the path of Apophis, even to the precision of knowing when an asteroid will come close to us in the near future (and whether it will or will not hit us).

- Annotate your model, so it clearly explains how we know where Apophis will be on April 13, 2029.

Summary Task

Today we completed a class consensus discussion of the unit! How did it go?

1. One thing that went well in the discussion:

2. One thing we can improve the next time we have a discussion:

3. One person who helped me learn today:

What did you learn from this person?

4. One idea that I contributed to my group or my class:

Explain what you know about the following questions, based on what we discussed today:

5. How are Kepler's Laws used to make predictions about whether Apophis will orbit near Earth?

6. How are Kepler’s Laws used to make predictions about when Apophis will orbit near Earth?

Will Apophis hit Earth in the 2030s?

While the chances of Apophis hitting Earth April 13, 2029 are very small, recall from the Engage phase that NASA scientists are concerned that the gravitational force exerted by Earth during its flyby might change its trajectory enough to put it on path for a collision with Earth in the 2030s.

Guiding Prompts:

- Use what you know about how gravity affects the motion of objects in orbit to develop a model that explains how gravitational force exerted by Earth during its flyby might change its trajectory enough to put it on path for a collision with Earth in the 2030s.

Directions for Read-Generate-Sort-Solve:

1. Read: Review the ideas represented in your model from the Explain phase.
2. Generate: On your group's chart paper, generate ideas about data that provide evidence to answer the guiding prompts.
3. Sort: Have everyone in the group state one or two ideas that they think are most relevant to the guiding prompts.
4. Solve: As a group, discuss the ideas you deemed most important, and come up with a response to the guiding prompts.

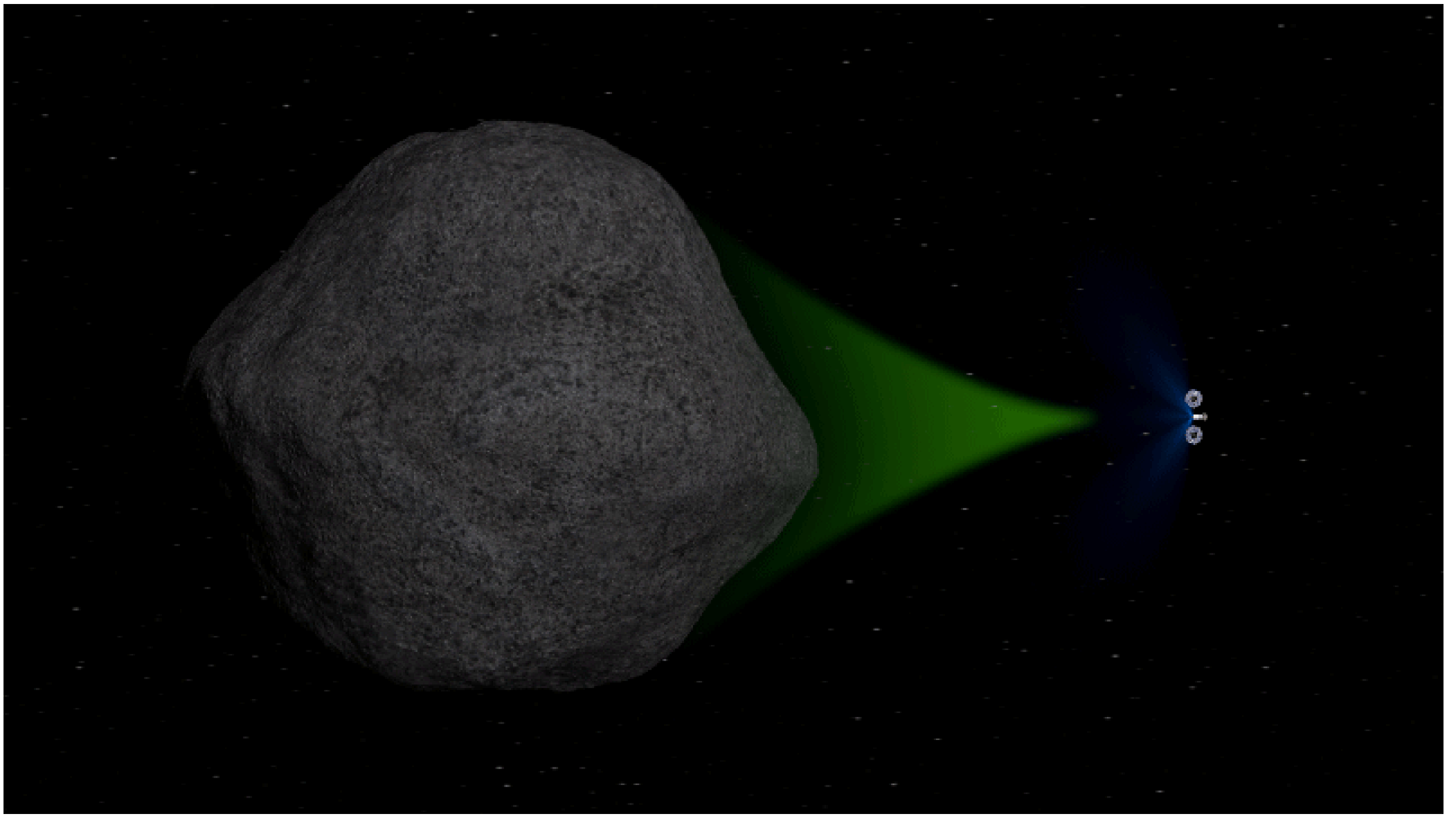
Generate Ideas.

Name:	**Name:**
Name:	**Name:**

Use what you know about how gravity affects the motion of objects in orbit to develop a model that explains how gravitational force exerted by Earth during its flyby might change its trajectory enough to put it on path for a collision with Earth in the 2030s.

Deflecting Asteroids

Although scientists are confident that Apophis will not impact Earth, there is the possibility of it or another asteroid changing paths and threatening our planet. To prevent that from happening, physicists have come up with the idea of a gravity tractor, which would use gravity to redirect the asteroid and deflect it away from Earth.



Asteroid Orbits Performance Task Rubric

<table>
<tr><th>Asteroid Orbits</th><th>Proficient</th><th>Developing</th></tr>
<tr><td>Explanation Rubric</td><td>Claim and Evidence

Effectively and clearly provides a evidence in support of the claim that includes all of the elements below:
Relevant evidence about how scientists predict where asteroids will be
Relevant evidence about how gravity tractors work
Evidence is data from an investigation or resource in the learning cycle
Scientific Reasoning & Logic

Effectively and clearly provides scientific reasoning and logic that includes all of the elements below:
An accurate explanation of the impact of gravity on the orbital trajectory and velocity of an object
Includes a logic statement that links the evidence to the claim (including words such as because and therefore)</td><td>Claim and Evidence

Provides evidence in support of the claim that includes some of the elements below:
Relevant evidence about how scientists predict where asteroids will be
Relevant evidence about how gravity tractors work
Evidence is data from an investigation or resource in the learning cycle
Scientific Reasoning & Logic

Effectively and clearly provides scientific reasoning and logic that includes some of the elements below:
An explanation of of the impact of gravity on the orbital trajectory and velocity of an object
Includes a logic statement that links the evidence to the claim (including words such as because and therefore)</td></tr>
<tr><td>Scale, Proportion, and Quantity</td><td>Explanation includes algebraic thinking which describes how data can be used to predict the effect of a changing variable on another</td><td>Explanation does not include algebraic thinking which describes how data can be used to predict the effect of a changing variable on another</td></tr>
<tr><td>Student Self- Score</td><td>Circle One

Proficient   Developing</td><td>Glow:

Grow:</td></tr>
</table>

Teacher Score	Circle One	Glow:
	Proficient **Developing**	**Grow**:

Relevance to your life: Think about everything that you have learned throughout this unit so far.

1. What is one idea and/or skill you learned that you think is important to teach someone in your family or community?

2. To whom do you intend to teach this idea and/or skill? Why do you think it is important for this person to learn this idea and/or skill?