

Star Life Cycles 5E

Unit 1 Discovering New Worlds

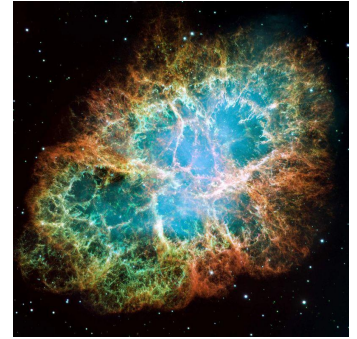
Earth and Space Science

Student Name:

What Was Supernova 1054?

Individually review the following sources, then answer the questions below:

- The text July 4, 1054
- The image called Crab Nebula
- The video of Supernova 1054



Crab Nebula

1. Based on the accounts provided by the Chinese, Arab, and Native American observers, what is a supernova?

2. How many days was Supernova 1054 visible in the sky?

3. How would you describe the Crab Nebula remnants of Supernova 1054?

4. What are your observations from the Supernova 1054 video?

Discuss with your group:

What is the overall story about Supernova 1054?

In the beginning. . .	Then. . .	Now. . .

5. What are your initial ideas about what caused the changes in the star that you just observed in the visualization?

6. What questions would you want to investigate further in order to help you determine what kind of star can support an Earth-like planet?

July 4, 1054: Crab Nebula Makes a Spectacular Debut in the Heavens

Chinese astronomers mark the beginning of Supernova 1054, heralding the birth of what will become known as the Crab Nebula.

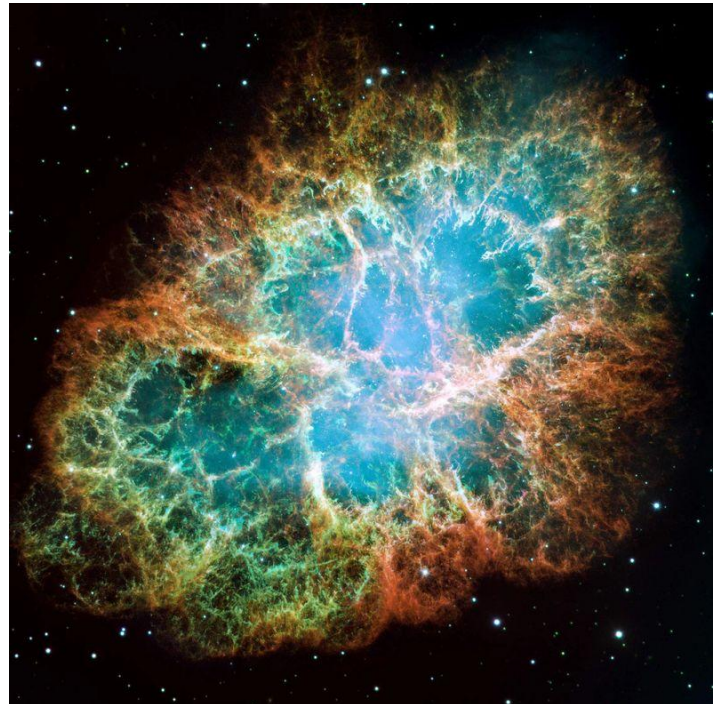
1054: A supernova noted by Chinese observers heralds the creation of the Crab Nebula. The exact date has been disputed, but most accounts accept the Chinese date of July 4.

Supernova 1054, as it is now known, was spotted in the constellation Taurus by Chinese astronomers, who recorded no fewer than 75 supernovas (or "guest stars," as they called them) between 532 B.C. and A.D. 1064. In this case, however, the magnitude was unusually large: The star shone roughly four times brighter than Venus and was visible in daylight for 23 days.

It remained visible in the night sky for 653 days.

The remnant of that exploding star is what we now know as the Crab Nebula. The nebula itself wasn't officially recorded until 1731 by English astronomer John Bevis.

The Chinese weren't the only ones to make an early sighting: Astronomers in the Arab world provided their own accounts, and archeological evidence found in North America suggests that native american sky watchers also recorded the supernova.



What Kinds of Stars Have Long and Stable Life Spans?

The Sun has been providing the Earth with energy for 5 billion years and it is expected to keep doing so for another 5 billion years. Other stars also exist for very long periods of time compared to how long humans have been around, making it impossible for humans to observe star lifespans. Scientists have been able to collect data from millions of stars in the universe that vary in age and have different properties. By programming this data into a computational model, we can simulate the life span of many different stars. This investigation uses a computational model called *Star in a Box*, which allows us to make predictions about how different stars change over time.

This simulation allows us to observe changes in size, temperature, brightness, and mass throughout the lifespan of a star. The goal of using this simulation is to help you understand the fate of stars based on their initial masses. More specifically, by the end of this activity you should be able to identify patterns in the relationship between a star's mass and how it changes over time.

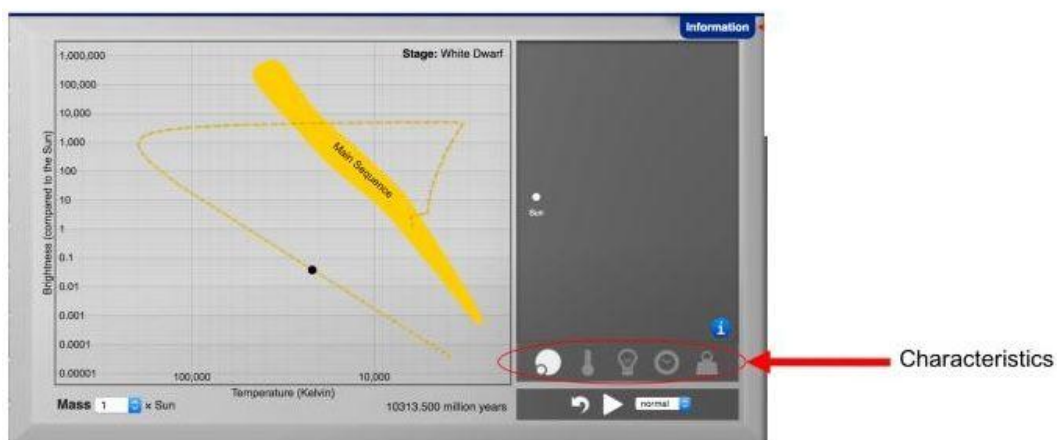
Before you begin the investigation, read over the user guide for *Star in a Box*. Be sure to ask your classmates or your teacher if you have any questions about how the simulator works.

Star in Box User Guide:

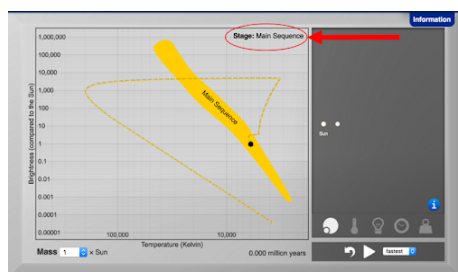
- Open your internet browser and search for [Star in a Box Simulation](#)
- Open the lid of your Star in a Box.

The graph shows a star's luminosity (rate of energy release) plotted against its temperature. On the right panel, you have data about five characteristics of your star: (1) size and color, (2) temperature, (3) luminosity, (4) time per stage, and (5) mass.

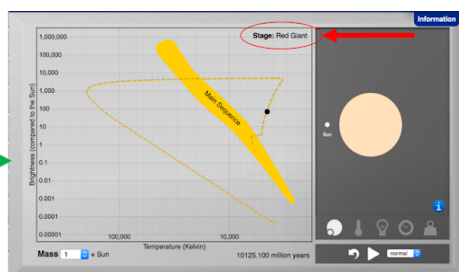
Based on the class questions, which data are the focus for this activity?



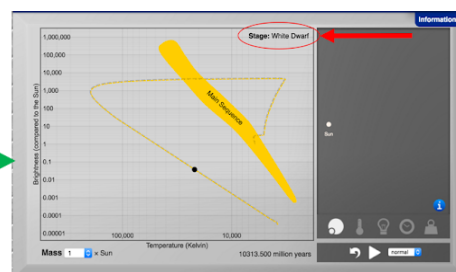
The name of the current stage of the star is in the upper right corner of the diagram. All stars begin in the Main Sequence stage. After you press “play” the star characteristics change so its place on the graph changes. Different places on the graph correspond to different stages of a star’s life cycle. Here is an example of the three stages a star like the Sun goes through:



Stage: Main Sequence

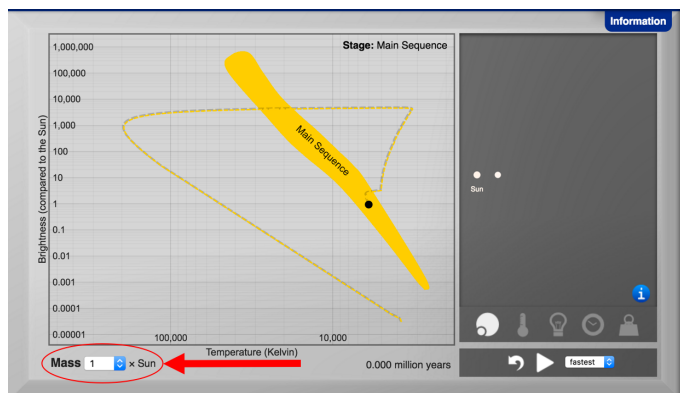


Stage: Red Giant



Stage: White Dwarf

When you open the lid, the default star has the same mass of the Sun, so you can consider this star to be our Sun or to be very similar to our Sun. You can change the mass, and select stars whose masses range from one fifth of the mass of the Sun to stars with a mass 40 times larger than the mass of the Sun!



Group the Stars Based on Life Cycle

Run the simulation on “fast” for stars of all solar masses in the simulation. Indicate below how you would group the stars based on the stages they go through.

Group	Group 1 (our Sun and stars like our Sun)	Group 2	Group 3
Stages of Life Cycle	1. Main Sequence 2. Red Giant 3. White Dwarf		
Group Which masses fall in this group?			

Group 1: Our Sun and Stars with Comparable Mass

Set the simulation to 1 solar mass. Observe how our Sun and stars with comparable masses are likely to change during the different stages of their life cycles.

Stage	Main Sequence	Red Giant	White Dwarf
Time in this stage 			
Change in size 			
Change in temperature 			
Change in luminosity 			
Change in mass 			

Group 2: _____

Set the simulation to one of the group 2 masses and run it so that you can observe stars in this group are likely to change during the different stages of their life cycles.

Stage			
Time in this stage 			
Change in size 			
Change in temperature 			
Change in luminosity 			
Change in mass 			

Group 3: _____

Set the simulation to one of the group 3 masses and run it so that you can observe stars in this group are likely to change during the different stages of their life cycles.

Stage				
Time in this stage 				
Change in size 				
Change in temperature 				
Change in luminosity 				
Change in mass 				

See-Think-Wonder

See What pattern did you observe in the data?	Think What do you think this pattern means?	Wonder What questions do you have about the pattern?

What Properties of Stars Give Us Clues About Their Life Spans?

Have you ever seen stars in the night sky? If you live in the city, you may see fewer stars than in the image below. From a dark place on Earth, many stars are visible.



Night Sky

1. What do you think we would see if we looked at that same portion of the sky with an even more powerful telescope?

2. What do you think we would see if we looked at the stars with a telescope that is in space?

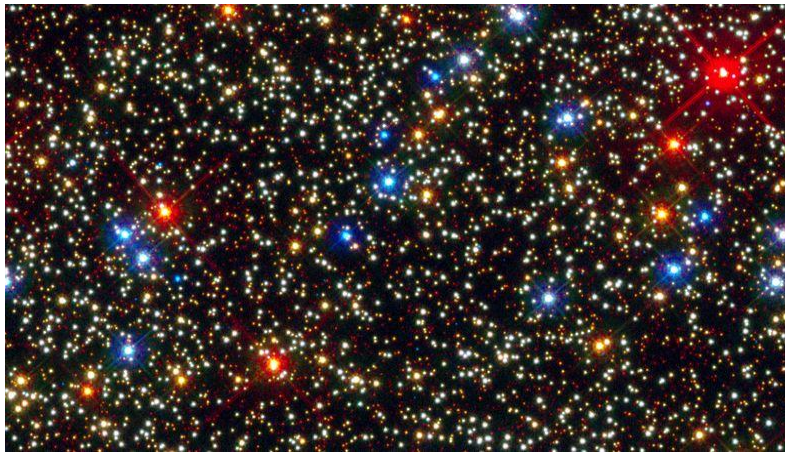
The Hubble Telescope



Hubble Telescope

In 1990, NASA launched the powerful Hubble telescope into space. Since then it has recorded images and collected data, revolutionizing our understanding of stars and space.

The image below is of the heart of a giant star cluster known as Omega Centauri. A collection of nearly 10 million stars in all, it's the largest of about 150 star clusters in the Milky Way.

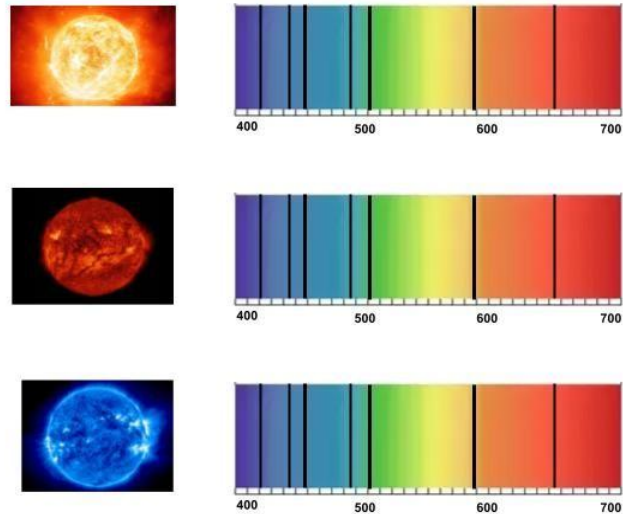


Omega Centauri

Examine the image and light spectra of several stars in the cluster closely, then respond to the questions that follow.

1. What do you observe about the stars in the Hubble image?

Spectra Data from Omega Centauri Star Cluster

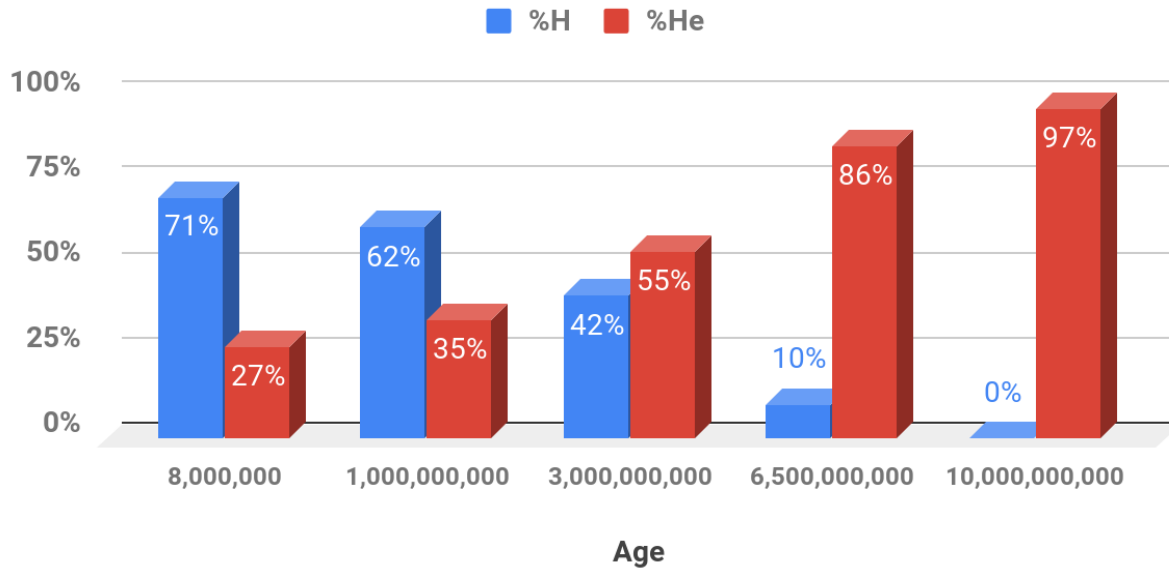


2. What do you observe in the star light spectra from stars in the Hubble image? Explain your observations.

3. What do you think explains the differences observed in the stars, given your observations about the spectra?

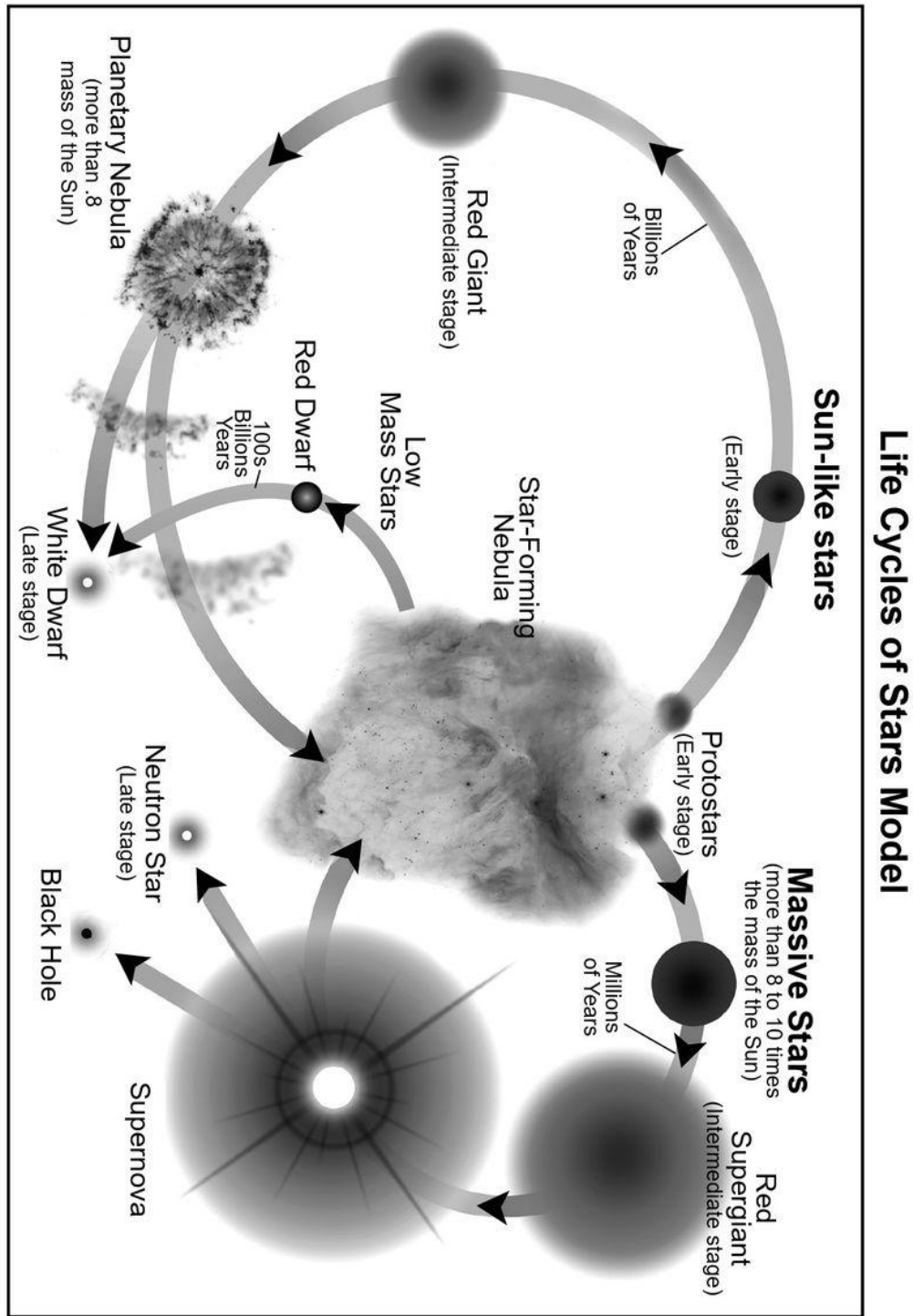
Composition of 1 Solar Mass Star

1 Solar Mass Percent Composition vs Age - Star Core



Star Life Cycles Optional Extension

The life cycles of stars can be modeled in many ways. In the previous activity, you used a digital model to view how stars of different masses change over time. These changes can also be viewed as in a model like the one shown in the *Life Cycles of Stars Model* below.



Use the three-level guide and the Star in a Box simulation to annotate and interpret the *Life Cycles of Stars Model*

Step 1 - Reading the Lines

1. What types of stars does this model include?

2. On the model, identify the three paths a star can take, and mark them in different colors. Number the paths 1-3 and describe the phases a star moves through for each one below:

Path 1:

Path 2:

Path 3:

3. Using the model, rank each path a star can take from fastest to slowest

Speed	Path Number	Number of years
fastest		
medium		
slowest		

Step 2 - Reading Between the Lines

Compare the diagram to the Star in a Box Simulation to respond to each prompt below.

1. On the model, annotate where the “main sequence” is for each star type.
2. On the model, annotate the masses of the stars from the star in a box that took each path
3. Use the Star in a Box Simulation and the *Life Cycles of Stars Model* to predict the behavior of stars of each of the following masses, including the phases those stars would go through and the approximate number of years it would spend in each phase

Star Mass	Phases it Would go Through	Approximate Number of Years in Each Phase
.75 x the sun		
3x the sun		
15 x the sun		

Step 3 - Reading Beyond the Lines

1. Compare the digital Star in a Box simulation model to the *Life Cycles of Stars Model*. How are these two models similar? How are they different?

2. When do you think it would be more useful to use a digital model like the Star in a Box simulation, and when would it be better to use an image like the *Life Cycles of Stars Model*? Support your answer with specific examples of what each model is helpful for.

How Do We Use Observable Properties to Identify Stars with Long and Stable Lifespans?

Objective: You just learned that there is a relationship between the mass of stars, their life span, and how characteristics such as luminosity and temperature change over their life spans. Through this activity, you will study a cluster of stars in order to identify what observable properties allow us to determine a star's mass, so that you can make predictions about their life spans and how they change over time.

Background: As you noticed in the image of the star cluster, stars exhibit many properties, so organizing our star data into a visual representation will make it easier for us to analyze the stars and look for connections between their observable properties, mass, and life span. You will be given a labeled chart and a series of stars to plot based on the data provided for each. From this star chart, you can deduce a lot of information about stars!

Each of the star data points has the following information:

- Star Name: the common or catalog name of the star
- Temperature: the temperature of the surface of the star (how fast molecules are moving on average)
- Luminosity: the rate at which a star emits energy compared to our sun (a fraction means it is dimmer than our Sun)
- Expected Life Span: the number of years the star is expected to exist before it runs out of fuel

Variables:

1. What variable is located on the x-axis of the chart?

a. What unit is used to measure this variable?

b. What is the range for this variable?

c. What is unique about the x-axis on this chart?

2. What variable is located on the y-axis of the chart?

a. What unit is used to measure this variable?

b. What is the range for this variable?

Plotting Stars:

1. Hand out the “stars” to each member of your group. Have each person put 4-5 stars on the chart. Write down 3 observations about what you see so far.

Initial Observations of the Data

2. Work together to put the rest of the stars on the chart, then look for patterns in the star data. List patterns in the data in the left column, and state the evidence that you used to identify each pattern in the right column.

List the patterns in the star data below	State the evidence for each pattern in the star data below

3. Draw vertical lines on your chart to separate the stars by color. Then, below the x-axis of your chart, write the colors that correspond to each section.

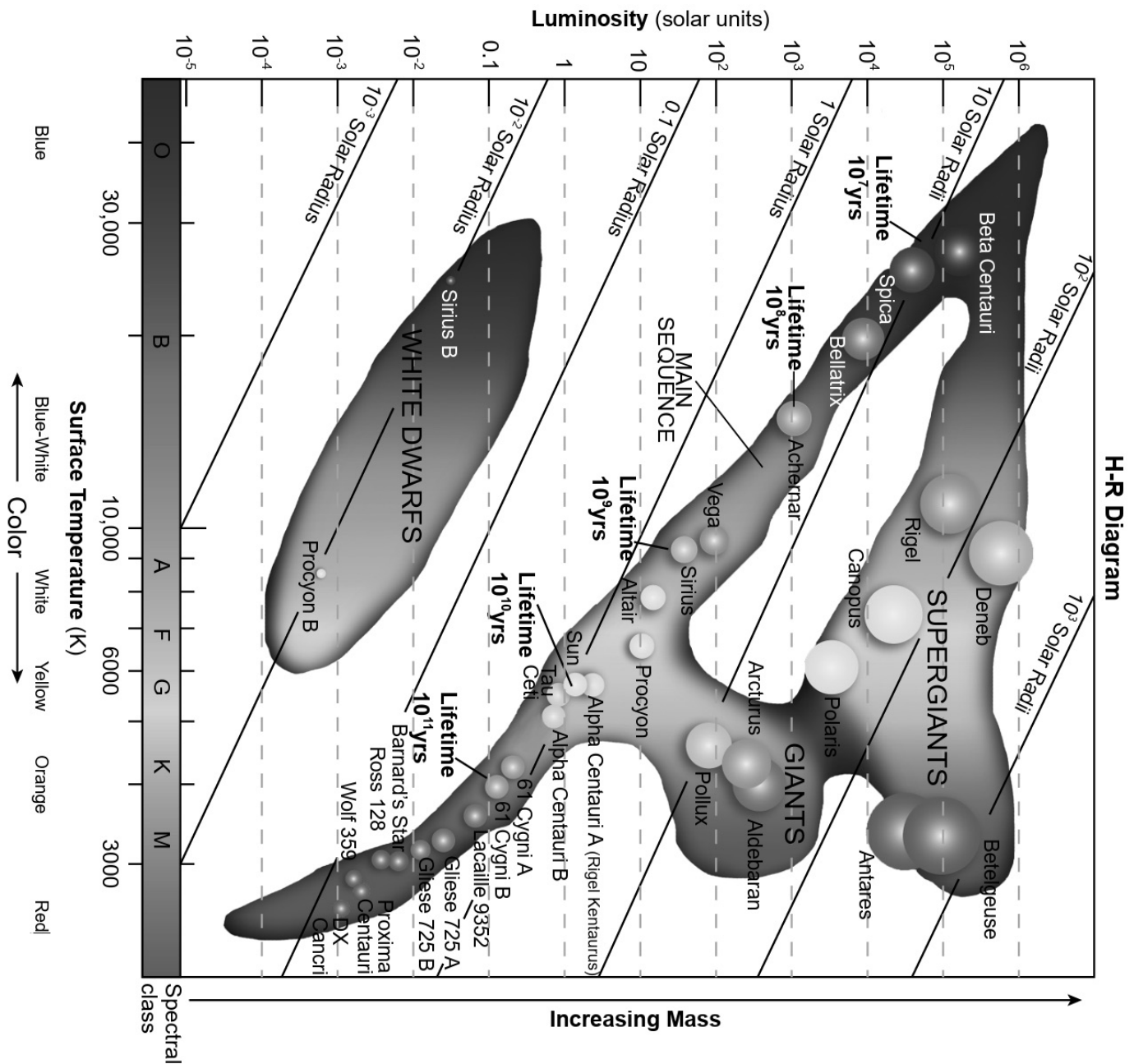
See-Think-Wonder

See What pattern did you observe in the data?	Think What do you think this pattern means?	Wonder What questions do you have about the pattern?

H-R Diagram Optional Extension

The H-R diagram you constructed mirrors H-R diagrams used by scientists, though different versions of the diagram contain slightly different information and may be written in slightly different ways. Scientists become fluent with reading different versions of this diagram by comparing it to ones they have seen before and interpreting any additional information given.

Compare your diagram with the one below and analyze this new diagram by answering the questions that follow the image.



Step 1 - Reading the Lines

1. Locate the sun and circle it clearly.
2. According to the diagram, how long is the lifetime of the sun?

-
3. Read the left side Y axis. What is it showing?

-
4. The numbers are written in scientific notation (using exponents).

When it says 10^6 , it means 1 with 6 zeros after it (in standard notation, that is 1,000,000).

When it says 10^{-5} , it means to move the decimal point 5 to the left of the 1 (.00001). Rewrite the numbers in standard notation so they are easier to read.

5. View the X axis. What is it showing?

-
6. Mark where color is indicated on the graph.

7. Look at the right side Y axis. What is it showing?

-
8. What information is present on this diagram that was not on your H-R diagram?
-
-
-
-

Step 2 - Reading Between the Lines

1. Find a star with a lifespan of approximately 10,000,000 years.

a. State the name of the star:

b. What is the approximate temperature of that star?

c. What is the approximate luminosity of that star, in both scientific and standard notation?

d. What is the approximate size of that star (how many solar radii)?

e. What color is the star?

2. Find a white dwarf star.

a. State the name of the star:

b. What is the approximate temperature of that star?

c. What is the approximate luminosity of that star, in both scientific and standard notation?

d. What is the approximate size of that star (how many solar radii)?

e. What color is the star?

3. Find a supergiant star.

a. State the name of the star:

b. What is the approximate temperature of that star?

c. What is the approximate luminosity of that star, in both scientific and standard notation?

d. What is the approximate size of that star (how many solar radii)?

e. What color is the star?

Step 3 - Reading Beyond the Lines

1. Based on your experience creating and reading H-R diagrams, explain what this diagram shows you and when you might use it

2. When might the version of the H-R diagram that you made be more useful than this one? When might this one be more useful than the one you made? Support your answer with specific examples of how each one can be used.

3. Identify one star that is likely to be Earth-like, and potentially host life. Support your answer using specific information from the diagram.

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4. Identify one star that is NOT likely to be Earth-like, and is not likely to host life. Support your answer using specific information from the diagram.

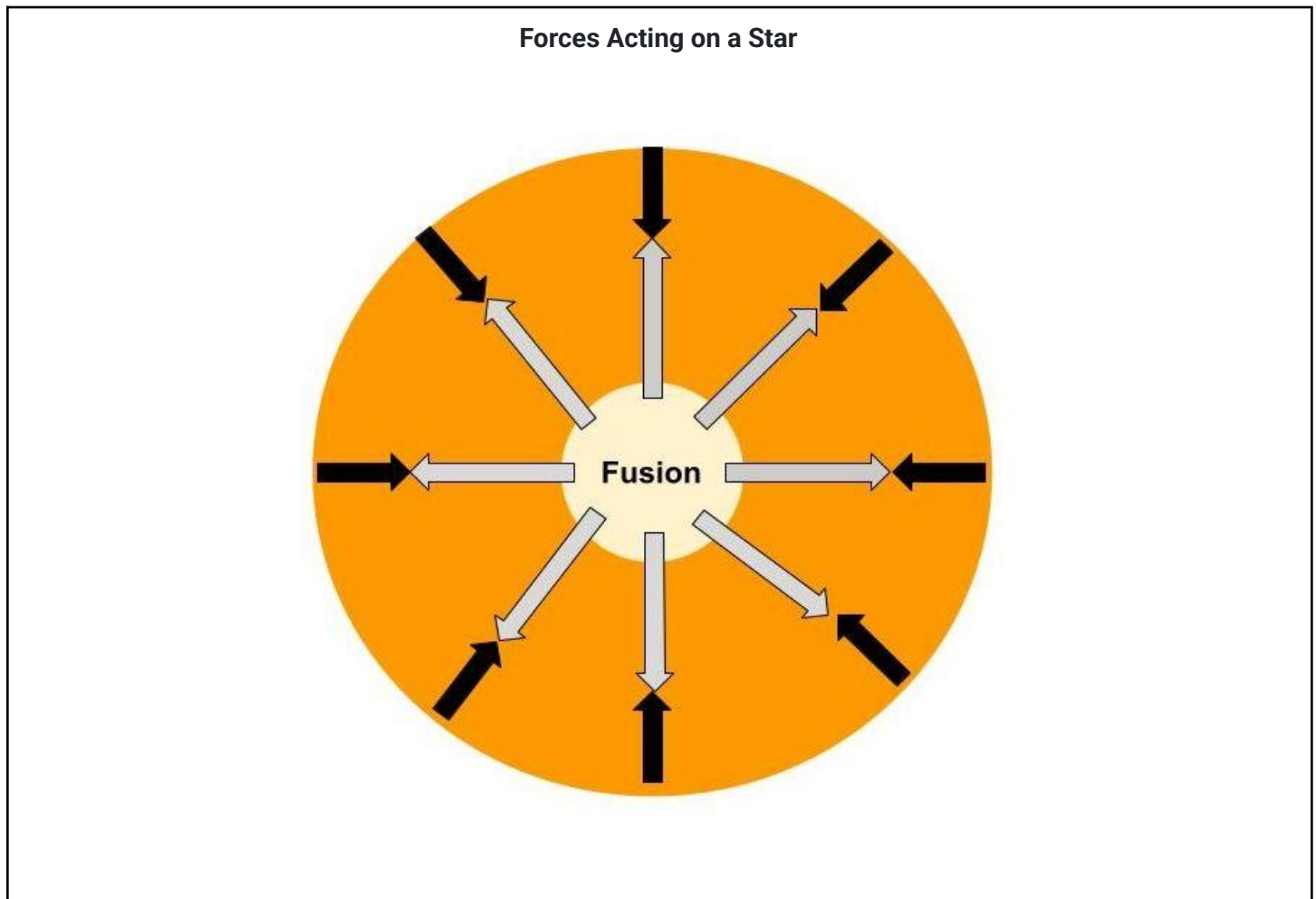
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5. Identify one star that is likely to explode as a supernova. Support your answer using specific information from the diagram.
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-
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How and Why do Stars Change

Forces Within a Star

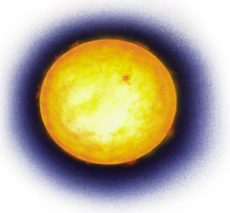
There are several forces acting on a star. Every object in the universe that has mass (e.g., atoms, planets, the Sun, yourself), generates gravity, a force that attracts other objects and particles towards its center. This force is very weak, but **the more mass an object has, the more gravity it generates**. Inside a star, gravity pulls inward, trying to collapse the star in on itself. You can picture this by imagining your hands squeezing a stress-ball. When gravity pulls hydrogen gas particles together inside a star, they collide more frequently and with more force, which leads to nuclear fusion. A small percentage of the mass from the hydrogen gas is lost when it is fused into helium, because it is converted into tremendous amounts of energy. This net gain in energy from nuclear fusion in the core pushes outward, trying to blast matter into space. Stars whose size changes relatively little have achieved a state of **equilibrium**, which means that the forces pushing in and the forces pushing out are equal and balance each other out. As long as the star has enough hydrogen fuel in its core to continue fusion reactions, the star will maintain equilibrium and stay as a main sequence star. This means that **when the star shrinks or expands, it is because the force of gravity that pushes inward and the internal fusion force that pushes outward are not equal anymore**. In other words, the forces are not in equilibrium.

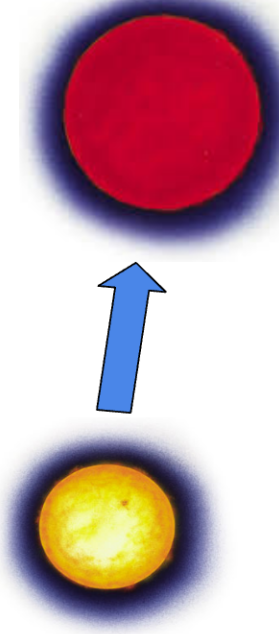
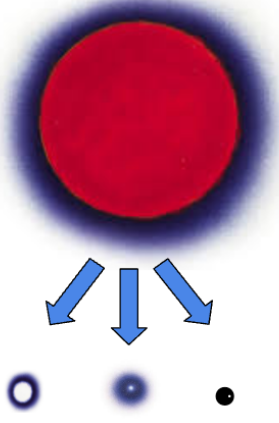
1. Use the text above to label the parts of the diagram called **Forces Acting on a Star**.



2. Make a prediction about the star in this diagram. Is it at equilibrium? How do you know?

Forces acting on a star lead to changes over their life cycles. Draw the forces pushing outward and inward at each stage of a star's life cycle. For each stage, decide on the size of gravity and fusion pressure arrows you want to draw so that they reflect the pattern in size change you observed during each stage.

Hydrogen gas and a dust cloud form new stars.	Explanation Be sure to discuss the role of the force of gravity and/or fusion force in your explanation for why new stars form from a hydrogen and dust cloud. Don't forget to include evidence to support your claim.
	
Stars change very little while they are in the Main Sequence stage.	Explanation Be sure to discuss the role of the force of gravity and/or fusion force in your explanation for why stars change very little while they are in the main sequence stage. Don't forget to include the evidence to support your claim.
	
Main Sequence stars change quickly when they grow into a Red Giant	Explanation Be sure to discuss the role of the force of gravity and/or fusion force in your explanation for why a Main Sequence star eventually grows in size to become a Red Giant. Don't forget to include evidence to support your claim.

	
Depending on a star's initial mass, the last stage of a star's life cycle is either a White Dwarf, Neutron Star, or Black Hole. These are some of the most dense objects in the universe.	Explanation Be sure to discuss the role of the force of gravity and/or fusion force in your explanation for why stars become much smaller and incredibly dense (compact) at the end of their life cycles.
	

What connections are there between star life cycles and the rate of nuclear fusion in stars?

In order to start explaining the relationship between a star's initial mass and the length of a star's life cycle, think back to what you observed in Star in the Box and respond to the questions below. You will need to provide evidence for each response, so refer back to your observations from Star in the Box if necessary.

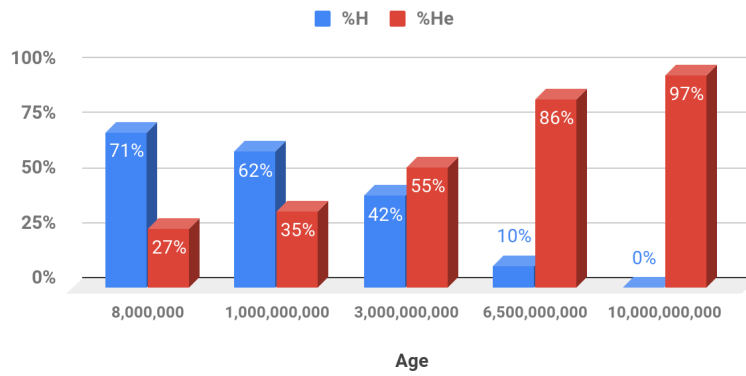
1. In which stage are stars the most stable? What explains this stability?

2. In what stage do stars spend most of their life cycles? Why?

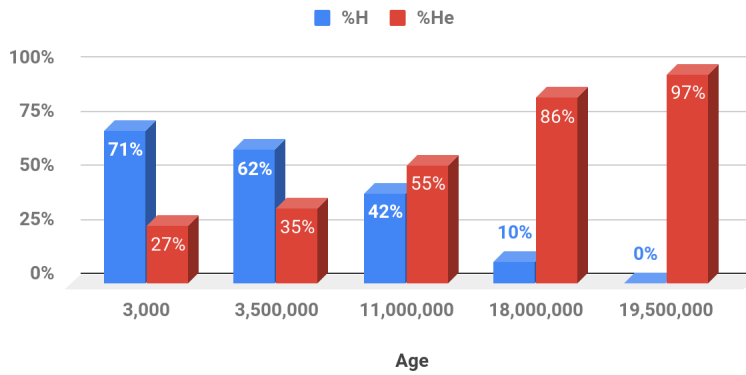
3. Which stars spend the least time in this stage? High or low mass?

4. The Percent Composition vs. Age graphs (on the next page) show the hydrogen and helium ratios in main sequence stars of different initial masses. What connections do you see between the amount of time stars of different masses spend in the main sequence and the data below?

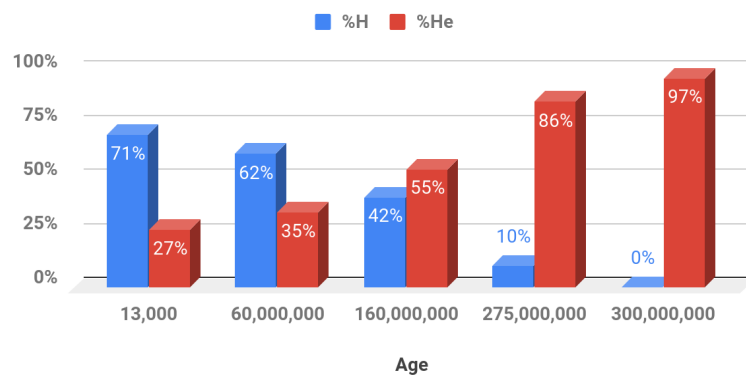
1 Solar Mass
Percent Composition vs Age - Star Core



10 Solar Mass
Percent Composition vs Age - Star Core



3 Solar Mass
Percent Composition vs Age - Star Core



Summary Task

We recently 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. Why was studying our Sun alone not enough to identify *patterns* that we can use to make claims about which stars are most stable and which stars change the fastest?

-
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-
2. How was studying many stars helpful in identifying *patterns* that we can use to make claims about which stars are most stable and which stars change the fastest?

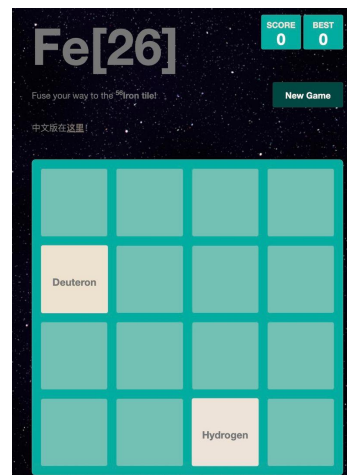
-
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3. Why was it important to figure out why some stars are more stable than others?

-
-
-
-
4. Why might figuring out why things change and why they stay the same be something important to think about when investigating phenomena or finding solutions to problems?

Why do more massive stars change and die faster?

As you remember from the text, *Forces Within a Star*, inside a star gravity pushes hydrogen elements together so close and with such a force that sometimes these elements fuse into heavier elements. This game simulates just that! The goal is to make one tile of ^{56}Fe , or iron-56. A star needs to have a lot of gravity in order to push elements together tightly enough to create heavier elements. As you might remember, the more mass a star has, the more gravity it has.

In order to play this game, you just need to press any of the four arrow keys to make a move. This causes all the tiles to slide as far to that side as possible. Every time you manage to combine two element tiles, the score will increase. Remember from the video that when two atoms are combined, some mass is transformed into energy. In the game, when you combine two elements, your score will increase, so for now let's call the points in the game **energy points**. The higher your score, the more mass was transformed into energy. Finally, when you reach Game Over, this means your star has died.



1. Review your notes about fusion first. Play the [Iron \[26\] Game](#) for 5 minutes, and try to relate what you are observing to what you know about fusion below.

2. Now consider the role of gravity. As you know by now, gravity pulls elements closer to each other. Remember too that the more gravity, the faster elements can fuse with each other. As an example, consider a star with low mass (like the Sun), and a star 20 times the mass of the Sun.

Revisit the Iron [26] game again, how do you think you can represent the difference in gravity of a low mass star and a high mass star in the game? Consider the following:

- a. What role does gravity play in nuclear fusion?

- b. How would this be different in a low mass star vs a high mass star? Why?

c. How would you show this using the nuclear fusion game?

Using the Fe [26] game to model nuclear fusion in a star

Work with a partner in order to model nuclear fusion in a low and a high mass star with the *Fe [26] game*. One partner should act as timekeeper and recorder of observations, while the other partner plays the game.

1. The timekeeper/observer sets the timer to 90 seconds.
2. When the timekeeper starts the timer, the game player should use the method you agreed upon with your classmates to represent gravity in low mass stars.
3. Switch roles, this time to simulate gravity pushing light elements together in a high mass star. **Be sure that the timekeeper/observer records all observations of what is happening in the game.**

Our Sun and Stars with Comparable Mass	High Mass Stars
Gravity: Describe how you simulated gravity for these stars.	Gravity: Describe how you simulated gravity for these stars.
Observations (e.g. energy points, the elements that are formed):	Observations (e.g. energy points, the elements that are formed):

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Part 1: What's the relationship between mass of a star and the elements it produces?

Since our Sun was formed, it has been fusing hydrogen to produce helium and energy. This is the process that occurs during the main sequence stage, which is most of a star's lifetime. When hydrogen in a star's core is all used up, the star begins to burn helium and forms progressively heavier elements like carbon, oxygen and so on, until iron is formed. All these processes release a lot of energy! But do all stars produce elements as heavy as iron?

1. Revisit your observations. How did the types of elements produced by your model of a low-mass star compare to the types of elements produced by your model of a high-mass star? Model both again if necessary. You can use the periodic table of elements below to explore details of the elements produced.

Periodic Table of the Elements

Legend:

- metal (blue)
- non-metal (purple)
- noble gas (green)
- solid
- liquid
- gas

I		II												III	IV	V	VI	VII	
Li 3 6.9	Be 4 9.0											B 5 10.8	C 6 12.0	N 7 14.0	O 8 16.0	F 9 19.0	Ne 10 20.2		
Na 11 23.0	Mg 12 24.3											Al 13 27.0	Si 14 28.1	P 15 31.0	S 16 32.1	Cl 17 35.5	Ar 18 40.0		
K 19 39.1	Ca 20 40.1	Sc 21 45.0	Ti 22 47.9	V 23 50.9	Cr 24 52.0	Mn 25 54.9	Fe 26 55.8	Co 27 58.9	Ni 28 58.7	Cu 29 63.5	Zn 30 65.4	Ga 31 69.7	Ge 32 72.6	As 33 74.9	Se 34 79.0	Br 35 79.9	Kr 36 83.8		
Rb 37 85.5	Sr 38 87.6	Y 39 88.9	Zr 40 91.2	Nb 41 92.9	Mo 42 95.9	Tc 43 98.0	Ru 44 101.1	Rh 45 101.1	Pd 46 106.4	Ag 47 107.9	Cd 48 112.4	In 49 114.8	Sn 50 118.7	Sb 51 121.8	Te 52 127.6	I 53 126.9	Xe 54 131.3		
Cs 55 132.9	Ba 56 137.3	La 57 138.9	Hf 58 178.5	Ta 59 180.9	W 60 183.8	Re 61 186.2	Os 62 190.2	Ir 63 192.2	Pt 64 195.1	Au 65 197.0	Hg 66 200.6	Tl 67 204.4	Pb 68 207.2	Bi 69 209.0	Po 70 209	At 71 210	Rn 72 222		
Fr 87 223	Ra 88 226	Ac 89 227	Rf 90 261	Db 91 262	Sg 92 266	Bh 93 264	Hs 94 277	Mt 95 268											
* Lanthanoids		Ce 58 140.1	Pr 59 140.9	Nd 60 144.2	Pm 61 145	Sm 62 150.4	Eu 63 152.0	Gd 64 157.3	Tb 65 158.9	Dy 66 162.5	Ho 67 164.9	Er 68 167.3	Tm 69 168.9	Yb 70 173.0	Lu 71 175.0				
** Actinoids		Th 90 232.0	Pa 91 231	U 92 238.0	Np 93 237	Pu 94 244	Am 95 243	Cm 96 247	Bk 97 247	Cf 98 251	Es 99 252	Fm 100 257	Md 101 258	No 102 259	Lr 103 260				

Periodic Table of Elements

2. What is the relationship between the mass of a star and the mass of the elements it produces?

-
-
3. What is the relationship between the mass of a star and the amount of energy it releases?
-
-

When chemical and physical processes occur, the amount and types of atoms involved are conserved -- in other words, the mass is conserved! But what about in nuclear reactions? The table below contains data associated with a few examples of nuclear fusion reactions that can take place in a star's core. Examine the *Example Nuclear Fusion Reactions* data below, then respond to the questions that follow.

Example Nuclear Fusion Reactions

Nuclear Fusion Reaction	Atoms Before Fusion	Protons + Neutrons Before Fusion	Atoms After Fusion	Protons + Neutrons After Fusion
Fusion of hydrogen	hydrogen-1 + hydrogen-2	3	helium-3	3
Fusion of helium	helium-3 + helium-4	7	beryllium-7	7
Fusion of beryllium and helium	beryllium-8 + helium-4	12	carbon-12	12
Fusion of carbon and helium	carbon-12 + helium-4	16	oxygen-16	16

1. Were the types of atoms conserved? Cite evidence from the table to support your response.
-
-
-

2. As you probably remember from middle school, the protons and neutrons of an atom make up all of its

mass. Was mass (protons + neutrons) conserved in the nuclear fusion reactions? Cite evidence from the table to support your response.

Part 2: Why Do More Massive Stars Change and Die Faster?

Use evidence from the *Fe [26] game* to explain why a 20 solar mass star has a shorter life span than a 1 solar mass star?

- 1. As you know by now, the majority of a star’s composition is hydrogen, so which has more hydrogen fuel to begin their life span, a 1 or 20 solar mass star?

- 2. Explain why a high-mass star has a much shorter lifespan than a low-mass star despite the fact that a high-mass star has much more hydrogen (fuel) to burn.

Part 3: Putting it All Together (Think-Talk-Open-Exchange)

Why are high-mass stars able to produce heavier elements than low-mass stars?	Why do high-mass stars have higher luminosities than low-mass stars?	Why is it that high-mass stars have much more initial hydrogen fuel to burn than low-mass stars, yet they have a much shorter lifespan?

Discussion Notes:



How are elements heavier than iron produced?

You may have noticed when using the Iron [26] computational model, that no elements heavier than iron were produced. So where does the energy required to produce elements like copper, gold, silver, and all other elements heavier than iron come from? The formation of elements heavier than iron requires much more energy than gravity can lead to in a star's core.

1. Consider what you have learned and observed as you have been investigating stars. Can you think of an event in a star that might provide the energy necessary for elements heavier than iron to be produced?

2. Supernova explosions produce elements like copper, gold, silver, and all other elements heavier than iron. What do you think explains why these elements were able to form in a supernova explosion? Use evidence from the Supernova 1054 video and text to support your response.

Star Life Cycles Model Rubric

Star Life Cycles	Proficient	Developing
Model	The model effectively and accurately shows what is happening within the Sun that explains why it has had stable properties long enough to sustain life and includes all of the components below: - Arrows that represent force of fusion pushing outward from the center of the Sun where nuclear fusion is taking place. - Arrows that represent the force of gravity pulling inward toward the center of the Sun. - The arrows represent fusion force and gravitational force as close to the same magnitude. The components of the model “speak for themselves” for the most part. OR There are legends, keys, or written captions to clarify the components.	The model is incomplete in showing what is happening within the Sun that explains why it has had stable properties long enough to sustain life, missing one or more of the components below: - Arrows that represent force of fusion pushing outward from the center of the Sun where nuclear fusion is taking place. - Arrows that represent the force of gravity pulling inward toward the center of the Sun. - The arrows represent fusion force and gravitational force as close to the same magnitude. The components of the model do not really “speak for themselves.” OR Legends, keys, or written components are insufficient to clarify the model.
Stability and Change	Either the model or a written explanation cites the Sun’s luminosity and temperature as evidence that it is a stable main sequence star with equal magnitudes of fusion force and gravitational force, and makes the connection to why the Sun’s properties are currently changing very little. Either the model or a written explanation shows that the relatively low mass of the Sun is the reason why gravity leads to hydrogens fusing together at a slower rate than in heavier stars and the reason why the Sun has had stable properties (size, temperature, and luminosity) for such a long time. Either the model or a written explanation shows that the Sun’s relatively stable properties have allowed liquid water to exist on Earth long enough for life to evolve.	There is little or no consideration of the Sun’s luminosity and temperature as evidence that it is a stable main sequence star with equal magnitude of fusion force and gravitational force and/or no connection is made to why the Sun’s properties are currently changing very little. There is little or no consideration of the Sun’s low mass as a reason why gravity leads to a slower rate of fusion than in heavier stars and is the reason why the Sun’s properties (size, temperature, and luminosity) have been stable for such a long time. There is little or no consideration of the Sun’s relatively stable properties as a reason why liquid water has been able to exist on Earth long enough for life to evolve.

	Response to reflection prompt 1 clearly articulates why it is useful to understand stability and change when investigating other phenomena.	Response to reflection prompt 1 does not clearly articulate why it is useful to understand stability and change when investigating other phenomena.
Patterns	Students explain why it was necessary to investigate stars at three different scales (solar system, supercluster, atomic) in order to explain star stability. Response to reflection 2 prompt clearly articulates why it is useful to look for patterns at different scales of a system when investigating phenomena.	There is little or no consideration of the necessity to investigate stars at three different scales (solar system, supercluster, atomic) in order to explain star stability. Response to reflection prompt 2 clearly articulates why it is useful to look for patterns at different scales of a system when investigating phenomena.
Student Self- Score	Circle One Proficient Developing	Glow: Grow:
Teacher Score	Circle One Proficient Developing	Glow: Grow:

Star Life Cycles Argument Rubric

Argument based on Star Life Cycles	Student makes a claim identifying which star is most likely to host an Earth-like planet. The claim is supported with relevant/accurate evidence from the star data set, investigations, or readings, including: • Temperature, luminosity, and placement HR-diagram Reasoning is provided to support the claim, including: • Connection between evidence cited and mass, stability, and life span. • Connection between stability and capacity to host and Earth-like planet	Student makes a claim identifying which star is most likely to host an Earth-like planet. The claim is weakly supported with evidence from the tar data set, investigations, or readings. Reasoning is not provided to support the claim.
Stability and Change	The argument cites the star's luminosity and temperature as evidence to support the claim and the reason it is predicted to be a stable main sequence star with equal magnitudes of fusion force and gravitational force, and makes the connection to why the stars's properties are currently changing very little. The argument cites the relatively low mass of the star as evidence to support the claim and the reason why it is predicted that gravity leads to hydrogens fusing together at a slower rate than in heavier stars, therefore likely to be a star that exhibits stable properties (size, temperature ,and luminosity) for a long time. The argument discusses why the stars' relatively stable properties means it's possible that liquid water has existed on a planet it hosts long enough for life to evolve. Response to reflection prompt 2 clearly articulates why understanding stability and change was useful in developing the argument.	There is little or no consideration of the star's luminosity and temperature as evidence to support the claim and the reason it is predicted to be a stable main sequence star with equal magnitudes of fusion force and gravitational force. There are no connections made to why the stars's properties are currently changing very little. There is little or no consideration of the star's mass as evidence for supporting the claim and the reason why it is predicted that gravity leads to hydrogens fusing together at a slower rate than in heavier stars. There is no connection made to why the star is likely to be a star that exhibits stable properties (size, temperature, and luminosity) for a long time. There is little or no consideration of why the stability of the star's properties means it's possible that liquid water has existed on a planet it hosts long enough for life to evolve. Response to reflection prompt 2 clearly articulates why understanding stability and change was useful in developing the argument.



Patterns	Patterns from different scales of the galaxy (solar system, supercluster, atomic) are cited in the argument. Response to reflection prompt 2 clearly articulates why investigating stars at three different scales of the galaxy (solar system, supercluster, atomic) was useful in developing the argument.	Patterns from different scales of the galaxy (solar system, supercluster, atomic) are not cited in the argument. Response to reflection prompt 2 clearly articulates why investigating stars at three different scales of the galaxy (solar system, supercluster, atomic) was useful in developing the argument.
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?

3. Is there something you learned in this unit you would like to research further? If so, would you be willing to present your findings to the class and/or school community?

