Date: _____

Your Name: _____

New England Common Assessment Program

Released Science Inquiry Task

Lifetime of the Sun

2013

Grade 11

Science

Directions:

You will be reading a story and analyzing the data provided to answer a set of questions. Thoroughly read each question and explain all of your answers. You may include labeled drawings or diagrams to help you answer the questions.

This Word Bank provides definitions for words used in this task. You may refer back to this page throughout the session.

Word Bank

Astronomical unit (AU)	the mean distance from the Sun to Earth; equal to 93 million miles (140 million km)
Fusion	a process that joins the nuclei of light atoms to form atoms with a heavier mass
Hertzsprung-Russell (H-R) diagram	a plot of stars on a graph that measures each star's luminosity against its temperature
Infer	to conclude or judge from evidence
Luminosity ($L_\odot$)	the brightness of a star compared to the brightness of the Sun
Red giant star	a star with a solar mass between 0.1 M_{Sun} and 3.0 M_{Sun} that no longer fuses hydrogen into helium, causing its core to collapse, heat up further, and push the outer layer of the star outward, increasing its volume up to 2.0 AU
Red supergiant	a star with a solar mass between 3.0 M_{Sun} and 10.0 M_{Sun} that is no longer main sequence; the core collapses, creating greater heat, and material is pushed from the core outward as far as 20 AU
Refute	to challenge the correctness or validity of a statement
Solar mass (M_{Sun})	a unit of measurement where one solar mass is equal to the Sun's mass
Supernova	a star that suddenly increases greatly in brightness

GO ON

Lifetime of the Sun

Kim and Jay, two high school students, wondered about the fate of the closest star to Earth, the Sun. Kim shared the following excerpt from an article with Jay:

> **Giant Dying Star Caught Devouring Alien Planet**
>
> A swollen star near the end of its life has been caught devouring one of its own planets—a scenario that could one day be replayed on Earth when our own sun dies in billions of years, scientists say.
>
> Astronomers discovered the cosmic crime scene while studying an ancient star that has expanded in its old age to became a so-called "red giant." The star, called BD+48 740, is older than our sun and much bigger. Its radius is 11 times larger than that of our sun.
>
> As the star swelled into a red giant, it likely absorbed its innermost planet, researchers said.
>
> "A similar fate may await the inner planets in our solar system when the sun becomes a red giant and expands all the way out to Earth's orbit some five billion years from now," study team member Alex Wolszczan, an astronomer at Pennsylvania State University, said in a statement. The Earth orbits the sun at a distance of about 93 million miles (150 million kilometers).

Kim and Jay wondered if the Sun would eventually grow so large that it would "absorb" Earth or turn into a black hole. They have learned that a black hole is caused when a large star falls in on itself, or collapses. They also wondered if all stars follow the same path during their life cycle. Kim and Jay asked their science teacher, Mr. Jones, if the Sun would become so large that it would "absorb" Earth or become a black hole. Mr. Jones suggested they research the life cycle of the Sun so Kim and Jay gathered the following preliminary information about stars.

- The Sun's mass makes up over 90% of the total mass of the solar system.
- Stars are typically 90% hydrogen and 10% helium.
- When a star can no longer fuse hydrogen to form helium, the star's core collapses and heats up, pushing the material outside the core outward, and producing a new star that is many times larger in volume than the original star. This new star is called a giant.

That night Kim and Jay began making notes and collecting information that might help them answer the research question they had chosen.

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Research Question:

How does the life cycle of our sun compare to the life cycle of other stars?

As they continued their research to answer their question, Kim and Jay learned the following information about stars.

- Depending on their size, main-sequence stars will become a giant star, a supergiant star, or a white dwarf.
- The more massive the star, the faster it burns its nuclear material, and the less time it remains in the main sequence.
- A star's luminosity ($L_{\odot}$), or rate at which radiation is produced in its core, is exponentially related to its mass. The higher the mass, the greater its luminosity and the shorter its life as a main-sequence star.

To answer the research question, Kim and Jay considered how stars change and how the Sun might be similar to other stars. They know that astronomers can classify physical properties of stars, such as surface temperature, distance, color, luminosity, mass, and size.

In this investigation, you will compare the Sun's luminosity and surface temperature to those of other stars in our galaxy to answer Kim and Jay's research question.

GO ON

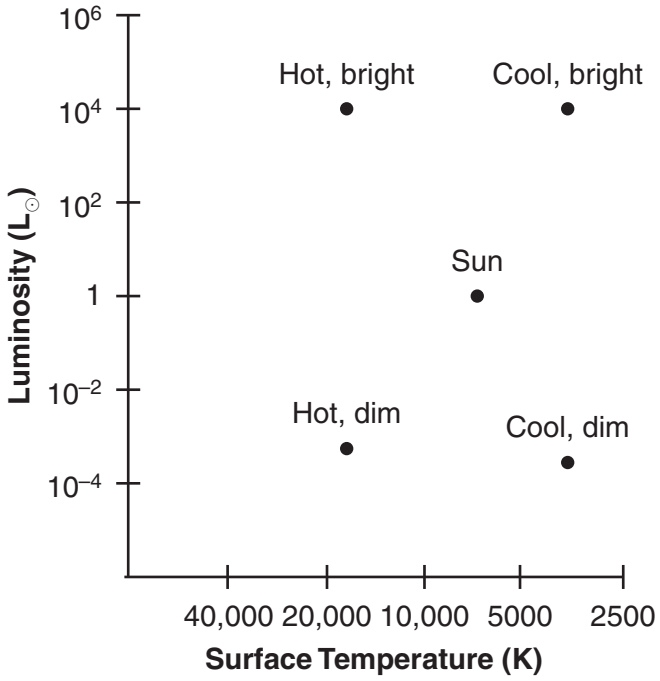
Part 1: Forming a Hypothesis

Answer question 1 on page 1 in your Student Answer Booklet.

1 Explain how one piece of information given in the story could be used to determine how the life cycle of our sun compares to the life cycle of other stars.

Kim and Jay showed Mr. Jones this diagram they had found online.

Diagram 1: Luminosity Versus a Star's Surface Temperature



Mr. Jones told them that luminosity ($L_\odot$) is a unit that uses the Sun as a value of 1 $L_\odot$.

Answer question 2 on page 1 in your Student Answer Booklet.

2 Based on Diagram 1 and the information Kim and Jay have found thus far in the story, describe additional information that can be inferred when comparing other stars to the Sun. Cite evidence to support your answer.

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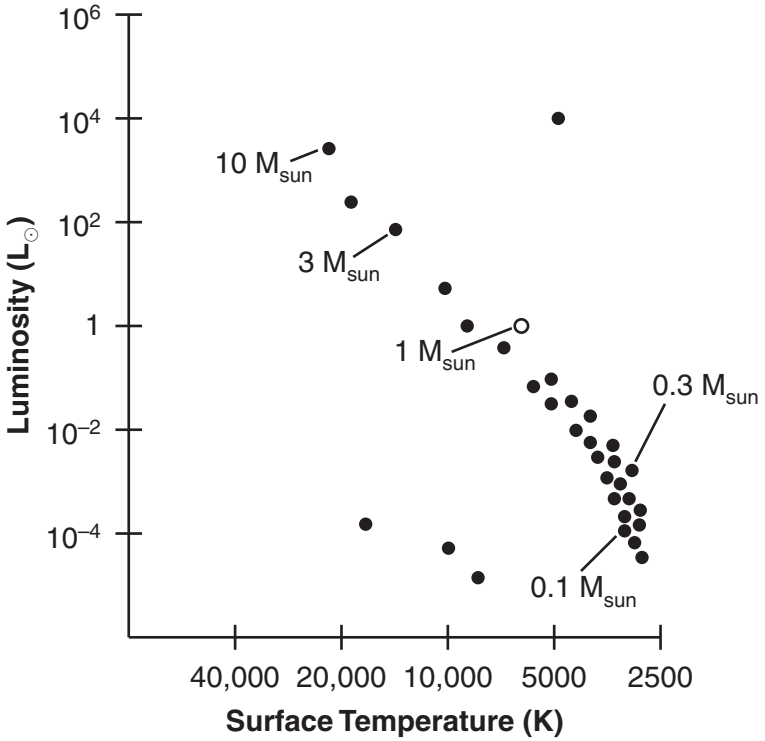
Mr. Jones showed Kim and Jay a Hertzsprung-Russell (H-R) diagram. He explained that when scientists Ejnar Hertzsprung and Henry Norris Russell independently plotted their observations of luminosity and temperature of sample stars in the Milky Way galaxy, they found a number of unique trends that would lead to the current understanding of the life cycle of stars.

- The Sun is in the main sequence, which is found in the continuous, generally diagonal line or band ranging from the upper left to the lower right in the H-R diagram. This line represents stars of average size with luminosities that predictably correspond to their surface temperatures.
- Main-sequence stars are believed to be in the stable, middle phase of their development; they are expected to move off the main sequence once the hydrogen in their core is exhausted.
- The H-R diagram led astronomers to classify the majority of stars as main-sequence stars, as shown in Diagram 2.

Diagram 2: Hertzsprung-Russell Diagram



GO ON

Mr. Jones explained to Kim and Jay that a star's mass determines its position in the pattern of stars on the H-R diagram. He also told them that solar mass (M_{Sun}) is a comparison of the mass of one star as it relates to the mass of the Sun. The following observations can be used to help understand Diagram 2.

- Most main-sequence stars range from 0.1 M_{Sun} to 10.0 M_{Sun} solar masses.
- Stars with solar masses between 0.1 M_{Sun} and 3.0 M_{Sun} will spend 90% of their lives as main-sequence stars.
- A star with a solar mass greater than 10 M_{Sun} produces temperatures and pressures that make it possible for fusion of different elements to occur simultaneously.

Answer questions 3 and 4 on page 2 in your Student Answer Booklet.

3 Describe the characteristics that affect the life cycle of stars that are less massive than the Sun **and** stars that are more massive than the Sun. Use evidence from Diagram 2 to support your answer.

4 Based on Diagram 2, predict the luminosity ($L_{\odot}$) and temperature (K) of a star with a solar mass of 100 M_{Sun}. Use evidence from Diagram 2 and information from the story to support your answer.

GO ON

Mr. Jones showed Kim and Jay a data table that shows the temperature (K) and luminosity ($L_\odot$) of ten stars found in the Milky Way galaxy. A copy of the data table is shown below.

Data Table 1: Ten Stars in the Milky Way Galaxy

Name	Temperature (K)	Luminosity ($L_\odot$)
Capella CD	3,200	10^{-1}
Rigel	28,000	10^{5}
Sirius A	9,000	10^{1}
Betelgeuse	3,200	10^{4}
Vega	9,000	10^{1}
Procyon A	6,500	7
Altair	8,000	10^{1}
Regulus	20,000	10^{3}
Sirius B	10,000	10^{-3}
Sun	5,800	1

Kim and Jay used the information in Data Table 1 to make a scatter plot of the ten stars to compare the Sun with other stars.

Answer question 5 on page 3 in your Student Answer Booklet.

5 On the grid provided, construct a scatter plot of the stars included in Data Table 1. Be sure to correctly label and title your scatter plot and identify (label) the stars.

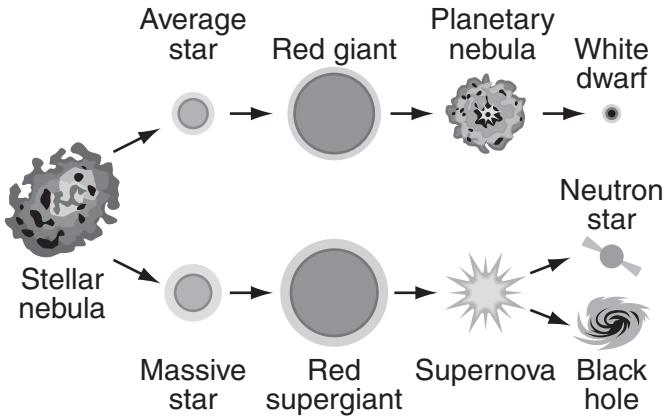
Answer question 6 on page 4 in your Student Answer Booklet.

6 Identify which stars in Data Table 1 or your scatter plot do **not** fit well with the pattern of the other stars in your scatter plot. Use your data to describe how these stars compare to the Sun.

GO ON

Kim and Jay learned that stars begin their life cycle as a stellar nebula but can take two different paths. The following diagram shows the two main paths stars typically take.

Life Cycle of a Star



Although Kim and Jay used the same information, diagrams, and graphs, they developed different predictions about what will happen to the Sun when it is no longer a main-sequence star.

Kim's prediction:

Kim predicts that the Sun will become a red supergiant after it leaves its main-sequence stage because the Sun is so much larger than Earth.

Jay's prediction:

Jay says that although the Sun is the most massive object in our solar system he disagrees with Kim's prediction and thinks that the Sun is not a large mass star. He predicts that when the Sun leaves its main-sequence stage it will become a red giant star and, over time, will end as a dim, hot, white dwarf star.

Answer question 7 on page 4 in your Student Answer Booklet.

7 Choose the prediction that most accurately represents the life cycle path the Sun will follow. Use information from the Life Cycle of a Star diagram to support your answer.

GO ON

Mr. Jones told Jay that he saw on the news that astronomers recently discovered a star in a nearby galaxy. Its luminosity is 10^8 $L_\odot$, and it has a surface temperature of over 50,000 K. Jay believes that the recently discovered star is a main-sequence star.

Answer question 8 on page 5 in your Student Answer Booklet.

8 Use information from Diagram 2 to support or refute the idea that the new star is a main-sequence star.

STOP