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# Planning and Pacing Guide



TERC

## Chapter 1: Cosmic Questions

| Date | Activity Name                                    | Time     | Materials                     | What Students Do   | Engage   | Explore   | Explain  | Evaluate  | Extend to Astrobiology  |
|------|--|----------|-------------------------------|--|--|---|--|---|---|
|      | Challenge<br>Where Do You Stand                  | 25       | none                          | Write a position paper about the legitimacy of searching for life on other worlds    |  |   |  |   |   |
|      | Activity 1<br>Mystery Message                    | 100      | colored pencils, graph paper, | Decipher a “mystery message” puzzle  | Play a game to demonstrate that images are a powerful way to convey information  | Solve a puzzle, identifying patterns in visual and aural clues                                  | Astrobiology requires creative thinking  | Put puzzle in its real-life context. Contrast different ways to contact extraterrestrials                       | Research different ways of communicating across the universe  |
|      | Activity 2<br>Puzzling Picture                   | 50       | none                          | Examine several images for evidence of life or habitable conditions                  | Look for life or evidence of life in desert and forest images                    | Identify elements in a large image by examining only small parts of it                          | Images convey information effectively. The amount of data affects one’s ability to interpret                                       | Contrast understandings based on observation with those based on interpretation                                 | Put metaphor into the context of looking for life on other worlds   |
|      | Activity 3<br>Every Picture Tells A Story        | 50       | none                          | Interpret images using metadata  | Interpret images of Mars and Europa  | Relate features found on Earth to features seen in the Mars and Europa images                   | Metadata is an important component in the interpretation of images   | Describe the features, processes, and sequence of events shown in each image                                    | Assess the role images, metadata, and Earth analogies play in Astrobiology  |
|      | Activity 4<br>Extraordinary Claims               | 100      | none                          | Examine the difference between science and pseudoscience.                            | Read about the characteristics of science and pseudoscience                      | Analyze a science and pseudoscience article about the “Face” on Mars                            | Currently, there is no evidence for extraterrestrial life. Unlike pseudoscience, scientific explanations adhere to strict criteria | Create a tabloid story, pointing out what makes it pseudoscience  | Devise strategies for distinguishing science from pseudoscience   |
|      | Activity 5<br>How Many Worlds Might Harbor Life? | 50       | calculators                   | Estimate the number of worlds in our Milky Way Galaxy that may have intelligent life | Define extraterrestrials. Discuss whether they exist and how one might find out. | Identify the factors involved in estimating the number of worlds in the universe that have life | Many factors influence the potential for extraterrestrial life. Firm data exist for only a few of these factors.                   | Estimate values for each term of the Drake Equation and calculate the chances of hearing from extraterrestrials | Consider how the Drake Equation might be used to influence public opinion to make a case for or against the search for life on other worlds |
|      | Meeting The Challenge<br>Where Do You Stand?     | 50       | none                          |  |  |   |  |   |   |
|      | <b>TOTAL TIME</b><br>minutes<br>class periods    | 425<br>9 |                               |  |  |   |  |   |   |

## Chapter 2: Worlds in Our Universe

| Date | Activity Name   | Time | Materials                                | What Students Do   | Engage  | Explore  | Explain  | Evaluate   | Extend to Astrobiology  |
|------|---|------|--|--|---|--|--|--|---|
|      | Challenge<br>Location, Location, Location!  | 25   | none                                     | Develop an advertisement for a world that can support life   |   |  |  |  |   |
|      | Activity 1<br>How Well Do You Know the Worlds in Our Solar System?                  | 100  | Planetary Information sheets, game cards | Play four games to become familiar with the planets and moons in our solar system  | Scan the Planetary Information Sheets to become familiar with the 9 planets and 6 large moons in the solar system | Play four games, each of which has students compare and contrast the solar system's planets and moons                                      | There are nine planets and six large moons in our solar system, each with unique features  | Using Venn diagrams, group the planets and moons and explain their similarities and differences                | Consider what the diversity of planet types in our solar system suggests about other planets in the universe                    |
|      | Activity 2<br>What is the Scale of the Solar System?                                | 75   | yarn, golf ball, index cards             | Make a solar system model  | Estimate the size and placement of Earth around a four-centimeter sun   | Determine each planet's diameter and distance from the sun. Establish a scale for solar system model                                       | Planets and moons are tiny objects compared to the distances between them  | Position each planet in the solar system model and compare the size of the sun to the planets and their orbits | Identify some of the implications for life of planetary size and distance from the sun  |
|      | Activity 3<br>What Types of Stars Are in Our Universe?                              | 75   | Star circles (color), butcher paper      | Make a display showing the abundance of different kinds of stars in the universe and how temperature, color, mass, and age affect a star | Examine star circles to learn the characteristics of three to five stars  | Place star circles on an axis. Determine the abundance of different kinds of stars and how temperature, color, mass, and age affect a star | The sun is a yellow star in the middle of the color and brightness spectrum. Star color is a function of temperature, and about 5% of stars are yellow | Compare the sun to other stars, and determine whether it is typical or exceptional                             | Determine the type(s) of star to consider when looking for habitable worlds. Estimate the size of the habitable zone            |
|      | Activity 4<br>The Life Stories of Two Stars   | 75   | colored pencils, drawing materials       | Create a presentation of the birth, life, and death of a low-mass and a high-mass star   | Brainstorm the different stages in the life cycle of a star   | Read about the life cycle of a low-mass and a high-mass star and depict the life cycle of each kind of star                                | Low mass stars have long lives, becoming red giants and white dwarfs. High-mass stars have brief lives, becoming supergiants and ending as supernovae  | Predict the fate of Earth and our solar system as the sun ages   | Contrast the frequency of star formation in regions with few and many stars   |
|      | Activity 5<br>What Types of Galaxies and Regions in Galaxies Are Conducive to Life? | 50   | none                                     | Identify which kinds of galaxies are experiencing star formation and might be suitable for life  | Brainstorm ideas about what a galaxy is and what makes one kind different from another                            | Read about three different kinds of galaxies, analyze images of each kind of galaxy, and interpret what is happening in each image         | Elliptical and irregular galaxies seem inappropriate for life. Spiral galaxies have zones conducive for life   | Determine which types of galaxy and which regions within a galaxy are most conducive to life                   | What does the fact that not all galaxies or portions of galaxies are habitable suggest about the possibility of life elsewhere? |

|  |  |           |                                       |  |  |   |  |   |   |
|--|--|-----------|---------------------------------------|--|--|---|--|---|---|
|  | Activity 6<br>How Many Galaxies Are<br>Out There?        | 50        | calculators                           | Estimate the number of<br>galaxies in the universe | View an image showing a<br>large number of galaxies<br>in a very small portion of<br>the sky | Estimate the number of<br>galaxies in the image | There are hundreds of<br>billions of galaxies in the<br>universe | Use the number of galaxies<br>in the image to estimate<br>the number of galaxies in<br>the universe | Consider how the propor-<br>tion of galaxies actually<br>suitable for life influences<br>the probability of life in the<br>universe |
|  | Meeting the Challenge<br>Location, Location,<br>Location | 75        | colored pencils,<br>drawing materials |  |  |   |  |   |   |
|  | <b>TOTAL TIME</b><br>minutes<br>class periods            | 525<br>11 |                                       |  |  |   |  |   |   |

## Chapter 3: Where Do Elements Come From?

| Date | Activity Name  | Time | Materials  | What Students Do  | Engage  | Explore   | Explain  | Evaluate  | Extend to Astrobiology   |
|------|--|------|--|---|---|---|--|---|--|
|      | Challenge<br>Carbon's Ultimate Road Trip               | 25   | none   | Make a display detailing how an atom of carbon is created, dispersed, incorporated into a planet, and made available to organisms |   |   |  |   |  |
|      | Activity 1<br>Searching for Micrometeorites            | 125  | magnets, sandwich bags, pie tins, petri dishes, microscopes, slides, cover slips | Collect micrometeorites, remnants of the material out of which the solar system was made  | Ask students the difference between meteors, asteroids, and comets  | Collect samples. Examine them for micrometeorites. Use the number of micrometeorites in a sample to estimate the amount of material Earth receives                            | Meteors, asteroids, comets, and micrometeorites are remnants of the material out of which the solar system was made                        | Articulate what micrometeorites reveal about the early solar system and the role dust and gas played in its formation | Collect samples at other times of year. Relate the number of micrometeorites found each time to the occurrence of meteor showers |
|      | Activity 2<br>The Fact of the Matter                   | 50   | colored paper, hole punch, glue, plastic bags                                    | Make a model of the parts of an atom  | Brainstorm answers to the question, "What is the universe made of?" and generate a list of student ideas  | Construct models of six kinds of atoms. Discern the parts of an atom and identify the kinds of atoms modeled  | All matter is made of atoms, which consist of protons, neutrons, and electrons   | Describe limitations of the model. Articulate what makes one kind of atom different from another                      | Give two reasons supporting the idea that matter behaves similarly throughout the universe                                       |
|      | Activity 3<br>Modeling the Forces in an Atom           | 25   | magnets, Velcro tape   | Make a model of the three forces holding an atom together   | Generate a list of student answers to the questions, "How do protons, neutrons, and electrons stay together? What holds atoms, molecules and everything else together?" | Use Velcro-covered magnets to model the forces within an atom, and relate the model to the actual forces within an atom and how the forces work together to make new elements | The three fundamental forces of nature—gravitational, electromagnetic, and nuclear forces—hold atoms together and determine their behavior | Sketch the steps two protons in a star go through to fuse   | Explain why scientists are so interested in understanding the structure of elements and the forces governing them                |
|      | Activity 4<br>The Nuclear Fusion Reaction Inside Stars | 50   | calculators  | Analyze equations of fusion reactions to understand how fusion reactions inside stars create new elements                         | Work through an example of how a star forms helium from hydrogen in a fusion reaction   | Complete additional equations showing how a star's fusion reactions can create different elements   | New elements can be formed when atoms fuse. Because mass can be converted to energy, the input mass can be different from the output mass  | Explain the fusion process in terms of input and output elements, noting that mass is lost in the process             | Describe how life on Earth benefits from the fusion reactions occurring in the sun   |

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|--|---|----------|--------------------|--|--|---|---|--|--|
|  | Activity 5<br>Tracing Our Roots to<br>Space             | 25       | balloons, confetti | Design a classroom model depicting the stages in a star's life cycle | Figure out apparent impossibility of creating elements more massive than iron during normal fusion reactions | Use a confetti-filled balloon to model the stages of a star's life cycle and how heavy elements form during a supernova explosion | High-mass stars blow apart in supernovae, which eject material into space. That material is later recycled into new stars and planets | Articulate why all naturally occurring elements can only have been born inside stars | Describe the different ways a supernovae has affected or could have affected life on Earth |
|  | Meeting the Challenge<br>Carbon's Ultimate Road<br>Trip | 100      | drawing materials  |  |  |   |   |  |  |
|  | <b>TOTAL TIME</b><br>minutes<br>class periods           | 400<br>8 |                    |  |  |   |   |  |  |

## Chapter 4: What is Life?

| Date | Activity Name   | Time      | Materials   | What Students Do  | Engage   | Explore  | Explain  | Evaluate   | Extend to Astrobiology   |
|------|---|-----------|---|---|--|--|--|--|--|
|      | Challenge<br>Designing an Experiment to Test for Life             | 25        | unknown samples   | Devise an experiment to test an unknown sample to see if it contains life               |  |  |  |  |  |
|      | Activity 1<br>Life, A Long-Term Observation                       | 150       | thermometers, colored pencils, clipboards                             | Select a study site and observe it over an extended period of time                      | Identify the biotic and abiotic components in six “Mystery Site” images                    | Map a study site. Observe and document the biotic and abiotic components   | Biotic and abiotic factors interact. Organisms adapt to the abiotic factors in their environment                               | Write a field guide documenting the site’s features and explaining the interactions between the site’s biotic and abiotic components | Debate the pluses and minuses of having humans (versus robots) investigate (a) an Earth-based site and (b) an extraterrestrial site            |
|      | Activity 2<br>Defining Life                                       | 50        | plastic ant, silk flower, live earthworm, gummy worms                 | Develop a working definition of life  | Brainstorm a list of the characteristics of life and develop an initial definition of life | Use definition to group cards into life and non-life categories, explaining each placement                                     | While there is no single definition of life, organisms share a basic set of characteristics and functions                      | Refine the list of the characteristics of life into a working definition   | Develop a definition of life to help you identify life elsewhere in the universe   |
|      | Activity 3<br>Identifying Life                                    | 75        | sand, sugar, active dry yeast, antacid tablets, 1 can of Mountain Dew | Determine whether any of the three “mystery powders” contain something alive            | Observe the behavior of “sewer maggots” and determine whether they are alive               | Test three powders for signs of life, using observations to support each determination   | There is no single test that can establish the presence or absence of life   | Evaluate the completeness of the current working definition of life. Refine it if necessary  | Identify additional tests that could show that the yeast is alive. Articulate why biomarkers are easier to detect than organisms are           |
|      | Activity 4<br>What Does Life Need for Survival?                   | 125       | assorted materials brought in from home                               | Create different habitats to establish that life needs water, energy, and raw materials | Brainstorm what any organism must have in order to live a long time                        | Create 12 habitats that promote the growth of a variety of organisms. Identify what each habitat has in common with the others | A habitable place must supply water, raw materials, and energy. Life can exploit different sources of energy and raw materials | Identify sources of energy, water, and raw materials in each habitat   | Discuss whether all life or just Earth-based life requires water, energy, raw materials. Discuss how a world might make these things available |
|      | Meeting the Challenge<br>Designing an Experiment to Test for Life | 100       | brine shrimp eggs   |   |  |  |  |  |  |
|      | <b>TOTAL TIME</b><br>minutes<br>class periods                     | 525<br>11 |   |   |  |  |  |  |  |

## Chapter 5: The Chemistry of Life

| Date | Activity Name                               | Time | Materials  | What Students Do   | Engage  | Explore   | Explain  | Evaluate  | Extend to Astrobiology  |
|------|---|------|--|--|---|---|--|---|---|
|      | Challenge<br>Chemistry of Life Exhibit      | 25   | none   | Use understanding of bonding, chemical reactions, and the major macromolecules to produce an exhibit. The exhibit stresses the importance of carbon to life on Earth |   |   |  |   |   |
|      | Activity 1<br>From Elements to Molecules    | 100  | vinegar, baking soda, limewater, beakers. For demos: 5 ml HCL, 5 ml of ammonia (concentrated), silver nitrate, NaCl, copper sulfate, sodium carbonate, barium chloride, calcium acetate, alcohol, test tubes | Make element models that illustrate why atoms and molecules react and explore the logic of how they are arranged on the periodic table                               | Observe 4 chemical reactions that produce visible, spontaneous changes                                    | Make models for the first 18 elements and group them according to their structure. Relate atomic structure to chemical reactivity | Molecules offer atoms a more stable arrangement than is possible were they to remain separate. Atoms react chemically based on the number of electrons in their outermost shells | Explain how the periodic table organizes elements based on their chemical and physical properties, and use it to predict which elements will bond to form molecules | Describe why living things use molecules rather than elements to construct and operate their bodies   |
|      | Activity 2<br>Photosynthesis                | 100  | geranium leaves, isopropyl alcohol, baking soda, filter paper, funnels, petri dishes, hot plate, iodine, starch, safety glasses  | Investigate photosynthesis by extracting pigments from a leaf and by examining two substances produced in photosynthesis   | Discuss where photosynthesis occurs in a plant and the key reactants and products involved in the process | Conduct three experiments investigating different parts of the photosynthetic process   | Photosynthesis is a series of chemical reactions that convert light into chemical energy. Pigments capture the energy in different wavelengths of light                          | What advantage might photosynthesizers have over organisms that derive energy from chemicals in the environment?  | How does photosynthesis introduce energy and carbon into an environment? Why might photosynthesis not always be appropriate for life in the solar system? |
|      | Activity 3<br>Food and Raw Materials        | 50   | food samples (hot dogs, peanuts, cereal, raisins, nutrition panels for each sample)  | Identify the common components of the foods—carbohydrates, proteins, and fats—by analyzing nutrition labels for different food samples                               | Brainstorm reasons why we eat   | Analyze nutrition labels for different food samples and identify the kinds of molecules foods have in common                      | Food is made up of macromolecules that provide organisms energy and raw materials  | Explain the role each kind of molecule plays in nutrition. Trace the origin of macromolecules and how they cycle in the food chain                                  | Establish why habitable worlds must include biogenic elements, the components of macromolecules   |
|      | Activity 4<br>Energy and Essential Elements | 50   | food samples, corks, paper clips, matches, clock or stopwatch  | Burn food samples to determine which contains the most energy  | Predict which kind of food and which macromolecule contains the most energy                               | Burn food samples. Determine which food contains the most energy  | The proportions of carbohydrates, proteins, and fats determine the amount of energy in a food  | Contrast respiration and photosynthesis and explain how respiration releases energy from food   | Show how photosynthesis and respiration tap light energy and cycle carbon   |

|  |  |           |   |   |  |  |   |   |  |
|--|--|-----------|---|---|--|--|---|---|--|
|  | Activity 5<br>Carbon-based Life                    | 75        | gumdrops,<br>toothpicks, or<br>molecular model<br>kits  | Build models of carbon-<br>based molecules    | Discuss the atomic and<br>molecular nature of carbon             | Construct models of<br>various forms of carbon<br>and explain how the<br>different molecular<br>arrangements give<br>each form of carbon its<br>properties     | Carbon atoms can bond<br>to one another in the<br>form of chains, rings, and<br>branching networks. Life<br>on Earth is carbon-based                  | Debate whether life needs<br>to be carbon-based and<br>whether all forms of<br>carbon are suitable for life | Consider what the<br>advantages of being<br>carbon-based implies<br>about the search for life<br>elsewhere                         |
|  | Activity 6<br>Are There Alternatives to<br>Carbon? | 100       | “Devil in the Dark”<br>video (Star Trek),<br>“Silicon Avatar”<br>video (Star Trek<br>Next Generation) | Debate whether life could<br>be silicon-based | Watch science fiction video<br>clips about silicon-based<br>life | Examine carbon’s and<br>silicon’s positions on the<br>periodic table and explain<br>how silicon’s atomic<br>structure limits the kinds<br>of bonds it can make | Though silicon’s structure<br>is similar to carbon’s, its<br>structure limits the kinds<br>of bonds it can make<br>and the strength of those<br>bonds | Identify silicon’s significant<br>limitations as a molecule<br>of life and why life is<br>carbon-based      | Make the case that the<br>chemistry found on Earth<br>is likely to be typical<br>of the chemistry found<br>throughout the universe |
|  | Meeting the Challenge<br>Chemistry of Life Exhibit | 100       | poster board,<br>drawing materials  |   |  |  |   |   |  |
|  | <b>TOTAL TIME</b><br>minutes<br>class periods      | 600<br>13 |   |   |  |  |   |   |  |

## Chapter 6: Cellular Basis of Life

| Date | Activity Name                                     | Time     | Materials  | What Students Do  | Engage  | Explore   | Explain  | Evaluate   | Extend to Astrobiology   |
|------|---|----------|--|---|---|---|--|--|--|
|      | Challenge<br>How Small Can Life Be?               | 25       |  | Make models of two types of cells that are the basis of life on Earth. Write an “executive summary” summarizing what they have learned about our current understanding of the cell as it relates to life on Earth |   |   |  |  |  |
|      | Activity 1<br>Observing Cells                     | 100      | prepared slides: volvox, plant guard cells, human nerve cells, bacteria, microscopes, slides, cover slips, methyl cellulose, dropping pipettes | Observe different kinds of cells under the microscope   | List evidence that could be used to convince someone that all living things are made of cells | Visit stations and view 8-10 different kinds of cells under the microscope                          | All life on Earth uses the cell as its basic structural unit. All cells share a basic design. A cell’s form reflects its function            | Explain what becomes possible when there is an inside environment separated from an outside environment. Relate a cell’s structure to its function | Argue for and against the idea that life on other worlds will be made of cells   |
|      | Activity 2<br>From Prokaryotes to Eukaryotes      | 100      | tape, scissors   | Identify which cell parts belong with a prokaryotic cell and which belong to a eukaryotic cell  | List information that would be good to know before classifying cells                          | Match images of cell parts with the appropriate kind of cell  | Prokaryotic cells are less complex than eukaryotic cells. Each cellular structure has a specific function                                    | Design a poster displaying each kind of cell. Explain why it is useful to classify cells into different types                                      | Articulate why it is important for astrobiologists to distinguish between the two types of cells                             |
|      | Activity 3<br>On Being the Right Size             | 50       | agar, phenothalien, ammonia solution, metric rulers, safety glasses, plastic spoons  | Investigate how quickly dye penetrates different-sized cubes as a way to see how an object’s size influences its ability to exchange materials with the outside environment                                       | Discuss whether success should be defined as greater numbers or greater complexity            | Place different-sized agar cubes into a solution and compare the amount of penetration in each cube | Smaller cells have a large surface area to volume ratio, allowing them to absorb and distribute materials more efficiently than larger cells | Explain how small cell size offers a survival advantage in environments where raw materials and energy are limited                                 | Use the data collected in the activity to make the case that prokaryotic cells occurred on Earth before eukaryotic cells did |
|      | Activity 4<br>Getting Small                       | 50       | scissors, toothpicks, clay, glue, string   | Build a model of a virus and compare it with prokaryotic and eukaryotic cells   | Brainstorm the absolute minimum set of organelles a cell needs to survive                     | Build a model of a virus  | The lower limit to cell size occurs when a cell is too small to fit the structures it needs to live  | Debate whether viruses are alive and whether they, or prokaryotes or nanobes, are the smallest form of life on Earth                               | Argue for and against the idea that the structures found in some Martian meteorites represent life                           |
|      | Meeting the Challenge<br>“How Small Can Life Be?” | 100      | none   |   |   |   |  |  |  |
|      | <b>TOTAL TIME</b><br>minutes<br>class periods     | 425<br>9 |  |   |   |   |  |  |  |

## Chapter 7: Evolution and Diversity

| Date | Activity Name   | Time | Materials                                      | What Students Do   | Engage  | Explore  | Explain   | Evaluate   | Extend to Astrobiology   |
|------|---|------|--|--|---|--|---|--|--|
|      | Challenge<br>Variation in Humans                                    | 25   | PTC paper                                      | Collect data on variation in a human trait and write a short report that uses the data to speculate on how the variation in the trait might influence survival |   |  |   |  |  |
|      | Activity 1<br>What Is Natural Selection?                            | 50   | baggies, punchout dots, large sheets of paper  | Model natural selection by conducting two simulations  | Discuss how slapping mosquitoes influences the make up of the mosquito population | Conduct two simulations that model how populations change based on the individuals that survive. Examine how traits influence which organisms succeed under a particular set of conditions | Well-adapted individuals have a set of traits that enable them to meet the challenges posed by the environment and are more likely to produce offspring than poorly adapted individuals | Cite examples where survival depends on the interplay between an individual's traits and the prevailing environmental conditions             | Should the ability to contend with change be added to your working definition of life? Why or why not?   |
|      | Activity 2<br>What Are Populations and How Do They Change?          | 50   | graph paper                                    | Collect and graph data on four human traits and analyze how traits vary in a population  | List traits that can differ in individuals in a population                        | Collect and graph data on four easily measured human traits  | In a population, each trait is widely distributed. A bell-shaped curve shows this general distribution  | Why might having variation in a population might be beneficial to that population?   | Show how a population might change based on changes in the environment. Express the continuity of life as a function of variation in a population  |
|      | Activity 3<br>Are You Fit to Live Here?                             | 125  | agar, sterile petri dishes, or pre-made plates | Create several bacterial cultures to compare how altered conditions affect bacterial growth  | Define fitness by discussing the flu epidemic of 1918                             | Culture bacteria to see the effect of antibacterial substances. Use differences among the control and experimental plates to identify a range of tolerance in the bacterial population     | Fitness is a measure of how well suited an organism is to its environment. Natural selection fine-tunes populations so that most individuals are fit                                    | Show how the concept of fitness explains changes in the peppered moth population   | Identify the roles variation and fitness have played in the continuity of life on Earth as the Earth has changed over the past three billion years |
|      | Activity 4<br>How Can One Kind of Creature Give Rise to Many Kinds? | 50   | none   | Play a game that models how one species can evolve into several different species by responding to selection pressures   | Relate the creature in the game to modern-day rodents                             | Play a game illustrating how populations can change into new species over vast amounts of time   | By responding differently to selection pressures, segments of a population can become isolated, which can result in the rise of new species   | Place the evolved animals in their correct habitats. Suggest reasons why islands far from the mainland often have species found nowhere else | Explain why the process of developing new species is crucial to producing a diversity of life, both here on Earth and elsewhere                    |

|  |  |          |             |  |  |  |   |   |   |
|--|--|----------|-------------|--|--|--|---|---|---|
|  | Activity 5<br>Where Did All the Life on Earth Come From? | 50       | graph paper | Design two models that illustrate how phylogenetic trees map relationships among organisms | Brainstorm what factors influence how quickly a population diversifies | Make a graph-paper model to show how life diversifies from a common ancestor | The diversity of life we see today can be traced back through many different kinds of organisms to a few kinds of single-celled organisms | Describe how natural selection can produce the many species found on Earth. How might you determine how recently two kinds of organisms shared a common ancestor? | Debate whether evolution by natural selection is unique to Earth. Explain what it would take for a microbe to turn into an intelligent extraterrestrial |
|  | Meeting the Challenge<br>Variation in Humans             | 75       | none        |  |  |  |   |   |   |
|  | <b>TOTAL TIME</b><br>minutes<br>class periods            | 425<br>9 |             |  |  |  |   |   |   |

## Chapter 8: History of Life on Earth

| Date | Activity Name  | Time             | Materials  | What Students Do   | Engage  | Explore   | Explain  | Evaluate  | Extend to Astrobiology   |
|------|--|------------------|--|--|---|---|--|---|--|
|      | Challenge<br>WebQuest: Life on Earth<br>(Xtreme Files)             | 25               | internet access  | Create storyboards for a proposed documentary about the possibility of life on other worlds  |   |   |  |   |  |
|      | Activity 1<br>Timeline of Life on Earth                            | 125              | Life Beyond Earth video, paperclips, timeline cards                                      | Construct a timeline that puts in chronological order 40 key events in the history of life on Earth  | Brainstorm a list of events in Earth's history that affected life on Earth  | Sequence events from the oldest to most recent. Group them into themes related to the evolution of life. Make a timeline to display the events          | Living and non-living systems have changed one another. Catastrophic events have altered Earth and life on Earth   | Identify examples that illustrate how life responds to environmental changes. Describe what Earth and a possible ancestor looked like at different times in Earth's history | Discuss what the rapid appearance of prokaryotes suggests about how easily life develops and what the delayed appearance of eukaryotes suggests about the appearance of complex life |
|      | Activity 2<br>Origins: The Beginning of Life                       | 100              | a set of Legos (large), bubble solution  | Assemble a variety of structures that separate an inside environment from an outside one to gain insight into the origin of life and the first cells | List ingredients that would be important to include when creating life in a test tube. Debate whether cell membranes or genetic material came first | Build 3 structures to investigate the importance of having a reliable way to convey information. Investigate self-assembly by working with soap bubbles | Life requires a closed structure and a way to pass information to offspring. Certain molecular properties could help turn non-living chemicals into living systems | Build models that illustrate the challenges that must be overcome before non-living chemicals can function as a living system   | What conditions might have led to the origin of life on Earth? How might one determine whether these conditions exist elsewhere?   |
|      | Activity 3<br>Oxygen Changes Everything                            | 100              | a variety of leaves, sticky tags   | Observe photosynthetic organisms. Use the timeline to reveal how the accumulation of oxygen in the atmosphere affected life                          | Name as many kinds of photosynthetic organisms as possible. Estimate how abundant each one is   | View a diverse collection of photosynthetic organisms. Identify events on the timeline where life was affected by the buildup of oxygen                 | Photosynthesis dramatically changed the composition of Earth's atmosphere. Oxygen poisoned anaerobes and enabled aerobic organisms to emerge                       | Outline some scenarios for what Earth and life on Earth would be like now if photosynthesis had not developed   | Explain how understanding the history of photosynthesis and its affect on oxygen accumulation on Earth might be important in the search for life on other worlds                     |
|      | Activity 4<br>Impacts and Extinctions                              | 100-150          | Asteroids: Deadly Impacts (optional), flat containers, flour, corn starch or baby powder | Interpret three data sets to locate the impact crater that probably killed the dinosaurs   | Model an impact crater and define crater features   | Plot three data sets on a map and pinpoint the location of the impact crater that probably killed the dinosaurs   | Life can be seriously affected by large meteorite impacts, which can alter climates by throwing dust into the atmosphere   | Speculate about how life on Earth might be different today if the impact had not occurred   | Explain how meteor impacts can be beneficial to life on a planet and harmful to life on a planet   |
|      | Meeting the Challenge<br>WebQuest: Life on Earth<br>(Xtreme Files) | 100              | posterboard (2' X 3')  |  |   |   |  |   |  |
|      | <b>TOTAL TIME</b><br>minutes<br>class periods                      | 550-600<br>11-12 |  |  |   |   |  |   |  |

## Chapter 9: What is Habitability?

| Date | Activity Name  | Time | Materials   | What Students Do  | Engage  | Explore   | Explain  | Evaluate   | Extend to Astrobiology  |
|------|--|------|---|---|---|---|--|--|---|
|      | Challenge Modules for International Space Station              | 25   |   | Create a poster with designs for two new life-support modules for the International Space Station. One module will house humans, the other bacteria |   |   |  |  |   |
|      | Activity 1 Habitability Concept Map                            | 50   | large sheets of paper   | Design a concept map that shows how an organism gets everything it needs from the world on which it lives   | Brainstorm answers to the questions “What does life require?” and “How might a world provide the materials and conditions required by life?”            | Produce a habitability concept map that shows how an organism gets everything it needs from the world on which it lives   | Any habitable world needs to have an energy source and provide liquid water, raw materials   | Compare the Chapter 9 maps (based on preconceptions) with similar ones students made in Chapter 12, after they study habitability                        | Explain at least two ways a world might provide each required habitability factor   |
|      | Activity 2 Which Planets and/or Moons Are Candidates for Life? | 50   | none  | Rank the planets and moons as likely, possible, or unlikely places for life   | List ways to identify habitable a planet or moon  | Refer to the planetary sheets in the appendix and evaluate the habitability of the planets and moons in our solar system  | Habitable worlds have long-term stability, water, temperatures conducive to life, and a source of energy and raw materials   | Identify the top three candidates for life in the solar system   | Explain why it is easier to look for habitable conditions than for actual organisms. How would this fact influence a search strategy? |
|      | Activity 3 Worlds Within Termites                              | 75   | termites, petri dishes, magnifying glasses, microscopes, dissecting needles, forceps, saline solution | Dissect termites and use microscopes to find habitable environments in and on termites  | List the characteristics of a habitat. See if these characteristics are evident in a termite colony and in individual termites                          | Dissect a termite and make a slide of the contents of its gut. Make a card for each kind of gut organism. Describe the habitability of a Winogradsky column                               | A habitat must supply the basic requirements of life. Microbes can adapt to any environment that provides life’s basic requirements  | Create a display showing the challenges a termite gut poses for organisms living there and the adaptations the organisms have for meeting the challenges | How might the fact that microscopic places can support life influence the definition of habitability and a search strategy?           |
|      | Activity 4 Is the Moon Habitable?                              | 50   | none  | Contrast the habitability of Earth and the moon by comparing key habitability factors   | Locate the Earth and moon on a diagram of the inner solar system, making the point that the Earth and moon are on the same orbital track around the sun | Analyze Earth and moon images and discuss what they suggest about the habitability of both places. Read about the temperatures, geologic activity, and radiation levels on Earth and moon | Without an atmosphere, the moon is subject to extreme temperature swings and is unprotected from ultraviolet radiation. Because the moon is geologically dead, it cannot regulate its temperature or circulate raw materials | List five reasons that might explain why Earth has life while the moon seems lifeless. Rank them in order of importance                                  | Describe why temperature, radiation, and geologic activity are important to habitability  |

|  |  |           |  |  |  |  |   |  |   |
|--|--|-----------|--|--|--|--|---|--|---|
|  | Activity 5<br>Habitability of Radishes -<br>An Astrobiology Research<br>Experience | 125       | radish seeds,<br>potting soil, sand,<br>pots, paper cups,<br>light sources | Design and conduct an<br>independent, long-term<br>investigation examining<br>habitability factors | Complete the sentence<br>starting with: "Scientific<br>research is..." Observe<br>seeds. Discuss what they<br>need to grow and which<br>factors are testable | Design a six-week<br>experiment to test the<br>effect of a habitability<br>factor on the growth of<br>radish seeds | Scientific research is a<br>process that involves a<br>long-term commitment to<br>careful observation and<br>collection of data | Analyze and graph<br>experimental results and<br>present findings in an oral<br>or written forum | How many kinds of<br>science do astrobiologists<br>use in the search for life<br>in the universe? What<br>is common in all these<br>sciences? |
|  | Meeting the Challenge<br>Modules for International<br>Space Station                | 100       | none   |  |  |  |   |  |   |
|  | <b>TOTAL TIME</b><br>minutes<br>class periods                                      | 475<br>10 |  |  |  |  |   |  |   |

## Chapter 10: Finding Energy and Raw Materials on Habitable Worlds

| Date | Activity Name   | Time | Materials   | What Students Do  | Engage  | Explore  | Explain   | Evaluate   | Extend to Astrobiology  |
|------|---|------|---|---|---|--|---|--|---|
|      | Challenge Energy and Carbon on Your Habitable World   | 25   | Advertisement for a world created in Chapter 2  | Describe “features and benefits” of sources of energy and carbon available for organisms that might live on the world students designed in Chapter 2. |   |  |   |  |   |
|      | Activity 1 Shedding Light on a Planet                 | 50   | overhead projector, masking tape, meter sticks, graph paper   | Calculate the light intensities for the planets in our solar system and determine which have enough light energy to be potentially habitable          | Discuss the importance of sunlight to life on Earth   | Observe a demonstration of the inverse square law and calculate the light intensities for the planets in our solar system                      | Light provides energy to organisms and can help keep temperatures within the range required for water. Light intensity diminishes as one moves away from the light source | Identify which worlds have enough light energy to be potentially habitable   | If a habitable world has to be in a star’s habitable zone, how would this condition influence the number of habitable worlds in the universe? |
|      | Activity 2 Testing the Inverse Square Law with Elodea | 100  | sprigs of elodea, test tubes, lamps (40W), pond water, test tube racks  | Test how important light intensity is to photosynthetic organisms by measuring the effect of varying light intensities on the rate of photosynthesis  | List ways that the intensity of light is important to life on Earth   | Design and conduct an experiment to test how different light intensities affect the rate at which Elodea produces oxygen during photosynthesis | Photosynthesis is the process by which light is converted to products useful to an organism. Light intensity affects the rate of photosynthesis                           | Present results and relate experimental setup to how intensity varies on other worlds in the solar system  | How could life obtain its energy if it is underground or the intensity of the light reaching the world is insufficient for photosynthesis?    |
|      | Activity 3 Using Chemical Energy                      | 100  | yeast, test tubes, dropping pipettes, sucrose, glucose, lactose sugars, large beaker                                    | Design and conduct an experiment to test whether chemical compounds can provide an organism the energy it needs                                       | Identify alternative energy sources for life on worlds with insufficient light to support photosynthesis or, that like early Earth, have had too little time to evolve photosynthesis | Design and conduct an experiment to test how sucrose, glucose, and lactose compare as a chemical energy source for yeast                       | Respiration and fermentation enable organisms to tap chemical compounds to satisfy their energy needs   | Where does the energy stored in the sugar used by yeast come from? Draw a flowchart showing what needs to be in place before an organism can use chemical energy | Why is it unlikely that respiration would be the only way for life to obtain its energy on a habitable world?                                 |
|      | Activity 4 Redox Reactions and Energy for Life        | 100  | lemons, copper and zinc strips, wires with clips, LCD display, voltmeter, batteries, cardboard, golf balls, clothespins | Build two models that show how electron donors and acceptors yield energy during a redox reaction   | Build a lemon-clock to show that a redox reaction can supply energy   | Model how electron acceptors and donor pairs yield different amount of energy, and discuss the data collected                                  | Redox reactions convert energy into a form that can be used by organisms; and they occur when electrons move between electron donors and acceptors                        | Model how redox reactions provide the energy to form ATP. Contrast how yeast would grow in aerobic and anaerobic environments                                    | What is the implication for life elsewhere that there are so many redox pairings that provide energy to life on Earth?                        |

|  |   |           |  |   |  |  |  |   |  |
|--|---|-----------|--|---|--|--|--|---|--|
|  | Activity 5<br>Looking at Energy and<br>Carbon Sources                 | 100       | Winogradsky<br>column(s) from<br>week 1, map<br>of the world,<br>thumbtacks, yarn,<br>Habitable Worlds<br>Web site | Design an exhibit showing<br>the variety of ways life on<br>Earth obtains its carbon<br>and energy and how life<br>elsewhere might get its<br>carbon and energy using<br>similar strategies | Identify the different kinds<br>of organisms living in a<br>Winogradsky column | Research four ways life on<br>Earth obtains its carbon<br>and energy, and identify a<br>representative organism<br>for each strategy | Life has several ways to<br>tap Earth's different carbon<br>and energy sources,<br>with microbes exhibiting<br>the greatest diversity of<br>strategies | Design an exhibit that<br>shows the different<br>strategies organisms<br>use to obtain carbon and<br>energy and where these<br>organisms can be found | How can life on Earth<br>serve as an analog for life<br>on other worlds? |
|  | Meeting the Challenge<br>Energy and Carbon on<br>Your Habitable World | 50        | none   |   |  |  |  |   |  |
|  | <b>TOTAL TIME</b><br>minutes<br>class periods                         | 525<br>10 |  |   |  |  |  |   |  |

## Chapter 11: Planetary Systems that Contribute to Habitability

| Date | Activity Name   | Time | Materials   | What Students Do  | Engage  | Explore   | Explain  | Evaluate   | Extend to Astrobiology  |
|------|---|------|---|---|---|---|--|--|---|
|      | Challenge Children's Story: Follow the Water                            | 25   | none  | Write and illustrate a story, that can be understood and enjoyed by sixth graders, about how planetary systems contribute to habitability   |   |   |  |  |   |
|      | Activity 1<br>Why is Water So Central to Life?                          | 50   | goggles, ring stand, 1000 ml beaker, hot plate, citric acid, baking soda, aluminum foil | Conduct an experiment examining how water dissolves and transports chemicals and construct and analyze a model of the water cycle   | Brainstorm reasons why water is important to life   | Conduct an experiment examining how water dissolves and transports chemicals, and create and analyze a model of the water cycle               | Water is a powerful solvent that dissolves and transports substances and serves as a medium for chemical reactions. A water cycle distributes liquid water | Explain why liquid water is important to life, using data from the experiment. Use the model to show why a water cycle is important to life on Earth | Why do astrobiologists look for water or signs of life?   |
|      | Activity 2<br>The Case for Subsurface Water on Mars and Europa?         | 100  | transparencies of images  | Interpret images showing water-related features on Earth, Mars, and Europa and make a case for the presence of subsurface water on each body  | Brainstorm a list of features that might reveal the presence of liquid water on a planet or moon                                | Analyze images of the surfaces of Mars, Europa, and Earth. Use guiding questions to interpret the images and identify telltale signs of water | Surface features on both Mars and Europa suggest the presence of subsurface water  | Build a case for the presence of water on Mars and Europa by using images that show water-related features on Mars and Europa and Earth analogs      | How could you determine whether a world might have subsurface water. Why is the possibility of water on Mars and Europa so interesting? |
|      | Activity 3<br>How Does an Atmosphere Influence a Planet's Habitability? | 100  | beakers, food coloring, graph paper   | Make and analyze graphs to identify the role atmospheres play in surface temperature. Observe two demonstrations that examine heat and particle motion. State the role atmospheres play in habitability | Plot planetary temperatures against distance from the sun, revealing that atmospheres produce higher-than-expected temperatures | Observe two demonstrations and complete a sheet contrasting greenhouse and non-greenhouse gases   | Planets with atmospheres are warmer than expected. Greenhouse gases absorb, store, and reradiate energy from the sun                                       | Describe the different roles an atmosphere can play in making a planet or moon habitable. Why is temperature such an important habitability factor?  | How might the presence or absence of an atmosphere influence the search for life?   |
|      | Activity 4<br>What is Density?  | 50   | vegetable oil, alcohol, sugar, balance, hot plate, 250 ml beaker                        | Conduct a series of activities that define density and show the role it plays in convection   | Conduct a brief experiment with an unexpected outcome that defines density operationally  | Conduct six activities examining how changes in density cause changes in gases and liquids  | Gases and liquids move because of differences in density. Convection is the transfer of heat based on the mass movement of particles                       | List different ways to change the density of a liquid or gas.  | How might density influence planetary cycles?   |

|  |  |           |                       |   |  |   |  |   |   |
|--|--|-----------|-----------------------|---|--|---|--|---|---|
|  | Activity 5<br>How Do Planetary Cycles Influence Habitability?  | 50        | none                  | Learn what is required for a world to have planetary convection cycles, and determine which planets and moons in our solar system have these things | Identify everyday examples of convection   | Read about what is required for planetary convection cycles, and inventory the solar system's planets and moons for these factors | The more heat sources and convective materials a world has, the more likely it is to have at least one environment suitable for life                       | Rank the planets and moons in the solar system in terms of the presence of planet-wide convection processes | Why is it advantageous for a world to have several kinds of heat sources and several kinds of convective materials available?           |
|  | Activity 6<br>What are the Habitable Zone in Our Solar System? | 100       | colored sticky notes, | Determine the different kinds of habitable zones in our solar system and how big each one is  | Brainstorm and prioritize a list of factors required by prokaryotic and eukaryotic life. Define habitable zone as well as possible | Make flow charts to examine different habitability factors and determine their role in making a world habitable                   | A habitable zone contains worlds that can provide the minimum factors required by life. Its size depends on the complexity of the life for which one looks | Create a display showing the prokaryotic and eukaryotic habitable zones in our solar system                 | How can defining different kinds of habitable zones help determine which worlds in the solar system to explore and how to explore them? |
|  | Meeting the Challenge<br>Children's Story: Follow the Water    | 100       | none                  |   |  |   |  |   |   |
|  | <b>TOTAL TIME</b><br>minutes<br>class periods                  | 575<br>11 |                       |   |  |   |  |   |   |

## Chapter 12: Are There Habitable Worlds Elsewhere?

| Date | Activity Name                                      | Time     | Materials   | What Students Do   | Engage   | Explore   | Explain  | Evaluate  | Extend to Astrobiology  |
|------|--|----------|---|--|--|---|--|---|---|
|      | Challenge Life on Your Habitable World             | 25       | Habitable world advertisement and “features and benefits” sheet on energy available | Make trading cards for organisms that might be found on the habitable world created in chapter 2 and further defined in chapter 10   |  |   |  |   |   |
|      | Activity 1 Revisiting the Habitability Concept Map | 100      | none  | Design a concept map that answers the question, “What must a world provide to support life?”   | Identify examples that clarify what is meant by saying that habitability factors or processes are interrelated or interconnected | Design a concept map that consolidates and clearly presents an understanding of factors and processes that make a world habitable | Many interconnected factors affect habitability. However, the top habitability factors are the availability of liquid water, energy, and raw materials                                     | Write a paragraph contrasting the factors and processes that make a world habitable for simple and complex life. Reassess the list of habitable planets and moons | Which set or sets of factors and processes represent the minimum necessary for life?                |
|      | Activity 2 Extreme Life Card Game                  | 100      | sets of Life on the Edge cards  | Play card games organized around the premise that if life can exist under extreme conditions on Earth, then there may be organisms living under similar conditions on other worlds | Play a card game with a special deck of 15 large-sized extremophile playing cards  | Play the card games Go Fish and Concentration with a deck of 48 extremophile cards  | There is evidence for habitable conditions beyond Earth. Places mirroring Earth’s life-sustaining environments may harbor life   | Explain how life and conditions on Earth can be used as a model for life on other worlds  | What is the evidence for extraterrestrial conditions that may support extremophiles?                |
|      | Activity 3 How Much Life Is There in the Universe? | 100      | none  | Estimate how many extraterrestrial worlds in the universe have life  | Estimate the number of corn flakes in the United States  | Identify the terms involved in estimating the number of worlds in the universe with life  | One can identify the terms involved in determining if there is life in the universe. The large number of stars increases the probability that simple life exists elsewhere in the universe | Estimate the number of worlds in the universe with life by assigning probabilities or numbers to each term  | Which is more likely, worlds with simple life or worlds filled with technologically capable beings? |
|      | Meeting the Challenge Life on Your Habitable World | 100      | none  |  |  |   |  |   |   |
|      | <b>TOTAL TIME</b><br>minutes<br>class periods      | 425<br>7 |   |  |  |   |  |   |   |

## Chapter 13: How Do We Search?

| Date | Activity Name  | Time     | Materials   | What Students Do  | Engage   | Explore   | Explain   | Evaluate   | Extend to Astrobiology   |
|------|--|----------|---|---|--|---|---|--|--|
|      | Challenge Proposal for an Observatory to Search for Intelligent Life             | 25       | none  | Write and submit a proposal for building an observatory to search for intelligent life                  |  |   |   |  |  |
|      | Activity 1<br>Can We Find a Signal?  | 50       | portable radio with digital display, colored pencils, graph paper                               | Distinguish signals from noise and speculate about what kinds of signals intelligent life might send    | Play a game using clickers to produce signals and noise. Define signal and noise                 | Survey the radio dial, charting whether there is signal or noise at each frequency                                | Radio waves cover a range of bandwidths, but intentional signals are likely to be regular signals at a specific bandwidth   | Contrast three images that display the strength of electromagnetic waves   | Why is analyzing electromagnetic radiation a good way to learn about the universe?                           |
|      | Activity 2<br>Riding the Wave  | 50       | lengths of rope or flexible springs, stopwatch  | Model a standing wave to become familiar with the properties of waves                                   | List familiar sources of waves and the properties that characterize a wave                       | Model standing waves, calculate the speed of a wave, and measure and describe wave properties                     | A standing wave has a measurable amplitude, wavelength, frequency, and speed  | Describe how waves can convey information  | How does our understanding of the universe and the search for life depend on our ability to interpret waves? |
|      | Activity 3<br>Understanding the Electromagnetic Spectrum                         | 50       | poster paper, pushpins  | Make a display of the electromagnetic spectrum to become familiar with different types of EM radiation  | List as many kinds of electromagnetic radiation as possible and devices used to detect each kind | Make a chart of the different kinds of electromagnetic radiation based on differences in wavelength and frequency | Electromagnetic radiation comes in many forms, most of which we cannot see. Each kind has a unique wavelength and frequency | Contrast the properties and scale of different kinds of electromagnetic radiation. Identify instruments used to detect each kind | Why must some observatories be placed in space while others work well from the surface of Earth?             |
|      | Activity 4<br>Cosmic Fingerprinting - Using Spectral Lines                       | 50       | gas tubes (hydrogen, helium, neon), spectrum tube holder, diffraction gratings, colored pencils | Observe gases glowing inside tubes to see how spectral signatures can reveal the composition of the gas | Use a diffraction grating to observe the spectral lines of five different glowing gases          | Match plots and photos of five different spectra  | Each elemental gas has a unique spectral plot, which enables us to determine the type of gas that created the lines         | Draw plots of the five spectra that were viewed with the diffraction grating   | Why might analyzing spectral signatures be useful when studying the atmospheres of other planets?            |
|      | Meeting the Challenge Proposal for an Observatory to Search for Intelligent Life | 100      | none  |   |  |   |   |  |  |
|      | <b>TOTAL TIME</b><br>minutes<br>class periods                                    | 325<br>7 |   |   |  |   |   |  |  |

## Chapter 14: Searching for Extrasolar Planets

| Date | Activity Name   | Time     | Materials   | What Students Do   | Engage  | Explore  | Explain  | Evaluate   | Extend to Astrobiology  |
|------|---|----------|---|--|---|--|--|--|---|
|      | Challenge<br>Can You Find the Extrasolar Planet?                      | 50       | extrasolar planet dossier   | Examine dossiers for at least two sun-like stars. Using different observation techniques, determine whether a planet lies within a habitable zone around the suns                        |   |  |  |  |   |
|      | Activity 1<br>Observations of an Extrasolar Planet: Transit Method    | 50       | light bulb and base   | Analyze graphs of planets transiting a star to see how periodic changes in the amount of starlight can reveal the presence of an orbiting planet, its period, and distance from its star | Draw a graph of how the relative brightness of a light bulb changes as a ball orbits it   | Interpret brightness graphs of three transiting planets and determine their period   | When a planet transits its star, the amount of light from the star decreases, revealing the presence of an extrasolar planet                                       | Determine whether any of the extrasolar planets are in a habitable zone by seeing if any have Earth-like periods | To be in the habitable zone of a sun-like star, what orbital period should an extrasolar planet have? |
|      | Activity 2<br>Observations of an Extrasolar Planet: Astrometry Method | 50       | two sizes of Styrofoam balls, shishkabob skewers, thin string or thread | Use a model and images to understand how regular changes in a star's position can reveal the presence of an orbiting planet  | Model a star-planet system to identify its center of mass and see how distance and mass affect the location of the center of mass | Examine images to determine the period of planets orbiting three hypothetical stars  | A star's wobbling motion can reveal a planet's period, mass, and distance from the star  | Explain how a star's wobble reveals an orbiting planet and how the planet's mass influences a star's wobble      | How will detecting star wobbles help astronomers find new solar systems?                              |
|      | Activity 3<br>Observations of an Extrasolar Planet: Spectral Method   | 100      | battery operated buzzer or horn, rope                                   | Use models and spectral plots to see how a planet orbiting a star can change the star's motion, altering the frequency and color of its light  | Demonstrate a Doppler shift by whirling a horn or buzzer around on a long rope  | Interpret the blue- and red-shifting of spectral plots and absorption lines to detect a star's wobble and the period and mass of the orbiting planet | Stars moving toward a viewer blue-shift their light, while stars moving away red-shift their light. The faster a star's motion, the greater its blue- or red-shift | Use blue- and red-shifting to determine the period of an orbiting planet and whether it is in a habitable zone   | Contrast red- and blue-shifting as a way to detect extrasolar planets                                 |
|      | Meeting the Challenge<br>Can You Find the Extrasolar Planet?          | 75       | none  |  |   |  |  |  |   |
|      | <b>TOTAL TIME</b><br>minutes<br>class periods                         | 325<br>7 |   |  |   |  |  |  |   |

## Chapter 15: Exploring Planets and Moons

| Date | Activity Name  | Time | Materials   | What Students Do  | Engage  | Explore   | Explain   | Evaluate  | Extend to Astrobiology  |
|------|--|------|---|---|---|---|---|---|---|
|      | Challenge<br>WebQuest: Exploring – A<br>History of Discovery | 25   | Internet  | Complete a WebQuest to design blueprints and create a museum exhibit that overviews some of the missions that have allowed us to explore space.                             |   |   |   |   |   |
|      | Activity 1<br>Searching For Life                             | 75   | cafeteria tray, assorted objects (film canisters, coins, marbles, gum, cards, etc.) | Simulate the ways we explore our solar system—telescopes, flybys, orbiters, landers, and crewed missions  | Brainstorm ideas about how we have gathered information about the planets and moons in the solar system                       | Simulate different exploration techniques by observing a tray of objects several times under different conditions                 | We explore the solar system using telescopes, flybys, orbiters, landers, and crewed missions, each of which returns a different kind of information | Contrast the benefits and limitations of each exploration technique   | How could each exploration technique contribute to the search for life in the solar system?                           |
|      | Activity 2<br>A Case Study in<br>Exploration: Mars           | 75   | string, meter sticks, paperclips, audio tape of War of the Worlds or Web site       | Make a timeline to contrast the interplay between science and science fiction by comparing the occurrences of scientific discoveries and science fiction stories about Mars | List what students know about Mars and how they think this information was collected  | Produce two timelines showing how our scientific understanding and our fictional ideas of Mars have changed over time             | Our understanding of Mars has changed with the acquisition of new data. Science fiction reflects this changing understanding                        | Describe how science fiction ideas about Mars relate to our scientific understandings of the planet             | Which techniques that have helped us understand Mars have also helped us understand other worlds in the solar system? |
|      | Activity 3<br>Orbiters: Looking at the<br>Martian Poles      | 150  | ice cubes, dry ice, coffee cans, rubber bands, paper towels                         | Interpret three kinds of data returned by orbiters to show how these spacecraft help us understand other worlds   | Compare the behavior of water ice and dry ice. Model how a laser altimeter works by creating and measuring mystery landscapes | Analyze visual, thermal, and elevation data for the Martian ice cap to experience how each type of data informs our understanding | Combining different types of data is important when trying to understand a distant world  | Describe the advantages of using multiple versus single types of data when trying to understand a planet        | For what kinds of observations are orbiters best suited?  |
|      | Activity 4<br>Landers: On the Martian<br>Surface             | 75   | hydrogen peroxide, beef liver, yeast, manganese oxide, test tubes, wooden matches   | Model the kinds of tests a lander can carry out by testing samples for life and comparing their experiment with those conducted by the Viking landers                       | Brainstorm what conducting more experiments on the surface might be able to teach us about the Martian ice caps               | Test three mystery powders to determine whether any contain life. Develop a plan to respond to false positives                    | Life gives off by-products that can be used to identify its presence. Multiple testing helps address the problem of false positives                 | Describe the kinds of data the Viking landers were able to obtain and how false positives affected the missions | What are some advantages and disadvantages of sending a lander to the surface of a planet?                            |

|  |   |           |   |  |   |  |  |   |  |
|--|---|-----------|---|--|---|--|--|---|--|
|  | Activity 5<br>The Future: What Next on Mars?                          | 200       | video: Journey to Mars, Internet access | Debate the potential risks and benefits of a Mars sample return and a crewed mission to Mars | List some of the risks and benefits of crewed missions and sample returns, including contamination issues | Research the material needs and the risks and benefits of a crewed mission and a sample return | Crewed missions return high quality data but present logistical problems. Sample returns can reveal a lot about distant worlds but raise issues of contamination | Build a case for or against crewed missions and sample returns and present the arguments in class | What types of questions can each kind of mission answer, and which kind returns the most information per dollar spent? |
|  | Meeting the Challenge<br>WebQuest: Exploring – A History of Discovery | 75        | Internet access                         |  |   |  |  |   |  |
|  | <b>TOTAL TIME</b><br>minutes<br>class periods                         | 675<br>14 |   |  |   |  |  |   |  |

## Chapter 16: The End is the Beginning

| Date | Activity Name   | Time            | Materials          | What Students Do   | Engage | Explore  | Explain | Evaluate  | Extend to Astrobiology                            |
|------|---|-----------------|--------------------|--|--------|--|---------|---|---|
|      | Challenge Exhibit What You've Learned                           | 25              | none               | Select a final project from four provided to exhibit understanding of Astrobiology   |        |  |         |   |   |
|      | Activity 1 Design an Astrobiology Mission                       | 200-400 or more | varies             | Design an astrobiology-related space exploration mission   |        | Generate ideas for a mission, conduct research, and develop a proposal that will convince funders to finance the mission                                 |         | Use rubric to evaluate how well each aspect is addressed. Have a "funder panel" review all the proposals              | Summarizes many aspects of the astrobiology story |
|      | Activity 2 Individual Research Project (using Habitable Worlds) | 200-400 or more | varies             | Conduct an experiment that synthesizes the course's inquiry strand and demonstrates mastery of the scientific research process                   |        | Improve on one of the curriculum activities, take an activity in a new direction, or pursue a question of personal interest                              |         | Produce either a written report or a scientific poster. The scoring rubric contains the project's evaluation criteria | Summarizes many aspects of the astrobiology story |
|      | Activity 3 Writing an Astrobiology Science Fiction Story        | 200-400 or more | varies             | Write a science fiction story with an astrobiology theme   |        | Brainstorm potential topics, review the Short Story Sketch and Template, read the Backgrounder and sample stories, and produce one or more drafts        |         | Submit the completed story. The scoring rubric contains the project's evaluation criteria                             | Summarizes many aspects of the astrobiology story |
|      | Activity 4 Creating Astrobiology Space Art                      | 200-400 or more | varies             | Produce a work of art and a one-page overview of their creation that reflects their understanding of a topic or series of topics in astrobiology |        | Discuss the focus questions and decide how to illustrate their answers in a work of art. Observe samples of space art. Create one or more rough sketches |         | Create an Astrobiology Space Art exhibit. The scoring rubric contains the project's evaluation criteria.              | Summarizes many aspects of the astrobiology story |
|      | Meeting the Challenge Exhibit What You've Learned               |                 | varies by activity |  |        |  |         |   |   |
|      | <b>TOTAL TIME</b><br>minutes<br>class periods                   | 225-425<br>4-8  |                    |  |        |  |         |   |   |