SCIENTISTS IN THE FIELD

Where Science Meets Adventure

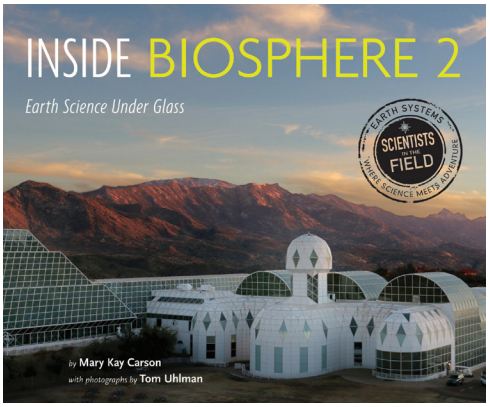
DISCUSSION AND ACTIVITY GUIDE

Inside Biosphere 2: Earth Science Under Glass

BY MARY KAY CARSON, PHOTOGRAPHS BY TOM UHLMAN

About the Series

Inside Biosphere 2: Earth Science Under Glass is part of the award-winning Scientists in the Field series, which began in 1999. This distinguished and innovative series examines the work of real-life scientists doing actual research. Young readers discover what it is like to be a working scientist, investigate an intriguing research project in action, and gain a wealth of knowledge about fascinating scientific topics. Outstanding writing and stellar photography are features of every book in the series. Reading levels vary, but the books will interest a wide range of readers.



Inside Biosphere 2: Earth Science Under Glass by Mary Kay Carson, Photographs by Tom Uhlman

About the Book

In 1991, eight people entered the amazing structure known as Biosphere 2, and spent two years living in the enclosed living environment. The experiment ran into problems, but today Biosphere 2 continues to be an important experimental facility. Because of its size, Biosphere 2 allows scientists to carefully control conditions for experiments about the changing ecosystems of our planet. *Inside Biosphere 2: Earth Science Under Glass* is a peek inside this amazing facility and the fascinating and important work currently being done there by scientists.

About the Author

Mary Kay Carson has always loved science and earned her college degree in biology. After serving in the Peace Corps, Mary Kay began her award-winning writing career by working on a classroom magazine, *SuperScience,* for Scholastic. She became a freelance writer and has written more than fifty books for young people. She lives in Cincinnati with her photographer husband, Tom Uhlman, and her dog, Ruby.

About the Photographer

Tom Uhlman has been a freelance photographer for more than twenty years. He enjoys taking all kinds of photographs, but his favorite is nature photography. He often works with his wife, Mary Kay Carson, on books for young readers.

EDUCATOR'S GUIDE

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Pre-Reading Activity

Form groups of four or five students. Each group is about to board a ship or space station or land on a deserted island for two years. Each group may bring anything (except transportation out of this place). Once your group arrives, you have ONLY those items you selected to bring. Nothing new may be added. Have each group member independently select items to bring. Once everyone has a list, discuss the lists within your group and create a master group list. Bring the whole class together. Discuss what should be done to prevent boredom. What would a daily or weekly or monthly routine look like? Create a whole class list and then begin reading *Inside Biosphere 2: Earth Science Under Glass*!

Lead a discussion about adding a pet to the class (this can be hypothetical) or setting up a terrarium or starting a garden. What materials and what preparation must be in place before beginning? Make sequential lists and save them for one of the activities below.

Think about projects you have done at home or school or in a club. What steps were involved in completing the project successfully or what steps would you have taken to improve the project (or both)?

Discussion Questions

Every day we use the restroom, throw things in the trash, and consume resources. Where does this waste go? How much waste does one person produce in a single year? How is our waste material handled by our community? What happens when we run out of fossil fuel? Is this likely to happen soon?

Habitat loss is a primary cause of many wild animals being threatened with extinction. Should we be planning more biospheres? Should we be doing more research on how to build artificial habitats?

Let's say that we decide to plant more maple trees in our neighborhood or add more sand to our beaches. Does it matter where these trees are grown? Does it matter where the trees or the sand comes from? When we add fish or other animals to our ponds, does it matter what kind? If we decide that we need more milkweed in our community, say, for our monarch butterflies, does it matter where the milkweed is grown?

How do you respond when things do NOT go according to plan? Talk about specific instances and discuss your reaction. Then brainstorm other possible reactions with the class.

Have you ever experienced cabin fever or claustrophobia?

Pick a plant, such as an apple tree. What does this tree require aside from sun, water, and soil to allow it to produce apples? What is the difference, aside from the fruit, between a tree like an apple tree and a tree found in a forest wilderness?

Review what we mean when we speak of ecosystems, habitats, and sustainability. Many times when we think of designing a habitat, we do not think of creatures like mosquitoes, poison ivy, flies, ants, and other so-called pests or invasive species. What place do these organisms have in a habitat? Would it be possible or desirable to remove an organism from the face of the earth? Is that also true for organisms we regard as pests like mosquitoes?

Think about your favorite foods, flowers, wild animals, rocks, or landforms or places to visit. What foods, plants, animals, etc., would you want to insure never become extinct? Is that possible? Excluding the possibility of some extraterrestrial or unique natural disaster, what steps should we take to preserve these things and the habitats that sustain them?

Think about something you enjoy doing. Now think about sacrifices you would be willing to make in order to keep doing this activity. How much are we willing to sacrifice in order to do a job we enjoy? When does the price of the sacrifice force us to move to other activities? Now change the terminology from "something you enjoy doing" to "something that must be done." Is there still a point in which the sacrifices are just too much?

How persistent are you when it comes to investigat-

ing challenging problems? What sorts of problems will you pursue for longer periods of time? What sorts of problems do you have little or no patience for solving?

If you were to spend two years with only eight people, what skills, knowledge, and character traits would you seek in your companions? Remember that not only will these be the only people with whom you can communicate (no Internet or phones), but these are the people who will cook, clean, fix things, solve problems, and more.

Applying and Extending Our Knowledge

On page 11 and 12 we read, *"The biosphere is our planet's living layer. It's where air, sunlight, water, and soil interact to support life in its millions of forms."* The text speaks of Earth being a closed system surrounded by cold, dark space. Keep in mind this quote from page 18, *"Was the two-year mission a failure? Not if it was an experiment and the goal was new knowledge."*

- Design a closed system. Use the list saved from the pre-reading activity if it helps. Work with your school's librarian to evaluate your plan.
- If your classroom has access to plastic terrariums, see if you can design a terrarium that keeps a plant (or plants) alive for the entire semester with no human intervention after the initial construction. Assign terrariums to groups of students (no more than four students to a group, if possible). Make sure to use plants that are easily obtained, free, and not threatened, because it is likely that the plants will die. Groups should have a written plan for why they believe their terrarium will support life BEFORE setting up the terrarium.
- At the end of the term, assess what is or is not working and redesign, adjust, or do nothing as the status of the terrarium dictates.
- Would it be possible to add a self-sustaining insect or bug population to the mix? Again, once the animals are added, humans may not intervene unless all admit that the design is a failure. Evaluate the progress regularly.
- Try creating a closed system with a water habitat, if you have access to aquariums. Once again, work in your library to plan your self-sustaining aquarium. Groups should have a written plan for why their aquarium will function without intervention BEFORE setting up the aquarium.

On page 19 and throughout the book, there are pictures of Biosphere 2. Examine the images of this place carefully.

- Compare the architecture of Biosphere 2 with the architecture in your neighborhood. What is the same? What is different? Most of the windows closer to the ground are rectangular and many of the windows above the rectangular windows are triangles joined to form rhombuses. Several of the roof areas are rounded and several structures have a dome feel to them. Remember that the buildings sit on a flat stainless steel "cookie sheet." The goal of building this project was to produce something that would last for at least one hundred years. What is the function of these shapes and this design? Why so many triangular shapes?
- Using blocks or Legos or cards or other items, have contests for building the sturdiest structure capable of supporting a variety of different weights.
- If we accept the fact that this structure is designed to last a long time, why do we not see more public housing or buildings constructed in a similar fashion? Is the reason primarily financial? Invite an architect and a structural engineer to discuss the pros and cons of the Biosphere 2 design relevant to public buildings and residential housing.
- Design a dome house in the Biosphere 2 style. Research some of the work Buckminster Fuller did with geodesic domes. Make these houses as attractive as possible. Then collect pictures of other architectural home styles that are the same size. Try to find houses that are pleasing to look at. Poll students or other people in your community about which of the houses would be their first choice. Do not suggest any preferences when polling. Present your findings to the class. Assuming that your dome house does not receive an overwhelming number of votes, how would you plan to make these houses more popular? Design a marketing campaign to improve the perception of dome houses.

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Common Core Connections

CCSS.ELA-Literacy.RST.6-8.3
Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.
CCSS.ELA-Literacy.W.7.7
Conduct short research projects to answer a question, drawing on several sources.
CCSS.ELA-Literacy.W.7.2.b
Develop the topic with relevant facts, definitions, concrete details, quotations, or other information and examples.
CCSS.ELA-Literacy.W.7.1.b
Support claim(s) with logical reasoning and relevant evidence, using accurate, credible sources and demonstrating an understanding of the topic or text.
CCSS.ELA-Literacy.W.7.2.d
Use precise language and domain-specific vocabulary to inform about or explain the topic or text.

In chapter two we learn about the work of Joost van Haren. On page 21, he is inspecting a leaf bag measuring the gas exchange during the photosynthesis process of the tree he is viewing.

- Prepare an online presentation explaining to younger students what photosynthesis is and how it works.
- We see in the caption on page 22 that the branch bags are made out of clear Mylar and that they are airtight. If the branch bag is sealed and is airtight, how does it allow the leaves to exchange gases? Prepare a diagram showing how the various pumps, fans, and tubing prevent the branch bags from killing all the leaves on that part of the tree.
- Find a hardy houseplant and seal one of its branches and all of its leaves in Mylar. Make sure it is as airtight as possible. Observe the plant over time and record what happens.
- Make a rain gauge and use it to measure the rain in your neighborhood. Share your rain gauge with younger students. Chart the amounts of rain you collect over time. Compare the rainfall you record with the amount of rain reported by different weather stations online. Why are there differences, if any?

Common Core Connections

CCSS.ELA-Literacy.W.7.1
Write arguments to support claims with clear reasons and relevant evidence.
CCSS.ELA-Literacy.W.7.1.b
Support claim(s) with logical reasoning and relevant evidence, using accurate, credible sources and demonstrating an understanding of the topic or text.
CCSS.ELA-Literacy.RST.6-8.3
Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.
CCSS.ELA-Literacy.RH.6-8.7
Integrate visual information (e.g., in charts, graphs, photographs, videos, or maps) with other information in print and digital texts.

Biosphere 2 was an attempt to create a self-sustaining environment in which resources were used effectively with little in the way of waste. One of the challenges was to deal with the increasing amount of carbon dioxide by carefully studying how leaves converted it to oxygen. In this country we produce a tremendous amount of garbage and other items that cause problems. Some waste is treated, cleaned, and returned for our use and consumption. Other waste products take a much longer period of time to decompose. If we have a closed system here on planet Earth, what happens to all of our rubbish?

- Keep a weekly trash log for a location in your neighborhood. Keep notes, drawings, and pictures documenting the type of trash, the amount, and other pertinent details (such as smell).
- Use your library to research how long it takes the various types of trash to decompose.
- Currently, there are differences between how the scientific community and the population as a whole perceive global warming. Is there a consensus in the scientific community concerning the cause of global warming? What do polls suggest that the average person believes the cause(s) to be?
- The previous activity suggests that scientists have not been effective in conveying their position on global warming. Is presenting the consensus of scientific research important? What should scientists do to be more effective in presenting the results of their research? Prepare an ad campaign to display in your school, either on bulletin boards or online, that shares the current position from the scientific community on global warming and what this may mean to the research being conducted inside Biosphere 2.

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Common Core Connections

CCSS.ELA-Literacy.W.7.7
Conduct short research projects to answer a question, drawing on several sources and generating additional related, focused questions for further research and investigation.
CCSS.ELA-Literacy.WHST.6-8.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.
CCSS.ELA-Literacy.W.7.1
Write arguments to support claims with clear reasons and relevant evidence.
CCSS.ELA-Literacy.W.7.1.b
Support claim(s) with logical reasoning and relevant evidence, using accurate, credible sources and demonstrating an understanding of the topic or text.
CCSS.ELA-Literacy.RH.6-8.7
Integrate visual information (e.g., in charts, graphs, photographs, videos, or maps) with other information in print and digital texts.
CCSS. ELA-Literacy.RI.6.7. Integrate information presented in different media or formats (e.g., visually, quantitatively) as well as in words to develop a coherent understanding of a topic or issue.

On page 29 we read about VOCs. The letters stand for volatile organic compounds. On the next page we read, *"VOCs are unstable chemicals that readily vaporize into the air and react with other gases."* The passage goes on to explain that these compounds are associated with things like paint, glue, and cleaners. Plants also produce these, and they produce them in greater quantities when the plants are stressed.

- Prepare a poster or an online presentation explaining in more detail what VOCs are and how they are formed.
- How are VOCs measured in the rainforest? How do they function as a predictor of draught levels?

Common Core Connections

CCSS.ELA-Literacy.RH.6-8.7
Integrate visual information (e.g., in charts, graphs, photographs, videos, or maps) with other information in print and digital texts.
CCSS.ELA-Literacy. RI.6.7. Integrate information presented in different media or formats (e.g., visually, quantitatively) as well as in words to develop a coherent understanding of a topic or issue.

Biosphere 2 had enormous plans to create a multitude of habitats, not the least of which was the plan to recreate a tropical coral reef. They imported sand, they had hundreds of milk trucks delivering salt water, they built a wave machine, and more. All of this was done in the hopes of learning how to sustain a reef habitat. Yet failure after failure visited this part of the project. From page 33, *"Trouble began back in the time of the original biospherians, who soon learned that an interconnected ocean ecosystem isn't an easy thing to recreate."*

- Put water in a pan and create as many different types of waves as possible. Remember that ocean waves come primarily from wind moving across water, but they may also be created by geological disturbances and tides. Can you simulate all these different types of waves?
- Find a tide chart for the Gulf of California. Make a model or produce a poster explaining what tides are and how they work. What would you need to do to your wave machine to mimic tides?
- One of the things that Rafe Sagarin learns is that it is impossible to disconnect the desert environment from the Gulf's ocean environment. Work in groups and brainstorm various theories that explain the connection between the ocean environment and the desert environment.
- Rafe looks at collections and data about the Gulf from earlier times. He looks at, among other things, the sizes of animals long ago and the sizes of those same species now. Look through old yearbooks or newspaper articles and find as many pictures as possible of the same spot on your campus for as many years as possible. Create a movie or a flipbook documenting the changes in your own school backyard. Encourage students to do this same thing with their own homes or other places for which they have a connection.
- One disturbing finding from research at Biosphere 2 is that the ocean is becoming more acidic. Have students explain the chemistry behind how this may happen.

Common Core Connections

CCSS.ELA-Literacy. RI.6.7. Integrate information presented in different media or formats (e.g., visually, quantitatively) as well as in words to develop a coherent understanding of a topic or issue.
CCSS.ELA-Literacy.RST.6-8.3
Follow precisely a multistep procedure when carrying out

experiments, taking measurements, or performing technical tasks.
CCSS.ELA-Literacy.RH.6-8.7
Integrate visual information (e.g., in charts, graphs, photographs, videos, or maps) with other information in print and digital texts.
CCSS.ELA-Literacy.W.7.7
Conduct short research projects to answer a question, drawing on several sources.
CCSS.ELA-Literacy.W.7.2.b
Develop the topic with relevant facts, definitions, concrete details, quotations, or other information and examples.

On page 46 we read, *"This knowledge is desperately needed right now. Soil erosion from farming, roads, and expanding cities is on the rise across the globe. Every year more fertile soil, the kind that crops can grow in, ends up in rivers and oceans. Yet scientists don't know how long it takes rock to become new, life-sustaining soil for farms, orchards, and healthy ecosystems."* What Luke Pangle is attempting to learn, among other things, is what happens to rain when it falls on a hill. Where does it all go? What happens to melting snow? The Landscape Evolution Observatory (LEO) was built to help measure, record, and provide solid data for testing theories about water and soil.

- Get several identical trays and fill them with dry soil. At one end, build up the soil so that it forms a hill. Make sure that all the hills in each tray are the same size. Pour the same amount of water on top of each hill at different rates of flow. Record what happens. How long does it take the soil to dry out? Repeat with different amounts of water.
- Repeat the experiment above but change the shapes of the hills or add rocks or objects. Plant some plants and try again when the plants have established roots and started to grow.

"There is no time to waste," says Nate (page 62). *"Climate change is here."*

- The typical response from many in the face of a quote like this is to assume that the change required applies more to other people than it does to us. Describe in a piece of writing what you could do personally to combat climate change. Include examples of changes you have already made, are beginning to make, or would like to make.
- How do people change long-standing traditions and habits? How would we begin to change the behavior of a state or nation? What steps would we need to take to, say, convince people to stop using air conditioning? How would you go about convincing people to use public transportation or to stop using gas engines?
- Present an online report showing what causes global warming in simple enough terms that younger students are able to understand. Make a list of as many contributing factors to global warming that your class or group can think of. Include on this list the challenges for eliminating or greatly reducing each item's contribution to global warming. What are the impediments for eliminating or reducing each item? Prepare a persuasive essay to deliver to Congress or the Senate that has the best chance of gaining political momentum that creates political and social change.
- Many readers in the United States are a long way from drought affecting the West and may feel no sense of urgency in changing behaviors. It may be easy to suggest changes for other states or other groups of people far away from us, but what changes in behavior do we need to make? What changes should our schools and communities adopt to reduce carbon dioxide, waste less, or use resources more efficiently? List your ideas and supply a brief annotation that explains each list entry.
- Smart cities are beginning to manipulate technology to use energy more efficiently. Research work being done to make your school, neighborhood, city, or state greener. Present a few of the more interesting findings.

Common Core Connections

CCSS.ELA-Literacy.RST.6-8.3
Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.
CCSS.ELA-Literacy.WHST.6-8.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.
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Write arguments to support claims with clear reasons and relevant evidence.
CCSS.ELA-Literacy.W.7.2.b

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Use precise language and domain-specific vocabulary to inform about or explain the topic or text.
CCSS.ELA-Literacy.RH.6-8.7
Integrate visual information (e.g., in charts, graphs, photographs, videos, or maps) with other information in print and digital texts.

Other Websites to Explore

Buckminster Fuller
en.wikipedia.org/wiki/Buckminster_Fuller
Biography of Buckminster Fuller and information on and links to important designs and inventions

Guide created by Ed Spicer, curriculum consultant, and Lynn Rutan, retired middle school librarian, now reviewer and blogger at *Bookends: The Booklist Youth Blog*.