National Aeronautics and
Space Administration

Astro-Venture

Design A Planet

Educator Guide

Featuring Activities in Astrobiology: Conclusion

Astronomy

Atmospheric Science

Biology

Geology

www.nasa.gov
http://astroventure.arc.nasa.gov

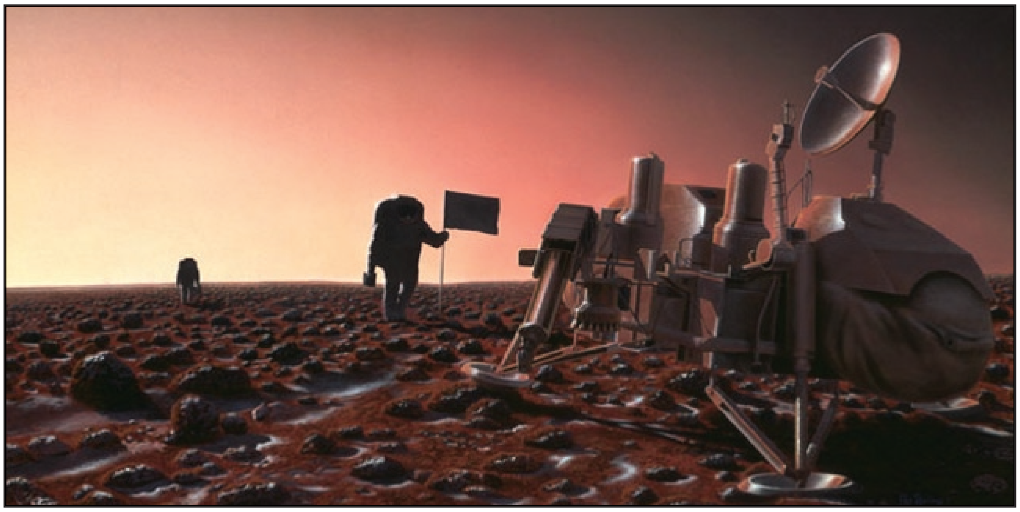
Educator Product	
Educators	Grades 5-8

EG-2005-10-501-ARC

Astro Venture: Design A Planet

Table of Contents

Design A Planet
Conclusion



“Return to Utopia” illustration: Mars crew approaching Mars lander from previous mission; Pat Rawlings, NASA

Students review the necessary planetary conditions for human survival. Using an online multimedia module, they design a planet that meets all human requirements for survival.

Main Lesson Concept:
While Earth is currently the only habitable planet we know of, computer modeling can be used to analyze data and see that there is more than one possible combination of variables that work together as a system to make a planet habitable.

Scientific Question:
What combinations of variables make a planet habitable? Why?

Note to Teacher: This lesson is written as a culminating assessment activity for all of Astro-Venture. However, the module is designed to stand alone, so there is a lot of flexibility in how it can be used. Design A Planet can be used at the beginning of Astro-Venture to provide a hook for the rest of the program, at the end of Astro-Venture as an assessment, or it can be used in isolation at home or in a museum environment.

Objectives	Standards
1. Students will apply knowledge of the basic characteristics of a habitable planet in a modeling environment to design their own habitable planet. 2. Students will describe how the different characteristics of their habitable planet work together as a system to make it habitable. 3. Students will identify the usefulness and limitations of a scientific model.	**Meets:** 2061 11B (6-8) #2 ITEA 2N (6-8) NSES A (5-8) #3 **Partially meets:** 2061 11A (6-8) #3 2061 4A (9-12) #1 thru #4 2061 9B (9-12) #3 **Addresses:** 2061 1C (6-8) #3

Design A Planet
Conclusion

Assessment	Abstract of Lesson
Printed Design A Planet results and written explanation.	Students review the basic requirements for human survival and discuss how these are met by the Earth system. Students discuss computer models and then engage in a simple online Design A Planet computer model in which they select a number of characteristics of a planet to see if they can come up with combinations that support human habitability. They then draw conclusions about the difficulty of designing habitable planets for humans versus habitable planets for extremophiles, and discuss extremophiles and planetary formation. Finally, students choose from a variety of final projects to describe their habitable planet's characteristics, how they work as a system to support human habitability, and the benefits and limitations of computer models.

Prerequisite Concepts	Major Concepts
• Humans need water, oxygen, food, gravity, a moderate temperature, and protection from poisonous gases and high levels of radiation to survive. (Astronomy Lesson 1) • Earth is habitable to humans because it has a yellow star, Jupiter in a circular orbit beyond three astronomical units (AUs), an Earth-size planet of a mass that is between one-fourth and four times the Earth's mass, and an orbit in the Habitable Zone. (Astronomy Lessons 1 and 2) • Systems consist of many parts that usually influence each other. Something may not work as well (or at all) if a part of the system is missing, broken, worn out, mismatched, or misconnected. (Astronomy Lesson 7) • A planet's temperature is determined by the temperature of its star, the distance of the planet from its star, and the thickness and composition of the planet's atmosphere. (Astronomy Lesson 9) • The following geologic characteristics allow Earth to remain habitable to humans: liquid outer core coupled with the planet's rotation and a thick atmosphere, a viscous mantle that moves slowly and causes slow motion of lithosphere (crust and upper mantle) of 3 to 5 centimeters a year. (Geology Lesson 1) • The movement of the crust and mantle allows carbon to be cycled in and out of the atmosphere, stabilizing the surface temperature. (Geology Lesson 6) • Plants are producers that use energy in light to make sugars out of carbon dioxide and water. Oxygen is released in this process. (Biology Lesson 3)	• Mathematical models can be displayed on a computer and then modified to see what happens. • Computer models are limited in how well they can represent the ways that something works. • The usefulness of a mathematical model for predicting outcomes may be limited by uncertainties in measurements, by neglect of some important influences, or by requiring too much computation. • Systems thinking involves considering how every part relates to other parts. • When one variable of a planet is changed, the whole system is usually affected.

Conclusion

Suggested Timeline (45-minute periods):

Day 1: Engage section
Day 2: Explore section
Day 3: Explain and Extend sections
Day 4: Evaluate section
Day 5: Evaluate section

Materials and Equipment:

- Human Survival Needs Transparency
- Computer Models Transparency (optional)
- One Virtual Planetary Laboratory (VPL) fact sheet and each VPL career profile for every group
- One class set of Astro Journal: Design A Planet Computer Model
- Design A Planet Results Transparency (optional)
- One class set of Design A Planet Project directions
- 1 to 30 computers with Internet browser, Internet connection and the Flash 6 Player installed
- A printer connected to the computers (optional)
- Projector or TV connected to a presentation computer (optional)
- Overhead projector
- Chart paper, blackboard, or whiteboard
- Project materials will vary by projects chosen but may include:
  - Lined paper
  - Typing paper
  - Poster paper
  - Marker, crayons, and/or colored pencils
  - Styrofoam™ balls, clay, or other materials to make 3-D planet models
  - Presentation software and computers
  - Video camera
  - Rulers
  - Graph paper

Preparation:

- Prepare class sets of Astro Journals.
- Prepare overhead transparencies.
- Make copies of Astro Journal and VPL Fact Sheets.
- Gather final project materials.
- Download and install Flash Player 7.0 or later on computers.
  Test these at http://astroventure.arc.nasa.gov by clicking "Design A Planet."
- Prepare chart paper with major concept of the lesson to post at the end of the lesson.

***System Requirements to Run Design A Planet Module**

Operating System	Browser
For Full Animation Version	
Macintosh OS X 10.3 or later	Internet Explorer 5.2 or later, Netscape 7.0 or later, Mozilla Firefox 1.0 or later
Windows XP or later	Internet Explorer 5.2 or later, Netscape 7.0 or later, Mozilla Firefox 1.0 or later
Computer Processor The Full Animation version does not run well on computers with slower processors. The recommended minimum processor is 1.4 GHz PC processor and 1.5 GHz Power PC Macintosh with dual processor running no other applications.	
RAM The recommended RAM for the Full Animation version of Design A Planet is a minimum of 512 MB.	

Operating System	Browser
For LiteVersion	
Macintosh OS X 10.3 or later	Internet Explorer 5.2 or later, Netscape 7.0 or later, Mozilla Firefox 1.0 or later
Windows XP or later	Internet Explorer 5.2 or later, Netscape 7.0 or later, Mozilla Firefox 1.0 or later
Computer Processor The recommended minimum processor for the Lite version is 800 MHz PC processor and 266 MHz Macintosh.	
RAM The recommended RAM for the Lite version of Design A Planet is a minimum of 512 MB.	
Plug-ins Both versions of Design A Planet require Flash Player 7.0 or later which can be downloaded free from http://www.macromedia.com/downloads	
Sound Astro-Venture uses narration and some sound effects, although all sound can be turned off. If sound is desired, computers will require a sound card and either headphones or speakers. Pairs of students using the same computer can use a y-cable to connect two pairs of headphones to one computer.	

Differentiation
Accommodations Pair advanced students with students that may need more guidance. Encourage students to talk about what they are learning. The final project choices are designed to capitalize on the learning styles of every student. Have students orally present any written sections of these final projects.
Advanced Extensions Research and report on a specific computer model. For what purpose was it developed? What was learned from it? What were its limits? In your opinion, was this a good use of a computer model? Why or Why not?

Engage

(approximately 35 to 40 minutes)

Family outing on Nantahala River; U.S. Forest Service, USDA

1. Review humans' survival requirements and how these are met by the Earth system.

- Put up the Human Survival Needs Transparency from Biology Lesson 1 (also included in the back of this lesson).

Conclusion

Note: Astronomy factors are in plain text. Atmosphere factors are italicized. Geology factors are bolded and Biology factors are underlined to differentiate them from each other.

Humans Need	Reason	Factors That Provide This
Food	Gives us energy so that we can move, grow, and function. It also gives us nutrients to build and mend bones, teeth, nails, skin, hair, flesh, and organs.	*Nitrogen is a nutrient.* <u>Carbon is another nutrient passed from organism to organism in the form of food.</u> <u>Sunlight provides energy for producers.</u> <u>Producers turn sunlight into food that consumers and decomposers consume.</u> <u>Decomposers break down dead things to provide nutrients for other living things.</u>
Oxygen	Helps us to obtain energy from sugars.	*Oxygen helps us get energy from sugars* <u>Producers release oxygen.</u>
Water	Allows nutrients to circulate through the body. Helps to regulate body temperature. The cells that make up our bodies are made mainly of water.	(related to temperature) *Water vapor is a greenhouse gas in our atmosphere*
Moderate temperature (Average global temperature above 0°C and below 50°C)	Allows us to maintain an average body temperature of 98.6°F/37°C and to maintain water in a liquid state at all times.	Star type Orbital distance Planetary mass (Orbits of large planets/objects could disrupt) *Greenhouse gases reradiate heat* **Crust and mantle motion cycle carbon in and out of atmosphere**
Protection from poisonous gases and high levels of radiation	To prevent cancer, disease, and damage to the body.	*Ozone protects from UV* *Our atmosphere doesn't have high levels of poisonous gases* **Liquid outer core forms a magnetic field that helps to protect from solar wind and space radiation**
Gravity	Allows our biological systems to develop and function normally. Holds the atmosphere to the Earth so it doesn't escape into space.	Planetary mass *Nitrogen provides pressure*

- Discuss what humans require for survival and how Earth meets these needs.
- Discuss how these factors work together as a system.

Note to Teacher: You may also want to refer to the concept maps from Biology Lesson 7 in discussing how the Earth works as a system.

2. Discuss computer models.

- Question: We only have one example of a planet that supports human habitability, so how can we know what other habitable planets might be like?
- *Answer: (Allow students to discuss their ideas about this.)*

- Discuss models that students might be familiar with and how they have used models in the past. Examples may include physical scale models that help to gain a better understanding of areas or objects that would otherwise be too big to take in, such as geographical maps, globes, or planetary models.

- Put up the Computer Models Transparency and ask students to think about and discuss the types of models scientists might use and for what purpose. Examples may include airplane models to test flight characteristics in wind tunnels, models of systems, such as a small ecosystem in an aquarium, to observe the effects of changes on the system, or computer models of plate tectonics or other Earth systems to observe long-term change on a short time scale or to predict the long-term effects of changes to a complex system.

- Ask students to brainstorm ideas of what scientists might be able to use computer models to study. Share with them some of the things NASA uses computer models to study. These include modeling of:
  - air flow over airplanes to design the most efficient airplane designs (called Computational Fluid Dynamics).
  - global warming on the Earth to predict future effects on Earth and try to determine causes.
  - the formation of our Moon to come up with a plausible theory for the Moon's formation.
  - the orbits of planets and other objects to see how the gravitational forces affect the motion of objects in close proximity or to predict future orbital paths such as the path of an asteroid orbiting close to Earth.
  - star and planetary formation to develop a reasonable theory of this process and the conditions that allow it to happen.
  - the atmospheres of fictional planets based on the biology, geology, and chemistry of the planet to compare with actual planet atmospheres to determine whether the planets are likely to have life or not.

- You may want to project the movie included in the Design A Planet module on "Virtual Planetary Laboratory." This can be accessed by clicking the "Virtual Planetary Laboratory" button in the bottom right-hand corner of the module. This short movie describes the last example listed above, giving more detail about the computer modeling that is being done to help in the search for life in the universe. A fact sheet on the mission and career profiles of the scientists involved are also included in this educator guide to share with students.

Note to Teacher: You may want to share with students that computer models often use complex math equations. So many of these math equations have to be calculated, that very large, fast supercomputers have to be used to do the calculations. These supercomputers work many times faster than a standard desktop computer. Without these supercomputers, it would take several years to calculate a computer model instead of a few weeks or months.

- Discuss the benefits of computer models. These may include the ability to:
  - simulate and observe long-term changes, such as mountain building or planetary formation.
  - better understand complex systems, such as the carbon cycle.
  - develop a reasonable theory to explain phenomena for which we have limited examples or are unable to replicate, such as the formation of our Moon or of our solar system.
  - predict scientific phenomena such as a tsunami or other environmental changes.
  - see the effects of a change on a system, such as the effect of increased greenhouse gases on the Earth's temperature and climate.
  - develop complex, efficient machines (such as airplanes) less expensively and more quickly than building and testing physical models.
  - develop a database of possible data points to help recognize something scientists are searching for but have not yet found, such as life on other planets.

- Discuss the limitations of computer models. These may include the following:
  - All computer models are based on assumptions, so a model is only as good as the assumptions upon which it is based. Assumptions include how objects or substances behave under certain conditions or how the quantities of the objects or substances used affect their behavior. For example, an earthquake model may assume that waves are traveling through a particular type of rock in a unified manner from the epicenter, or a planetary atmosphere model may assume that a particular gas can only be produced in a certain way.
  - Computer models are limited by the uncertainties in the math used. Math is often very helpful in helping to describe patterns, but may only estimate a result rather than give a precise result. Scientists may not have enough data points to generate an accurate mathematical relationship.
  - Computer models are limited by any variables not included in the model. Some systems are so complex that it may be impossible to include every variable, or scientists may not yet be aware of all the variables that affect a particular phenomenon. If a variable is not included, the model might not accurately represent that system. For example, a global warming model that is looking at predicting the affects of increased greenhouse gases on climate might include the effects of increased temperature on Arctic ice melting, evaporation, and sea levels, but might neglect to include changes to ocean currents which are largely responsible for transferring heat around the world. By leaving out this variable, the prediction of climate change is not likely to be entirely accurate.
  - Computer models can be limiting if they require too much computation. The computation required to generate results may be so complex and time-consuming that it only allows us to look at a few of the many possible outcomes.
  - Computer models are limited by the knowledge we have at the time the model was developed. If we don't have a lot of examples of something (such as life on other planets), the model will be limited by what we know about the few examples we have (life on Earth).

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3. Introduce the scientific question and purpose of the lesson.

- Tell students they will have the chance to use a simple computer model to design a planet that would be habitable to humans. This will give them the chance to apply all that they've learned about how Earth supports human survival to see if they can design a planet that's similar to Earth but not exactly the same. This will also give them a chance to see what kinds of planets NASA will be looking for and to see how all the planetary characteristics they've been learning about work together as a system.

- Introduce the scientific question they will be exploring: What combinations of variables make a planet habitable? Why?

- Ask students how difficult they think it will be to design a planet that is different from Earth but still habitable to humans and why they think this. They can record their thoughts about this in their Astro Journal.

Explore

(approximately 45 minutes)

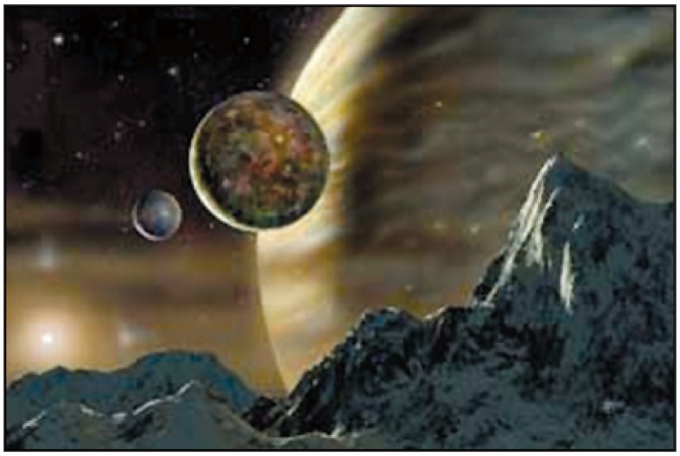

Illustration of gas giant HD70642 planet with hypothetical moons; David A. Hardy, Anglo-Australian Planet Search (AAPS)

1. Introduce students to the Astro-Venture Design A Planet Module.

- Tell students that they will be engaging in an online activity where they will enter characteristics of their planet and star system and will observe the resulting planet. They will be able to try many different combinations to see what kinds of planets they can design.
- Tell students that as they go through this module, they will want to record the different combinations they tried and the results they obtained to contribute to the class chart.
- You may want to go over the chart with students and record a sample attempt. Go to http://astroventure.arc.nasa.gov and click on the Design A Planet link. Project the Design A Planet module from a computer for the class to see. (To get to the main section where students design a planet, you will need to either view the Introduction or click "Skip" in the lower right-hand corner. The "Tutorial" shows the step-by-step sequence of how to use the module. Choose either "Design A Planet Lite" or "Design A Planet Regular" to go through the actual Design A Planet activity.

Note to Teacher: There are two versions of the Design A Planet module. The full animation version has more graphical animations but will run slowly on computers with slow processors. See the system requirements at the beginning of this lesson for more information. You may want to test this ahead of time to see which version would be best for the computers in your classroom. We also recommend quitting all other programs when running either version of Design A Planet.

Design A Planet
Conclusion

1. In the center of the circle, point out to students that each of the sections has clickable links to background information that will review the importance of that characteristic for life.
2. The audio can be turned off by clicking the speaker icon in the lower right of the interface. Text is provided so that all spoken information will appear as text.
3. Students will make each of their selections in the top right-hand box. Their selections will be recorded in the box just below.

   You can use the Earth as an example or ask students to suggest selections for each characteristic. The following directions are to generate a planet/system just like Earth.
   – For Star Type, click “Yellow Main Sequence Star.”
   – For Orbit, enter “1” AU.
   – For Planet Distance, enter “1.”
   – For Volcanoes, click “Yes.”
   – For Plate Movement, click “Yes.”
   – For Liquid Water, click “Yes.”
   – For Producers, click “Yes.”
   – The star they selected will display. Click “Continue” to see the resulting planet.
   – The resulting planet will display. Click “Continue” to see the resulting feedback.
   – Have students record the data about their attempt and the resulting planet in their Astro Journal.
   – In the top right, students can select “Design another planet” or “Quit.”
   – Click “Design another planet.”

4. Point out that after students complete one attempt, they can scroll up and down using the arrows in the "Log" to view previous attempts for reference.
5. Show students that they can learn more about each scientist by clicking on his or her photo or by clicking "Meet the Scientists."
6. The question mark icon in the bottom left of the circle brings up directions on how to navigate through the module.
7. The "Star/Planet Formation" button brings up a short movie on how stars and planets are formed.
8. The "Virtual Planetary Laboratory" button brings up a short movie describing a computer modeling program being developed by NASA astrobiologists to simulate virtual planetary atmospheres.
9. When students click "Quit" at the end, it will bring ask them to type in a Team Name. After they click Submit, a printable page provides feedback on what students accomplished. If students successfully designed at least one planet on which humans could survive, they will earn a printable certificate that states this. If they design a planet on which extremophiles could survive, but not humans, the certificate will indicate this and will encourage them to explore the rest of Astro-Venture to learn more about a planet on which humans could survive. If they are unable to design a planet with life, they will be encouraged to visit the rest of Astro-Venture to help them better understand the characteristics needed for habitability.
10. Below the Design A Planet multimedia module, there is a Glossary link that brings up glossary words in English and Spanish. Click on these words to get their text and audio definitions.

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2. Have students engage in the Design A Planet Module individually, in pairs, in small groups, or as a class.

- Students should visit: http://astroventure.arc.nasa.gov and click "Design A Planet."

Note to Teacher: You will need the Flash Player 7.0 plug-in, which can be downloaded and installed from: http://www.macromedia.com/downloads. When tested with grades 5 to 8, completion times ranged from 15 to 30 minutes, with an average completion time of 30 minutes for 5th graders and an average completion time of 20 minutes for 8th graders. Also, you may want to have accessibility to a printer, so students can print their certificates at the end of the module. Make sure students are clear about the printing rules for the certificate. This will be the only opportunity to print; students cannot go back later to print. You might consider using headphones if you want students to be able to hear the audio. Alternatively, they can click the speaker button to turn the audio off.

Explain

(approximately 30 to 35 minutes)

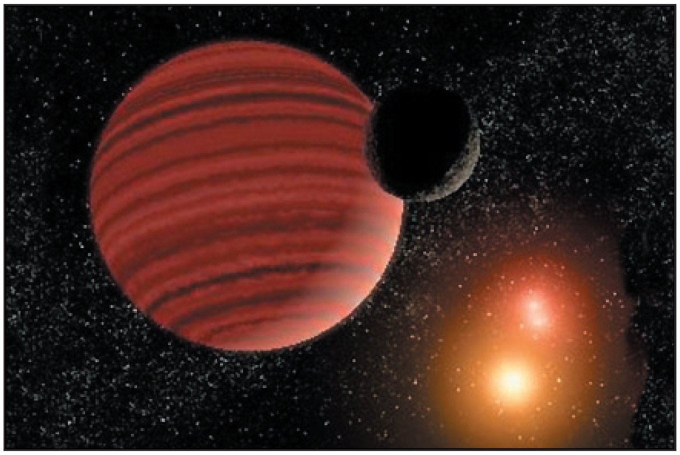


Illustration of gas giant planet and moon around double star; Anglo-Australian Planet Search (AAPS)

1. Have students share their results

- Ask students to share the characteristics of Earth-like planets that were habitable to humans and record each different combination on the Design A Planet Results Transparency or on a class chart.

- Discuss why these planets are habitable. What vital characteristics do they have that make them habitable to humans?
- You may want to refer to the Human Survival Needs Transparency for this discussion to discuss what characteristics the habitable planets have and how the different aspects of the planet meet these characteristics. Guide this discussion around systems and how these characteristics work together as a system to support human habitability. For example, discuss the characteristics that work together to give the planet just the right temperature.

Note to Teacher: The class should agree upon all successful combinations. If there are questions about any combinations, you may want to have a computer available for students to verify results.

- Have students share characteristics of planets that were not habitable to humans but were habitable to extremophiles. Record these different combinations on the transparency or class chart.

Note to Teacher: You may want to take this opportunity to discuss extremophiles with students. Extremophiles are organisms, such as microbes, on Earth that live in extreme environments in which humans and other animals could not survive. These environments might be extremely hot, like the hot springs in Yellowstone, or extremely cold, like Antarctic ice. Extremophiles have also been found in nuclear reactors, inside rocks, in pools of acid, and in many other places where humans wouldn't stand a chance of survival. Specific examples of these extremophiles are provided in the Design A Planet computer model, when students enter a combination that is not habitable to humans but might be to an extremophile. NASA astrobiologists are interested in these microbes because they are able to live where other life cannot. If we find life on another planet, it is likely to be the kind of life that can stand these kinds of extreme environments.

- Have students share characteristics of planets that were not habitable to any life. Record these different combinations on the transparency or class chart.

Design A Planet
Conclusion

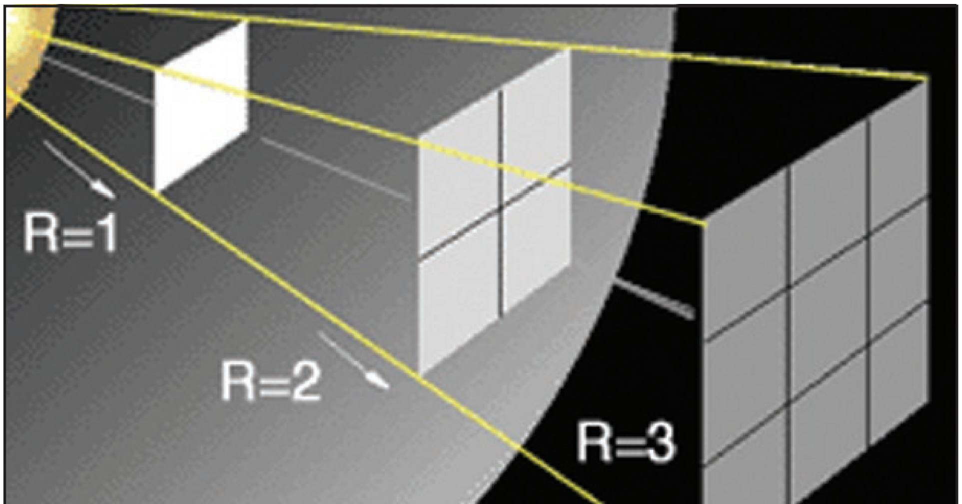
- Discuss human survival conditions that were especially difficult to maintain. These may include a moderate temperature and liquid water.

- Students may have entered “Yes” for producers or liquid water, but the resulting planet may not have had these. Discuss why this is. What other characteristics of the planet eliminated these characteristics? How can you explain this using systems in your explanation?

Note to Teacher: This is a good place to discuss two important sub-systems and related mathematical relationships that are modeled. These two sub-systems are: the planetary temperature system and the carbon cycle. A planet’s temperature is partly determined by the distance of a planet from its star, and there is a relationship between this distance and the amount of energy a planet receives. Scientists have determined that as a planet moves away from its star, the energy received by the planet decreases more quickly than you might think. We might think that if a planet were at twice the current distance from its star, its energy would be reduced by half. In fact, scientists have determined that the amount of energy lost is equal to the distance squared! This means that if Earth moved from its current position at 1 AU to twice this distance (2 AU), the amount of energy it would receive would decrease by two squared, and the Earth would receive four times less energy than it did at 1 AU. Thus, the Earth would receive one-quarter of its current energy at 1 AU. This relationship is called the inverse square law. You can find more information on this law, including visual explanations, on the Internet.

Another subsystem that plays a role in planetary temperature is the carbon cycle, which can be understood in terms of carbon sources and carbon sinks. An example of a carbon source is a volcano, which releases carbon dioxide into the atmosphere upon eruption. An example of a carbon sink is limestone. When limestone forms, it traps the carbon so it cannot escape into the atmosphere. The goal is to have a balance of sources of carbon and sinks for carbon in order to have a balanced amount of carbon dioxide in the atmosphere, so that this important greenhouse gas doesn’t cause the planet to be too hot or too cold. On Earth, this balance is achieved. Mars is an example of a planet where the sinks won, trapping too much of the carbon and making the planet very cold. Venus is an example of a planet where the sources won, producing way too much carbon dioxide that has caused this planet to be extremely hot. The size of the planet is also a factor because planetary mass will affect the carbon cycle and the total amount of carbon on the planet. A small planet that does not have plate tectonics will not have a carbon cycle. A large planet that is massive enough to have plate tectonics will have an active carbon cycle. In designing a planet, students determine sources and sinks by selecting planetary mass, volcanoes, and plate movement.

Design A Planet
Conclusion



The energy twice as far from the source is spread over four times the area, hence one-fourth the intensity. At three times the distance, it is spread over nine times the area.

- Cross off any duplicate attempts, so that all charted attempts are different.

Note to Teacher: There are an unlimited number of possible planet combinations, since students can enter nearly any number for planet mass and orbital distance. There are, thus, many possible solutions that will work. There are, in fact solutions that will work for each star type. Challenge your students to find at least one habitable planet for each star type. They might then try to determine the high and low range of the mass and distance for successful combinations.

2. Discuss overall conclusions about student results.

- Ask students to make observations about the number of combinations that resulted in habitability for humans compared to the number of combinations that resulted in habitability for extremophiles to the number of combinations that were not habitable.

Note to Teacher: Make sure that students understand that they cannot conclude that these proportions or percentages are accurate for all planets. These percentages only represent the results of the attempts made in class which may be based on prior knowledge of what students know and are probably based on characteristics similar to Earth; thus, students most likely have a higher percentage of success than if they were to enter random combinations or if they had a list of all possible combinations. Therefore, a random or complete list would most likely have an even larger difference between the various groups.

- Guide students to draw conclusions about the proportion of combinations in terms of the difficulty they found in finding successful combinations. Most likely the number of combinations that were habitable to humans was much smaller than the other two groups. Discuss what conclusions students can draw about this. (A planet that meets all human habitability requirements would be difficult to find, but planets that could support extremophiles might be easier to find.)

Note to Teacher: This is a great opportunity for students to do some math. Students could calculate ratios, fractions, and percentages to compare these three numbers, and/or they could graph the percentages in a pie chart.

- Have students complete sections 3 through 8 of their Astro Journal.

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3. Discuss planetary formation.

- Ask students if it is really possible to create different planets and star systems and how it was possible for students to do so in this activity. Students should realize that computer simulations are not real, and that it would not be possible to create a planet or star system.

- Ask students if they know how planets and stars form. Some may have watched the short animation in the Design A Planet module entitled "Star/Planet Formation." If students did not watch this animation, you may want to project this for the class to watch.

- Discuss the four steps outlined in the animation.

Note to Teacher: The following numbered steps are from the animated movie. We have provided additional bulleted information from our scientists to provide more details to you on how this process works.

1. Huge clouds of gas and dust swirl in the area where a star forms. The material is drawn into the shape of a flattened disk by the laws of physics.
   – A huge cloud of dust and gas (known to astronomers as a molecular cloud) begins to collapse under its own gravity. As the cloud collapses and condenses, conservation of angular momentum causes it to spin faster and faster, similar to an ice skater pulling in her arms. The dense interior of the cloud continues to collapse to form a protostar. Random motion causes individual molecules spinning within the cloud to crash into their neighbors. These collisions eventually flatten the cloud into a disk, which continues to spin around the newly formed star.

2. As this disc swirls around the parent star, particles clump together to form larger and larger chunks.
   – As this disc swirls around the newly formed star, gases condense into fluffy particles. The hottest part of the disk, the part closest to the star, contains gases that condense into metals at high temperatures (iron and nickel are two examples). In cooler regions farther from the star, more delicate gases like water vapor condense to form solids like water ice. These fluffy particles slowly clump together to form larger and larger chunks.

3. Eventually, these chunks sweep out paths of dust around the star. Some of them grow big enough to form planets.

4. The planets settle into an orbit around the star, just as Earth and the other planets of our solar system rotate around our star, the sun.
   – Observations of large planets orbiting close to the parent star suggest that this is not the whole story. Large planets (like Jupiter) may, in some solar systems, interact with the planetary disc and migrate closer to the parent star. In these cases, the giant planets may disrupt the formation of otherwise habitable, Earth-like planets.

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4. Discuss the benefits and limitations of computer modeling.

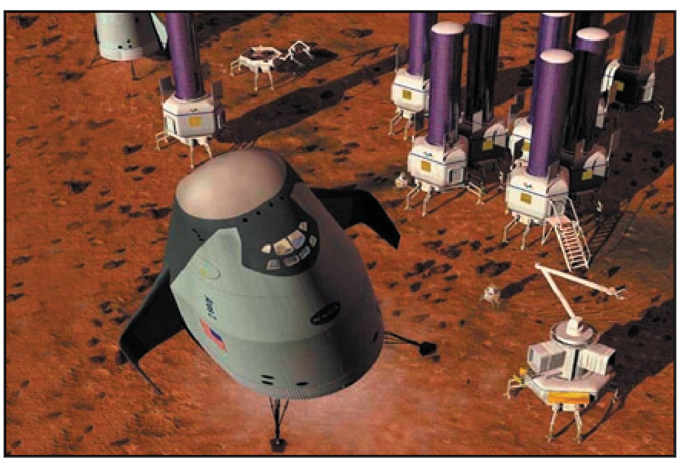
- Ask students how the Design A Planet computer model is helpful. Students might discuss that the model is helpful to see how small changes can affect the conditions of a planet and make it uninhabitable, or that it can help to see the many different combinations that are possible.

- Ask students what some of the limitations of the Design A Planet computer model might be. Students should realize that the computer model is based only on the knowledge that was available when the model was developed. Also, the model is based only on Earth life, so it may not be accurate for what we could find as we begin to search for life and find more and more planets. It also does not include all possible characteristics of a star system. For example, the computer model does not include influences of other planets in the system or the presence of poisonous gases in the atmosphere.

- You may also want to make students aware that scientists don't always agree, so the model reflects the assumptions of the specific experts who helped to make the model. Also, it is a very simple model that only looks at a finite number of variables.

Extend

(approximately 15 minutes)



"Neighborhood" illustration: Landing craft maneuvering among established extraterrestrial base; Pat Rawlings, NASA

1. Introduce the final project that will summarize student learning.

- Go over the Design A Planet Project directions and rubric in the Astro Journal and allow students to choose a project.

Design A Planet
Conclusion

Note to Teacher: The project choices represent a variety of learning styles and intelligences that give students the opportunity to express what they have learned in a format that appeals to them. However, all projects require students to demonstrate their learning and understanding of how their planet/star systems work as a system and the benefits and limitations of computer models.

- Have students begin work on a final project that summarizes their learning.

Evaluate

(approximately 90 minutes)

"Salute" illustration: Reflection of moon on visor of astronaut's helmet; Pat Rawlings, NASA

1. Have students complete their projects.

Note to Teacher: Depending on the amount of detail or refinement you want in final projects, you may want to allow additional class time for students to work on these projects.

2. Have students share their projects with the class. Discuss students' projects to ensure they have mastered the major concepts.

3. Collect students' final Astro-Venture Projects and evaluate them to ensure that they have each mastered the major concepts:

- Mathematical models can be displayed on a computer and then modified to see what happens.
- Computer models are limited in how well they can represent ways that something works.
- The usefulness of a mathematical model for predicting may be limited by uncertainties in measurements, by neglect of some important influences, or by requiring too much computation.
- Systems thinking involves considering how every part relates to other parts.
- When one variable of a planet is changed, the whole system is usually affected.

Design A Planet

Conclusion

Note to Teacher: After each lesson, consider posting the main concept of the lesson someplace in your classroom. As you move through the unit, you and the students can refer to the "conceptual flow" and reflect on the progression of the learning. This may be logistically difficult, but it is a powerful tool for building understanding.

Astro Journal: Design a Planet Computer Model

Name ______________________________ Date ______________ Class/Period ___________________

Scientific Question:
What combinations of variables make a planet habitable? Why?

1. Prediction: How difficult do you think it will be to design a planet that is different from Earth but still habitable to humans? Why do you think this?

2. Data: As you enter attempts in the computer model, record your combinations and results below.

Attempt Number	Star Type	Orbit	Planet Mass	Volcanoes	Plate Movement	Liquid Water	Producers	Results
Example: Earth	yellow	1 AU	1	yes	yes	yes	yes	habitable to humans
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								

3. Results: What combinations of variables make a planet habitable? Why?

Conclusion

4. Record the numbers of attempts by category below:
Number of total attempts:______ Number of planets habitable to humans:____ Number of planets habitable to extremophiles, but not humans:______ Number of uninhabitable planets:______
5. Data Analysis: Graph your results below.
6. Conclusions: How difficult was it to find a combination that resulted in a habitable planet for humans?

Conclusion

7. What conclusions can you draw about habitable planets for humans?

8. If a planet begins with water, will it keep it? Why or why not?

Design A Planet Project

You have used a computer model to design a planet and star system that can support human survival. Choose one of the following projects to show what you've learned. Be sure to include an explanation of:

- how your planet's characteristics work together as a system to support human survival.
- the benefits and limitations of computer models in science.

Project Choices

1. Write a report that describes the computer model you used to design a planet, the model's benefits and limitations, the characteristics of the habitable planet you designed, and how these characteristics work together as a system to support human survival. Include a paragraph on your opinion as to how computer models are best used in science.
2. Create a poster of the planet you designed. Include a picture of the planet and star, labels and description of its characteristics, and a written explanation of how these characteristics work as a system. Include a section of the poster that lists the benefits and limitations of the Design A Planet computer model used to design this planet.
3. Write a story about the planet you designed. Imagine that this planet is an actual planet that was discovered in another star system. Be sure to include the characteristics of the planet and star and how they work together as a system to make the conditions habitable to humans. Include a description of a new computer model that will be used to help prepare for future study of this planet. What will the model do? What are the benefits of this model? What are the limitations?
4. Write a poem or song about the planet you designed. Include two or three verses on the characteristics of the planet and star and a chorus that tells how the characteristics work as a system to support habitable conditions for humans. Write a second poem or song about computer models, what they are, their limitations, and benefits.
5. Build a 3-D model of your planet. Write a guided tour to accompany your model. Label the various parts of your model. In your written guide, describe these characteristics and explain how they work together as a system to support human habitability. Also, include an explanation of the computer model that was used to design this planet and the benefits and limitations of this computer model.
6. Use presentation software to develop a presentation that includes both pictures and either text or audio descriptions of your habitable planet, its characteristics, and how they work together to support human habitability. Include a description of the computer model used to design the planet, and describe the benefits and limitations of this model.
7. Use a video camera to create a news report or news interview on your planet. Describe the characteristics of the planet and how they work together to make the planet habitable. Describe the computer model that was used to design the planet. Include an editorial or debate on the benefits and limitations of computer models.
8. Compare your designed planet with the Earth in terms of its characteristics. Create a Venn Diagram comparing the two planets, their characteristics, and how these characteristics work together as a system to create habitable conditions for humans. Use graphs or scale models to show the relative sizes of the two planets and orbits. Describe the benefits and limitations of computer models, especially in terms of the math used in them.

Design A Planet
Conclusion

Your project will be evaluated using the following rubric:

4 Expectations Exceeded	• The project clearly and accurately describes all planetary characteristics that support human survival and accurately describes how these characteristics work together as a system. • The project includes three or more benefits and three or more limitations of computer models that are accurately described. • The project has all required parts, is creative, persuasive, uses details and examples, and all parts are accurate and clear.
3 Expectations Met	• The project clearly and accurately describes all planetary characteristics that support human survival and accurately describes how these characteristics work together as a system. • The project includes three benefits and three limitations of computer models that are accurately described. • The project has all required parts, and all parts are accurate and clear.
2 Expectations Not Quite Met	• The project is neither completely clear nor accurate in describing most planetary characteristics that support human survival and how these characteristics work together as a system. • The project includes one or two benefits and one or two limitations of computer models that are not completely accurate. • The project has most required parts, but some parts are inaccurate or unclear.
1 Expectations Not Met	• The report is neither clear nor accurate in describing most planetary characteristics that support human survival and how these characteristics work together as a system. • The project includes one benefit and one limit of computer models that are not accurate. • The project is missing several parts and is inaccurate or unclear

Human Survival Needs Transparency

Humans Need:	Reason:	What Factors Provide This?
Food	Gives us energy so that we can move, grow, and function. It also gives us nutrients to build and mend bones, teeth, nails, skin, hair, flesh, and organs.	*Nitrogen is a nutrient.* <u>Carbon is another nutrient passed from organism to organism in the form of food.</u> <u>Sunlight provides energy for producers</u> <u>Producers turn sunlight into food that consumers and decomposers consume.</u> <u>Decomposers break down dead things to provide nutrients for other living things.</u>
Oxygen	Helps us to obtain energy from sugars.	*Oxygen helps us get energy from sugars.* <u>Producers release oxygen.</u>
Water	Allows nutrients to circulate through the body. Helps to regulate body temperature. The cells that make up our bodies are made mainly of water.	(related to temperature) *Water vapor is a greenhouse gas in our atmosphere.*
Moderate temperature (Average global temperature above 0°C and below 50°C)	Allows us to maintain an average body temperature of 98.6°F/37°C and to maintain water in a liquid state at all times.	Star type Orbital distance Planetary mass Orbits of large planets/objects could disrupt. *Greenhouse gases reradiate heat.* **Crust and mantle motion cycle carbon in and out of atmosphere.**
Protection from poisonous gases and high levels of radiation	To prevent cancer, disease, and damage to the body.	*Ozone protects from UV.* *Our atmosphere doesn't have high levels of poisonous gases.* **Liquid outer core forms magnetic field that helps to protect from solar wind and space radiation.**
Gravity	Allows our biological systems to develop and function normally. Holds the atmosphere to the Earth so it doesn't escape into space.	Planetary mass *Nitrogen provides pressure.*

Note: Astronomy factors are in plain text. Atmosphere factors are italicized. Geology factors are bolded. Biology factors are underlined.

Computer Models Transparency

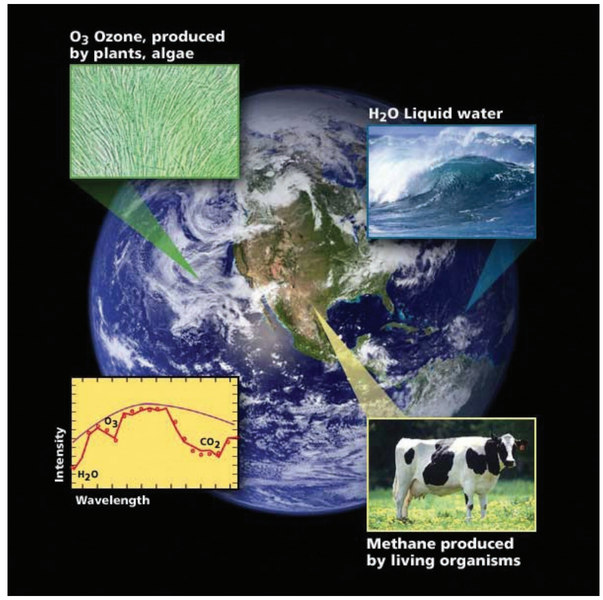
Computer Model Examples	Benefits	Limitations

Educational Topic

The Virtual Planetary Laboratory

- Take one Earth-sized planet.
- Add carbon dioxide, water vapor, and methane.
- Place in a circular orbit around a star like the Sun.
- Heat slowly for one billion years.

What do you get? **Life!**



Scientists have discovered over 100 planets outside of our solar system. These planets orbit stars like the Earth orbits the Sun, and scientists want to find out if any of them are living planets—planets that support life. We can't visit the planets or send spacecraft to them because they are too far away. So, NASA is planning to launch huge telescopes to search for life from a distance. To support this telescopic search for life, NASA is building a computer program called the Virtual Planetary Laboratory (VPL).

The VPL works like a planet-making machine that combines ingredients such as geology, climate, chemistry, and biology in all sorts of different ways to cook up computer-modeled planets. The VPL will help the team find out not only what a living planet might look like, but what non-living planets might look like as well.

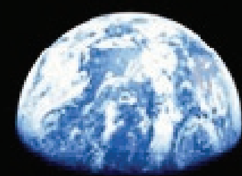
Artist Conception of VPL Workstation

For additional information on the Virtual Planetary Laboratory, visit:

http://vpl.ipac.caltech.edu/

The VPL research program is a team effort between twenty-one scientists from seven universities and research institutions who share their resources and knowledge. Most of the computational research will be done at the Jet Propulsion Laboratory/ Caltech, although all the institutions will provide scientific expertise.

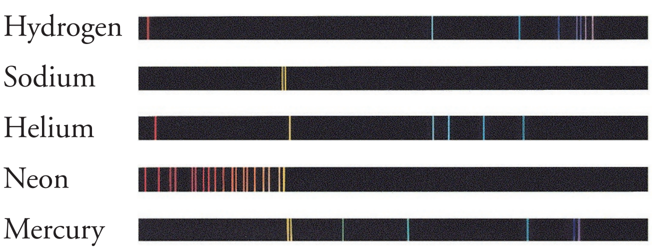
Design A Planet
Conclusion



One way to discover the far-off planets (which are many light years away) is to detect the very faint light they give off. If we could see planets outside our solar system, they would glow because their atmospheres reflect the light from the star that they orbit, just like the Earth reflects the light of the Sun.

Planets can also glow because they are warm and give off their own heat. Humans can't see that heat, but special telescopes can.

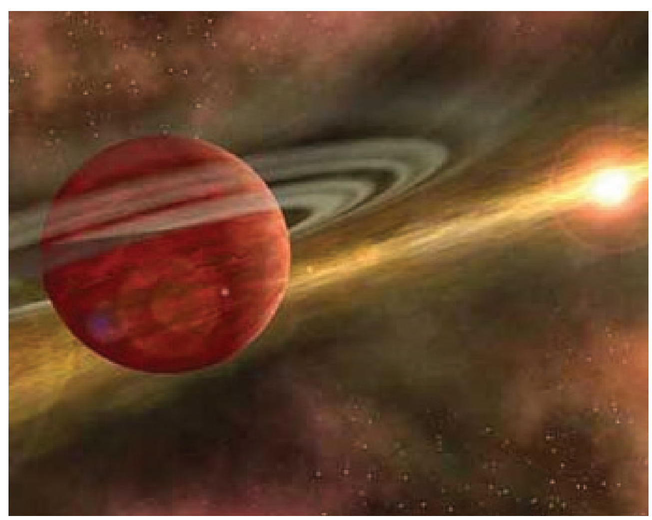
This is a picture of an Earthrise as taken from the moon during an Apollo Mission. Notice the reflection of the Sun's light on the Earth.



Spectrums of Familiar Elements

With information from telescopes, scientists can figure out the gases that make up the planet's atmosphere using a spectrometer. A spectrometer is a tool that breaks up the light given off by the planet into a spectrum. How does it work? When they interact with light, different types of atoms and molecules absorb and release certain wavelengths of light. These wavelengths show up as either dark or bright lines in very specific places. Every type of molecule or atom has a unique "fingerprint" of lines that show up in certain places along the spectrum. By studying the fingerprint of lines in an atmosphere, the team can identify the different molecules that make up the gases, like water vapor, ozone, or methane, that are present in the planet's atmosphere.

Each virtual (computer-modeled) planet the VPL creates will have its own unique virtual atmosphere. Every virtual atmosphere will be broken up into its own unique spectrum. That way, scientists can compare the spectrum of a real planet to the spectrum of a virtual planet. If the atmospheres are the same, chances are good that the planets will be the same, too! This is because the gases in a planet's atmosphere are created by the planet itself. The VPL will model many different types of atmospheres. For example, life on Earth produces oxygen, so the Earth has oxygen in its atmosphere. Scientists looking for life on other planets might look for oxygen in their atmospheres. But, life on other planets might produce another type of gas, so the VPL will be able to simulate a wide range of different environments and types of life.



Artist Conception of a Planetary System Beyond Ours

Right now, scientists only know about one living planet—Earth. There might be other types of planets that can support life, and the key to figuring out what these might be like is to play around with the ingredients.

Design A Planet Results Transparency

Attempt Number	Star Type	Orbit	Planet Mass	Volcanoes	Plate Movement	Liquid Water	Producers	Results
1								
2								
3								
4								
5								
6								
7								
8								
10								
11								
12								
13								
14								
15								

Astro-Venture Glossary

aerodynamics The way that air moves around objects.

aerospace Having to do with the Earth's atmosphere and space beyond Earth.

algebra A type of math that uses letters as symbols to represent numbers.

analysis The examination of something in detail by studying its parts.

aquatic Living or growing in water.

associate's degree A degree usually earned from a community college, junior college or vocational school after completion of two years of full-time study. This degree generally is equal to the first two years of study toward a bachelor's degree.

asteroid A rocky, metallic object that orbits a star.

asthenosphere Part of the upper mantle below the lithosphere that is partially molten

Astro Journal In Astro-Venture, your Astro Journal is where you record your observations and the scientific process.

astro A prefix, which means star or space.

astrobiologist A person who studies life on Earth and the possibilities for life in the universe.

astrobiology The study of life in the universe.

astronomer A person who studies the universe beyond Earth.

astronomical unit (AU) The average distance from Earth to the Sun, which is equal to 149,598,770 km or 93,000,000 miles.

astronomy The study of space beyond Earth.

astrophysics The science of the stars, objects related to stars and the forces that determine how they interact.

astrophysicist A person who studies the science of the stars, objects related to stars and the forces that determine how they interact.

atmosphere The air. The blanket of gases that surrounds some planets and moons.

atmospheric chemist A person who studies what the atmosphere is made of and studies chemical reactions that change what it is made of.

Astro-Venture Glossary (Cont.)

atom The tiniest particle of an element that has the same chemical properties of the element. The building blocks of all matter.

average Medium-sized. In the middle.

aurora Light radiated by particles in Earth's upper atmosphere.

B.A. (bachelor of arts) A university or college degree earned after completion of at least four years of study.

B.S. (bachelor of science) A university or college degree earned after completion of at least four years of study.

bachelor's degree A university or college degree earned after completion of at least four years of full-time study following high school. B.S. stands for a Bachelor of Science. B.A. stands for a Bachelor of Arts.

bacterium (pl. bacteria) A form of life that is usually one cell and can be seen only with a microscope. There are many different kinds of bacteria and they are the oldest type of life on Earth.

bio A prefix that means life. In Astro-Venture, bio is short for biography, which tells you more about a person's life or background.

biochemistry The study of matter that makes up living things, what the matter is made of, how it's structured and its features.

biological Related to life or living processes.

biology The study of life.

biotechnology The use of living things to create new products such as medicines or new techniques such as waste recycling.

black hole An area of space around an object where gravity is so strong that even light cannot escape from the area.

blue star A hot, bright, massive star that has a surface temperature between 20,000º-60,000º Kelvin.

boiling point The temperature at which a liquid becomes a gas.

bond (chemical) The force between atoms in a molecule.

botany The study of plants.

calculus A type of math that uses special kinds of symbols.

capacity The largest amount that something can hold.

Astro-Venture Glossary (Cont.)

carbon dioxide A colorless gas that can absorb heat in the atmosphere. Plants use carbon dioxide to make their food and animals exhale it when they breathe.

career The order of events that occur in a person's work, over time.

carnivore An animal that only eats meat.

cause Something that produces an effect or result. To produce an effect or result.

cell A microscopic unit that makes up all living things. All living things are made of cells or exist as a single cell.

Celsius A scale that measures temperature where water boils at 100°C and freezes at 0°C. Between the boiling and freezing points, the scale is divided into 100 parts. People in most countries use Celsius. It is named after Anders Celsius.

center of mass The balancing point between two masses.

ceramic Hard, breakable, heat-resistant material made by heating clay at a very high temperature.

chemical Having to do with the study of matter, what it's made of, how it's structured and its features.

chemical change (chemical reaction) When molecules interact to form new molecules.

chemist A person who studies chemistry.

chemistry The study of matter, what it's made of, how it's structured and its features.

chlorofluorocarbons (CFCs) Human-made substances made up of chlorine, fluorine and carbon atoms bound together, which break up and react with oxygen atoms in the upper atmosphere, causing ozone depletion.

college A school where bachelor's degrees can be earned following high school.

combustion A rapid chemical change that occurs when heat is produced faster than it can dissipate. The process of burning.

comet A ball of ice and rock that orbits a star.

community college A school that offers a two-year degree or certificate that is generally equal to the first two years of a four-year college.

compass A device used for finding direction. Using the Earth's magnetic field, the magnetic needle on a compass points north.

composition The parts that form or make up a whole.

Astro-Venture Glossary (Cont.)

computer electronics The study of computer devices and systems and how they work.

Conservation of Matter During chemical change, the number of atoms does not change. Matter is neither created, nor destroyed.

consume To eat.

consumer Any living that eats producers (such as plants) or eats other consumers. Some bacteria are consumers.

convection The rise and fall of material due to differences in temperature.

convection cell A circular current formed when heated material rises and cooler material sinks.

convert To change from one form to another.

core The center of a planet.

cosmic rays High-energy particles released when certain stars explode. Cosmic rays can be harmful to some life forms if they reach the Earth's surface.

crust The outermost layer of a planet with a solid surface.

current A flow of electric charge.

database A collection of data that is organized in a way so that it is quick and easy to find.

decomposer A fungus or bacteria that breaks down the waste and dead bodies of animals and plants, while returning important nutrients into the environment.

deflect To repel or divert something into a different direction.

demo A demonstration. In Astro-Venture, a demo demonstrates how to use the module.

dense Tightly packed matter within a certain space..

density The amount of matter in a certain unit of volume or space.

DNA (deoxyribonucleic acid) A long, complex molecule that contains the codes that control your cells' activities, the chemicals that make up your body and heredity.

doctorate The highest degree awarded by a university earned after completion of at least five years of study beyond a bachelor's degree. A Ph.D. is a doctorate of philosophy.

Doppler shift The change in wavelength as a source of light or sound moves toward or away from you or as you move toward or away from a source of light or sound.

Astro-Venture Glossary (Cont.)

ecosystem A complex system of all the living things in an area and how they interact with each other and their environment.

electrical engineering The scientific technology of electricity for use in designing and developing equipment that produces power and controls machines.

electronics The study of devices and systems that are powered by using electricity.

element A substance that cannot be broken down into other substances. Oxygen, gold and hydrogen are 3 of the 115 elements.

elliptical orbit An orbit that is more oval than circular.

energy What living things use to live, grow, and do work.

engineer A person who designs, constructs or builds. To design, construct or build.

engineering The use of math and science to design and build structures, equipment and systems.

Escherichera coli (E. coli) Bacteria that reside in the large intestines of humans and break down the food we eat.

evaporate To change from a liquid to a gas.

Europa One of Jupiter's 16 moons. Studies of Europa show that it is composed of liquid-water ocean covered by an ice crust. Because it has this liquid ocean, scientists hope to find life there.

extreme environments Places that have very hot or very cold temperatures, are very salty, or have a high acid concentration. Extreme environments are places such as a volcanoes, deep-sea mid-ocean volcanic vents, or cold arctic areas.

Fahrenheit A scale that measures temperature where water boils at 212°F and freezes at 32°F. In the United States, we use both Fahrenheit and Celsius, but most Americans are most familiar with Fahrenheit. It was developed by Gabriel Daniel Fahrenheit.

fieldwork Observations and work done in an actual work environment to gain real-life experience and knowledge.

flammable Easily set on fire.

fluid dynamics The study of liquids and how they move.

fluid mechanics The study of the effect of forces on liquids.

freezing point The temperature at which a liquid becomes a solid.

Astro-Venture Glossary (Cont.)

fungus (pl. fungi) A group of living things that absorb food from their environment and aid in the decomposition of dead things. Examples of fungi are mushrooms, yeast, and molds.

galaxy A large group of stars that are held together by gravity.

gas A state of matter that has no definite shape or volume. In a gas, the molecules are so loose, they can spread apart or can squeeze together, depending on the container they are in.

genetics The study of genes and how they transmit features from parents to their children.

geologist A person who studies Earth's origin, history and structure.

geology The study of Earth's origin, history and structure.

geometry A type of math that involves the measurement and features of shapes, points, lines, angles, surfaces and solids.

global effect The effect on the whole Earth that occurs as a result of some change.

graphics Information that is represented with images or pictures.

gravity A force of attraction that exists between objects. The greater the mass and diameter of an object, the greater its gravitational pull.

greenhouse effect Some gases, such as carbon dioxide and water vapor, absorb heat energy and hold it in the atmosphere raising the surface temperature of a planet.

habitable Fit to live in.

Habitable Zone (HZ) The range of distances from a star where liquid water can exist on a planet's surface.

hardware Computers and the equipment used with computers such as monitors, printers and disk drives.

herbivore An animal that only eats plants.

HR Diagram A diagram created by two scientists, Ejnar Hertzsprung and Henry Norris Russell, to show how the brightness and temperature of stars are related.

human factors engineering The use of psychology and other areas of science to develop systems that people use in a way that makes the system easy, safe and useful.

hypothermia An abnormally low body temperature.

Ice Age A long, cold period when a large part of a planet is covered with glaciers.

Astro-Venture Glossary (Cont.)

inert An element or substance that does not easily react or interact with other elements or substances.

junior college A school that offers a two-year degree or certificate that is generally equal to the first two years of a four-year college.

Kelvin A scale that many scientists use to measure temperature. Units of Kelvin are the same as Celsius degrees, but the scale is adjusted so that zero represents absolute zero, which is the temperature at which all particles (electrons, atoms, molecules, etc.) have minimal motion. Water boils at 373 Kelvins and freezes at 273 Kelvins. The Sun is about 5,000 to 6,000 Kelvins. This scale is named after the nineteenth-century British scientist Lord Kelvin.

laboratory A building used for scientific research.

Lactobacillus acidphilus (L. acidophilus) A type of bacterium that turns milk into yogurt.

limestone A type of rock usually formed in the oceans, made of carbon and calcium. Limestone is important in the carbon-rock cycle.

liquid A state of matter that has a definite volume but no definite shape. In a liquid, the bonds of molecules are looser than in solids so that the molecules can slide past each other.

lithosphere. The rigid layer formed by the crust and uppermost part of the mantle that moves together as plates on top of the Earth's surface. The lithosphere rides on top of the asthenosphere.

luminosity The amount of power or "wattage" put out by a star. How bright a star appears to us depends on its luminosity and its distance.

M.A. (master of arts) A university degree earned after completion of at least one year of study beyond a bachelor's degree.

magma Molten rock found in the upper part of the mantle and crust.

magnetic field Area surrounding magnets that deflects charged particles or other magnets.

main-sequence stars Stars ranging from hot blue to cool red dwarfs. The most common type of star. They are not giants, supergiants, white dwarfs or red dwarfs.

mantle The part of a planet between the crust and the core.

mass The amount of matter in an object.

master's degree A university degree earned after completion of one to two years of study beyond a bachelor's degree. M.S. stands for a Master of Science degree. M.A. is a Master of Arts degree.

matter Anything that has mass and volume. Anything that takes up space.

Astro-Venture Glossary (Cont.)

mechanical engineering The use of math and science to design and build structures, equipment and systems that produce heat or power.

melting point The temperature at which a substance changes from a solid to a liquid.

mesosphere The part of the Earth's mantle that is below the asthenosphere and above the outer core.

metal A group of elements that is shiny, bendable and conducts heat and electricity.

meteoroid Small rocky object that orbits a star.

meteorology The study of the conditions in the atmosphere, especially weather.

microbe A living thing that is so small, it can be seen only with a microscope. Bacteria, viruses, and algae are examples of microbes.

microbiology The study of microbes.

microscope An instrument that uses lenses to make small objects appear large.

migrate To move from one place to another, usually for breeding or feeding.

molecule A group of atoms bonded together. Molecules act like a single particle.

molten Made liquid by heat. Melted.

moon A natural object that orbits a larger object, usually a planet.

M.S. (master of science) A university degree earned after completion of at least one year of study beyond a bachelor's degree.

mutation A change in the DNA of a living thing.

navigate To control the path or route of a ship, aircraft or spacecraft.

nebula A huge cloud of gas and dust in space from which stars are born.

nervous system A system in animals that controls the body functions and senses. In humans it includes the brain, spinal cord and nerves.

network A number of computers connected together so that information can be sent between them.

neutron star The remains of a supernova that become an extremely dense, tightly packed star.

Astro-Venture Glossary (Cont.)

nitrogen A colorless, tasteless, odorless gas that makes up 78 percent of the atmosphere and is a necessary part of all living tissues.

Nitrogen Cycle The continuous movement of nitrogen from the atmosphere through bacteria, into the soil, to plants, to animals and its return to the air.

nutrient Any of a number of substances (such as nitrogen, carbon, and phosphorus) that all living things need to survive.

observation The act of watching carefully.

observatory A building designed for making observations of stars or other objects in space.

occupation The activity that a person does as their regular work. A job.

omnivore Any animal that eats both plants and animals.

orbit The path of an object around another object, caused by gravity. To move around another object.

organism A living thing.

oxidation A chemical change in which a substance combines with oxygen.

oxygen A colorless, odorless gas that is released by plants into the air, is essential to animals for breathing, and is highly flammable when it reacts with other substances.

ozone A gas made of three oxygen atoms bonded together. When ozone is located high in the atmosphere, it protects life from harmful ultraviolet radiation but can be harmful to life at Earth's surface.

ozone depletion When ozone loss is greater than ozone creation.

ozone layer The layer of gas in the stratosphere that protects the Earth from harmful ultraviolet rays.

paleontology The study of fossils.

particle A basic unit of matter or energy.

period of revolution (period) The amount of time it takes the planet to orbit its star. Earth's period is 365 $^1/_4$ days or one year.

Ph.D. (doctorate of philosophy) The highest degree awarded by a university, earned after completion of at least nine years of college study following high school. This includes four years to earn a bachelor's degree and five to seven years to earn a Ph.D.

Astro-Venture Glossary (Cont.)

photometer An instrument that measures the intensity of light.

photometry The measurement of the intensity of light.

photosynthesis The process by which plants, algae and some bacteria convert sunlight, water, and carbon dioxide to oxygen and sugar.

physical science Any of the sciences, such as chemistry, physics, astronomy and geology that investigate the features of energy and nonliving matter.

physics The study of matter and energy and how they work together.

physiology An area of biology that studies the major functions of plants and animals such as growth, reproduction, photosynthesis, respiration and movement.

phytoplankton Producers that live in oceans and convert sunlight, carbon dioxide, and water into sugars and oxygen. Phytoplankton include things like algae and some bacteria.

planet A body that orbits a star and does not give off its own light. A planet is generally much smaller than a star and can be made of solid, liquid, and/or gas.

planetarium A device that projects images of stars, planets and other objects in space and their movement onto the surface of a round dome.

planetary sciences The study of a planet or planets, what they are made of, how they are structured and their orbits.

plate A large, rigid segment of Earth's lithosphere that moves in relation to other plates over the mantle.

pole Areas of a magnetic field where magnetism is concentrated. Earth's magnetic field has a north pole and a south pole.

pollinate To place pollen on a flower so it can make a seed.

pre-calculus A math class taken to introduce calculus.

precipitate To cause water vapor to become liquid and fall as rain or snow.

predict To tell what you think will happen in the future.

pressure The amount of force pushing on an object caused by the molecules surrounding it.

prism A three-dimensional glass or crystal object with flat sides and edges that can break up light into separate colors, creating a spectrum.

Astro-Venture Glossary (Cont.)

probe A device sent into space to explore and research objects.

producer Living things that can make their own food from sunlight, carbon dioxide, and water.

property A quality that defines a substance.

propulsion dynamics The study of the forces that move, drive or propel an object forward.

protein Building blocks of life that make up skin, fingernails and other plant and animal tissues. Proteins also help animals to digest food and perform many other important functions for life.

protostar A young star that glows as gravity makes it collapse.

psychology The study of how the brain processes information and how humans behave.

radiation The transfer of energy by waves. Humans and other life forms can become very ill or even die from exposure to too much of certain types of radiation.

reactive An element or substance that tends to easily interact with other elements or substances.

reactivity The tendency to easily interact with other elements or substances.

red giant A very large, bright, but cool star that normally has a temperature between 3,000 to 6,000 Kelvins. After millions or even billions of years, when a main-sequence star has burned up the fuel in its core, it expands into a red giant.

red star (red dwarf) A very cool, dim, small star that burns very slowly and has a surface temperature less than 3,500 Kelvins.

regulate To keep under control or maintain a natural balance.

reproduction The act of producing children or offspring.

resistance The ability to withstand or oppose a force.

respiration The act or process of breathing.

restart To start over.

role-play To take on the role of another person. To pretend to be that person.

rotate To spin on an axis.

scavenger Any animal that eats dead animals.

Astro-Venture Glossary (Cont.)

sensor A device that detects and responds to a signal.

seismic waves Vibrations caused by earthquakes.

seismometer A scientific instrument designed to measure the vibrations caused by earthquakes as they travel through a planet.

software Computer programs that control how a computer functions.

solar flare A burst of gases from a small area of the sun's surface that puts out intense radiation.

solar wind Particles that move away from the sun at high speeds. The solar wind is deflected by Earth's magnetic field.

solar system Our Sun and the objects that travel around it.

solid A state of matter that has a definite shape and volume. In a solid, molecules are bonded together very tightly so that the solid keeps it shape or it is broken.

space science Any of several sciences, such as astrobiology, that study occurrences and objects in space other than Earth.

specialist A person who is an expert on a particular topic.

spectrometer An instrument that measures spectra.

spectroscopy The measurement and analysis of spectra.

spectrum (pl. spectra) A rainbow or band of different colors made when light is broken up into wavelengths.

sputtering The process by which particles are changed or sent into space if hit by solar wind and cosmic rays.

star A large, hot ball of gases, which gives off its own light.

star system A star and the objects that orbit around it.

star type The category that a star fits into based on the features it shares with other stars in that category.

statistics A type of math that involves collecting, organizing and interpreting numbers.

stratosphere A layer of the Earth's atmosphere that is above the troposphere, between about 11 and 50 km above the Earth's surface.

structure The way something is built or made.

Astro-Venture Glossary (Cont.)

subduction The process where a lithospheric plate dives beneath another lithospheric plate.

submit T o send, give or turn in. In Astro-Venture, you click "Submit" to send your Astro Journal answers to scientists for review.

supergiant Stars that are greater than ten times the mass of the Sun, expand into extremely large, bright stars called supergiants.

supernova A star that explodes. Often a supernova is a supergiant that has become unstable.

surface effect The effect on a small section of Earth as seen from the surface that occurs as a result of some change.

systems engineering The use of math and science to design and build groups of connected parts that work together as a whole.

technical institute A school that trains people in specific skills for certain occupations that use technology.

Tech Notes In Astro-Venture, the Tech Notes give you background information and a glossary about the topics you select.

telescope An instrument that collects light and makes distant objects appear larger and closer.

temperature The measurement of how hot or cold something is.

theory A general statement that explains the results obtained from scientific investigations.

thermal Having to do with heat.

thermodynamics T he study of how heat moves.

trigonometry A type of math that studies and compares angles in a right triangle.

trivia Factual information that is not important but may be interesting to know.

troposphere A layer of the Earth's atmosphere that begins at Earth's surface and extends to 11 km above the Earth's surface.

ultraviolet radiation (UV) Invisible radiation between visible violet light and X rays. Ultraviolet radiation causes sunburn and can harm life.

uninhabitable Not fit to live in.

universe All existing things, including Earth, the solar system and the galaxies.

Astro-Venture Glossary (Cont.)

university A school where bachelor's degrees, master's degrees and doctoral degrees can be earned following high school.

virus A particle so small it can be seen only with a microscope and can reproduce inside a living cell.

viscosity Measurement of how much a substance resists flow.

vocational school A school that trains people in specific skills for certain occupations.

volume The amount of space an object takes up.

water vapor The form water takes when it is a gas in the atmosphere.

wavelength The distance from one peak to the next on a wave.

weathering The process of breaking down rocks on Earth's surface.

white dwarf The end of a low mass star's life, when the star's core shrinks and its surface becomes white hot. These stars are very hot but dim.

yellow star A medium-sized star that has a surface temperature between 5,000 to 6,000 Kelvins.

zoology The study of animals.