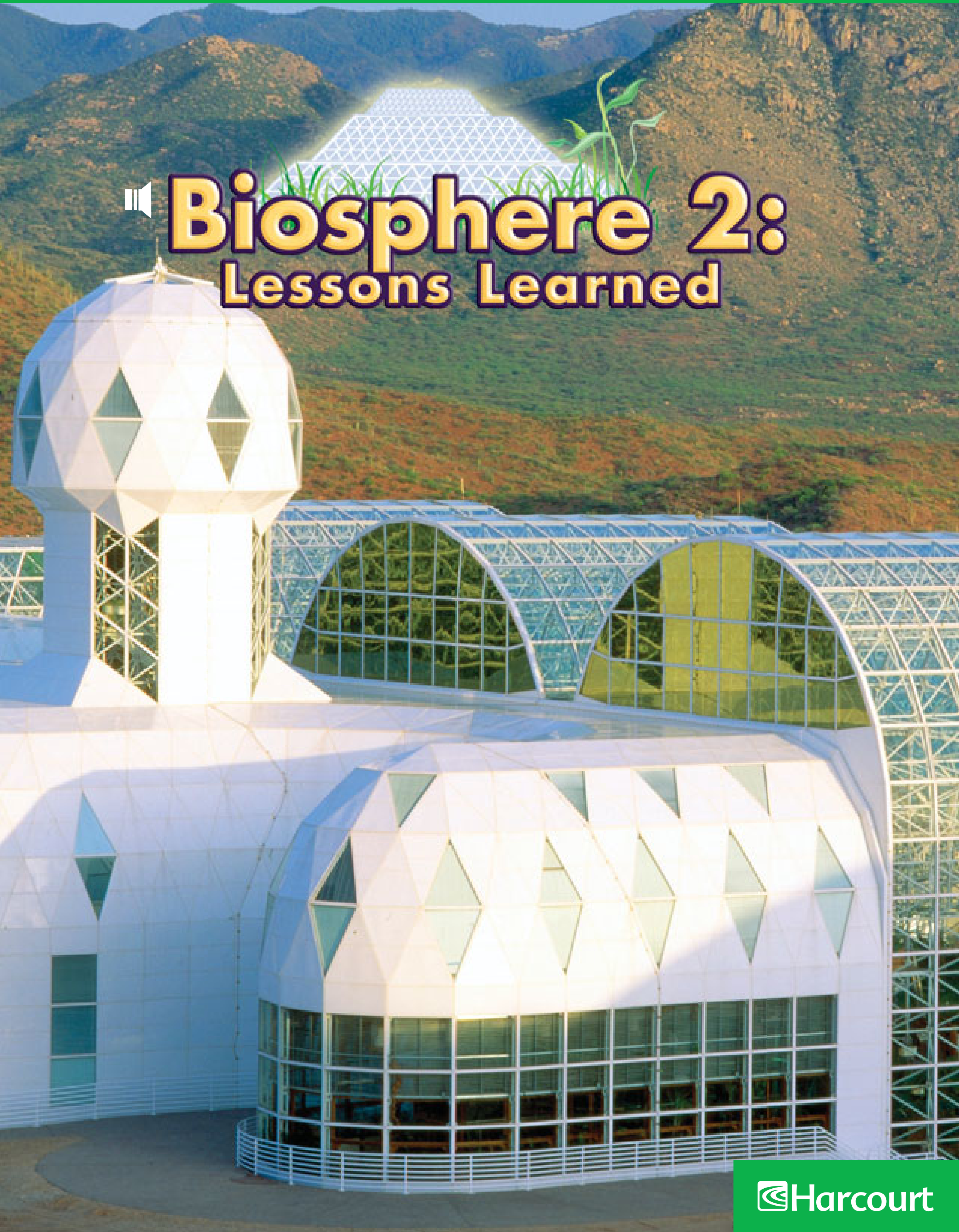
Biosphere 2: Lessons Learned



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Biosphere 2: Lessons Learned

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Printed in Mexico

ISBN 978-0-15-362471-1

ISBN 0-15-362471-X

2 3 4 5 6 7 8 9 10 126 16 15 14 13 12 11 10 09 08

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SCHOOL PUBLISHERS

"WOW! Look at that!" exclaimed Mike.

Mike, Jen, José, Ann, and Sue were members of the fifth-grade ecology club. They were on a field trip. During a game of "I Spy," which the group played while driving through the desert near Tucson, Arizona, Mike saw something amazing. It was Biosphere 2. The rest of the students turned to see the futuristic glass and steel structure that stood against the backdrop of the Santa Catalina Mountains. Their mouths fell open in astonishment.

"Quite impressive, don't you think?" asked Mr. Green, their advisor.

"It looks like a colony from outer space!" said Mike.

"Actually, it's for studying Earth's ecosystems, solving pollution problems, and learning how to produce more crops," said Jen, who had worked hard to prepare for this trip.

"But isn't it also to see whether humans could live on Mars or under the ocean?" asked Ann.

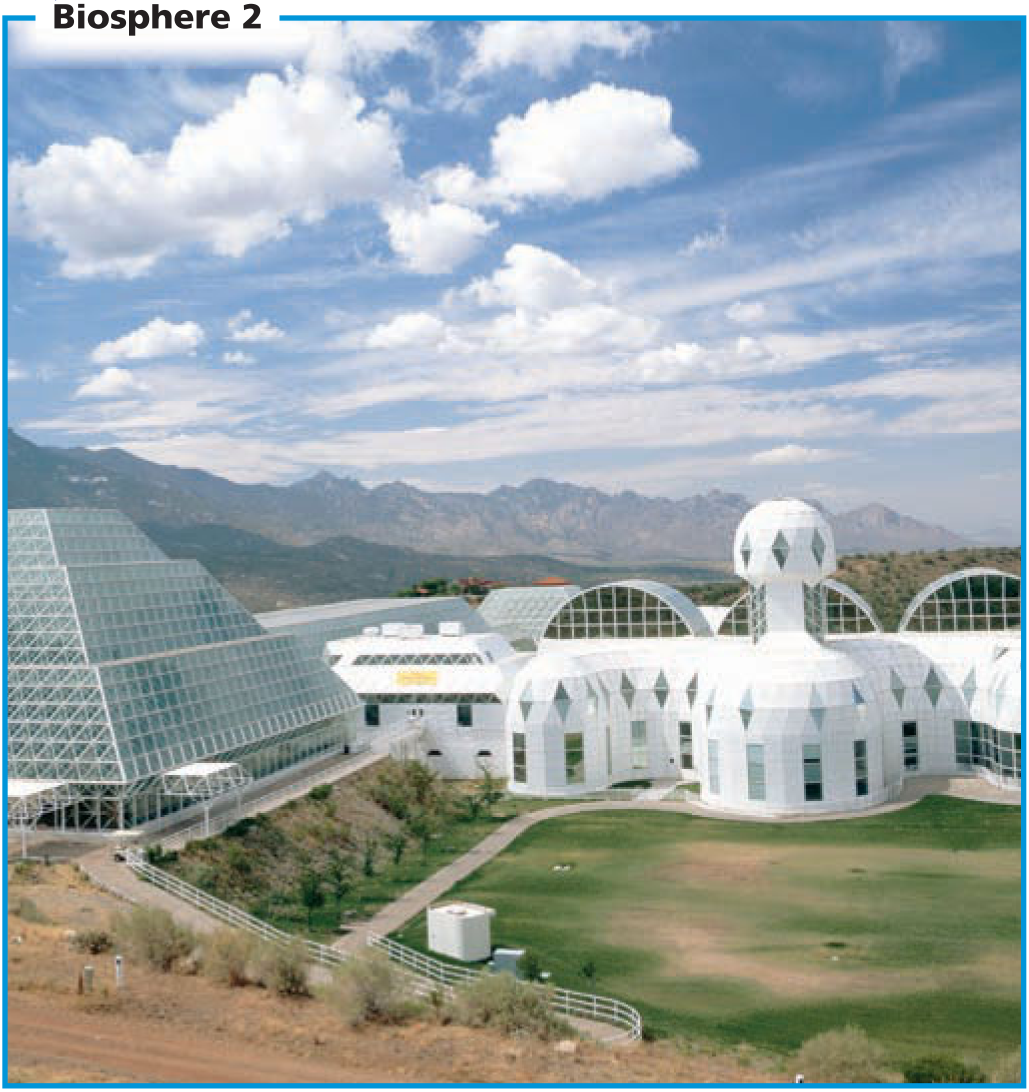
"Actually, you're both right," replied Mr. Green. "Biosphere 2 was originally designed to study self-contained systems, such as those that might be built on Mars. But it has a number of other uses, too, including education in global ecology. And that's why we're here!"

The students excitedly followed the signs to the visitors' center, where they were scheduled to meet their tour guide.

A young woman with a Biosphere 2 name tag walked up to the group and greeted them. "You must be the ecology club. Welcome to Biosphere 2! My name is Sally, and I'll be your tour guide today. If at any time you have any questions, please feel free to ask, and I'll do my best to answer them."

"I already have a question," said Jen. "Whose idea was this place, and what were they thinking?"

Biosphere 2

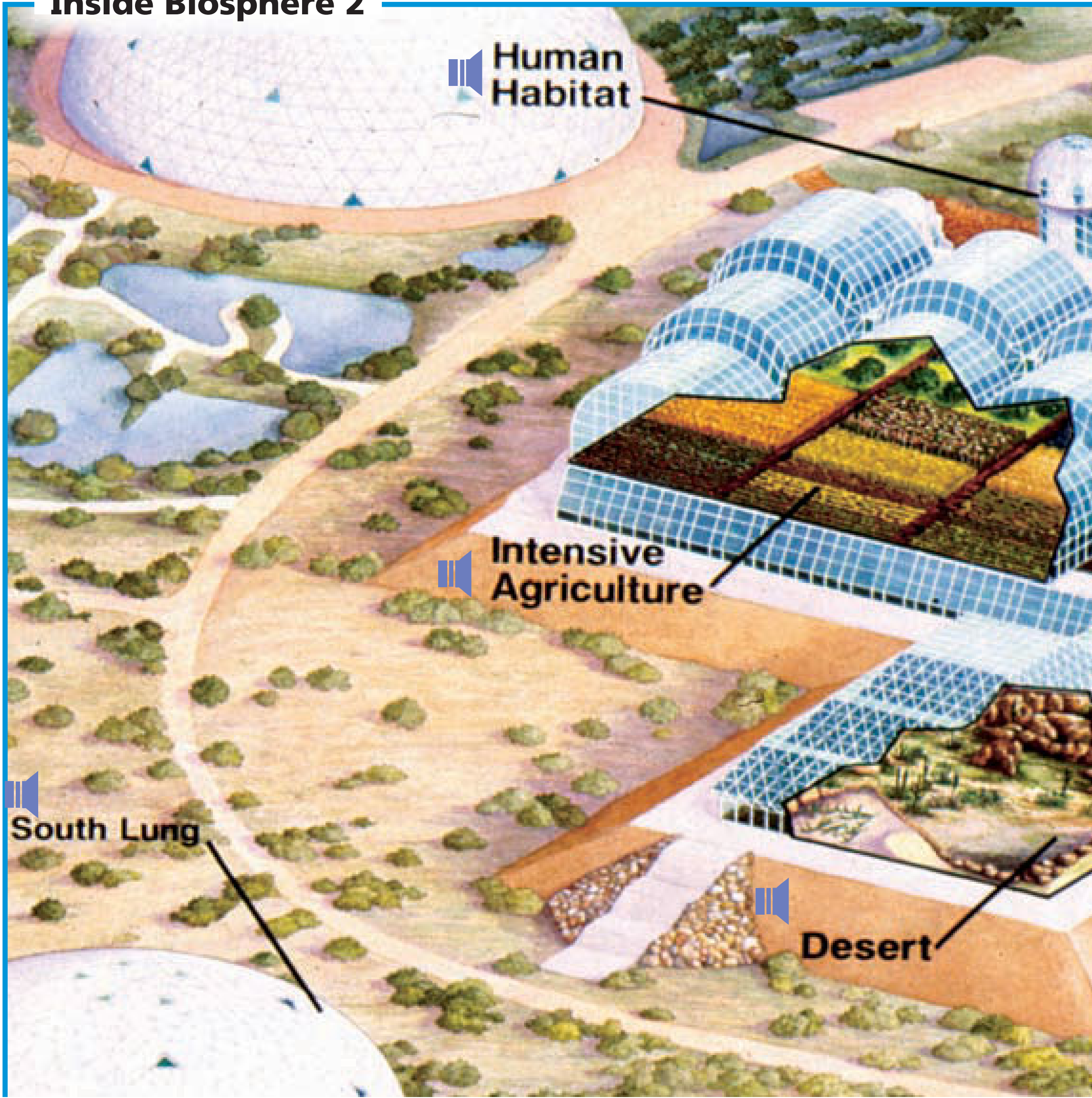


"Oh my," Sally laughed. "You're ready to get started! Well, the idea for Biosphere 2 began in the 1920's when a scientist named Vladimir Vernadsky theorized that Earth was a self-sustaining ecological system. Through the years, other scientists built on Vernadsky's work and theories. In the early 1980s, a team of people from the Institute of Ecotechnics decided to build a self-contained system to put the scientists' theories and knowlege to the test."

"What do you mean by a 'self-contained system'?" asked José.

"It's an enclosed system in which everything is recycled and sustained," Sally answered. "Nothing should be able to get either in or out, not even air. All the air, water, and nutrients must be recycled over and over again

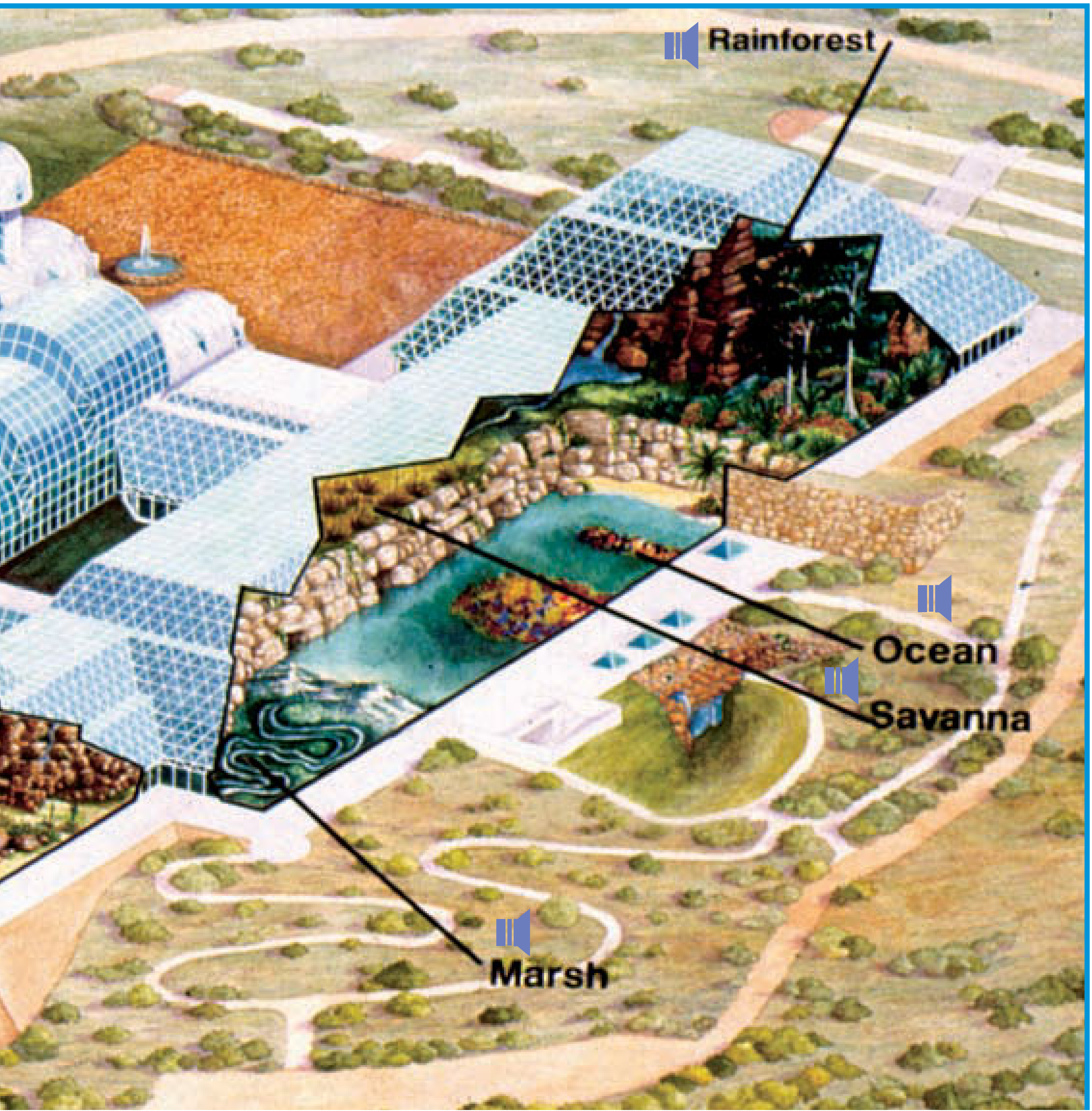
Inside Biosphere 2



inside the system. The environment must be carefully controlled to keep everything in balance."

"How is the environment inside Biosphere 2 controlled?" asked Ann.

Sally replied, "More than 1000 sensors are distributed throughout Biosphere 2 to monitor climate, air, soil, and water. This information is sent to an elaborate computer network that provides a continuous display of environmental variables and the status of the controls. All the variables, from waves, tides, waterfalls, and currents to rain, temperature, and humidity can be monitored. However, as you will learn, controlling the variables hasn't always been possible."



"I have three questions, " said José, looking at the notes he had prepared. "Who designed it, how long did it take to build, and how big is it?"

"A team of biologists, chemists, engineers, designers, and other experts were brought together to design Biosphere 2. It took four years to design and more than three years to build. It was completed in 1991. The glass-and-steel structure measures 7,200,000 cubic feet and includes a 900,000-gallon ocean."

"Wow!" exclaimed José, his eyes widening.

"If this is called Biosphere 2, is there a Biosphere 1?" asked Ann.

"That's a good question," said Sally. "Our very own Earth is Biosphere 1. It is the model after which Biosphere 2 was built. Inside Biosphere 2 are seven different mini-ecosystems that mirror those of Biosphere 1. Step over to this map for a moment." The group walked over to a large map of Biosphere 2 that was mounted on a panel.

Sally pointed out the locations of the different mini-ecosystems and explained, "As you can see on the map, there is the ocean that I just mentioned, and here are a desert, a savanna, a rain forest, a marsh, a farm, and a human habitat. Originally these mini-ecosystems were stocked with 3800 species. The designers hoped that these provisions would give the enclosed ecosystems enough material to be self-sustaining."

"Where are we standing right now?" asked Sue.

"We're standing in the human habitat," said Sally, pointing to the map. "It includes laboratories, a computer center, communications and office space, workshops, a library, and apartments for resident researchers. This habitat is where the biospherians, along with their goats and chickens, lived for two years."

"This looks like fun," Sue whispered to Ann. "I'd like to be a biospherian."

"Who are the biospherians?" Sue asked Sally.

"Four men and four women lived in Biosphere 2, beginning September 26, 1991. On that day, they sealed the airlock and began a two-year experiment," Sally explained. "The biospherians had to grow all their own food and maintain their water supply by recycling all the water they used. They also had to maintain a careful balance among all the living things inside the biosphere. The plants inside had to supply the necessary oxygen. The humans and other animals had to produce enough carbon dioxide for the plants to use."

"What did the biospherians eat? Could they ever have a pizza?" asked Mike.

"Actually, they could have pizza, but it would take four months to make it!" explained Sally. "They had to grow the wheat, then thresh it, then grind it—just to make the crust. They also had to milk a goat to make cheese, raise the tomatoes to make sauce, and so on."

"Were they able to grow enough food to survive for two years?" asked Mike.

"The biospherians had to put a good part of their working day into growing their food crops," Sally explained. "Even so, production was marginal due to unusually low light levels over the two El Niño years. The crew lost weight. Nevertheless, they were able to produce 81% of their food. They made up the difference by eating seeds that were stored for future planting. Later the seeds that the biospherians ate were replaced with seeds harvested from crops grown inside."

The Biospherians

"Did they have enough water to drink?" José asked.

Sally nodded, "Yes, they had some of the purest water on Earth to drink. Between 5000–10,000 gallons of fresh water were condensed directly out of the atmosphere every day. That was plenty for the biospherians to drink and to keep the plants watered."

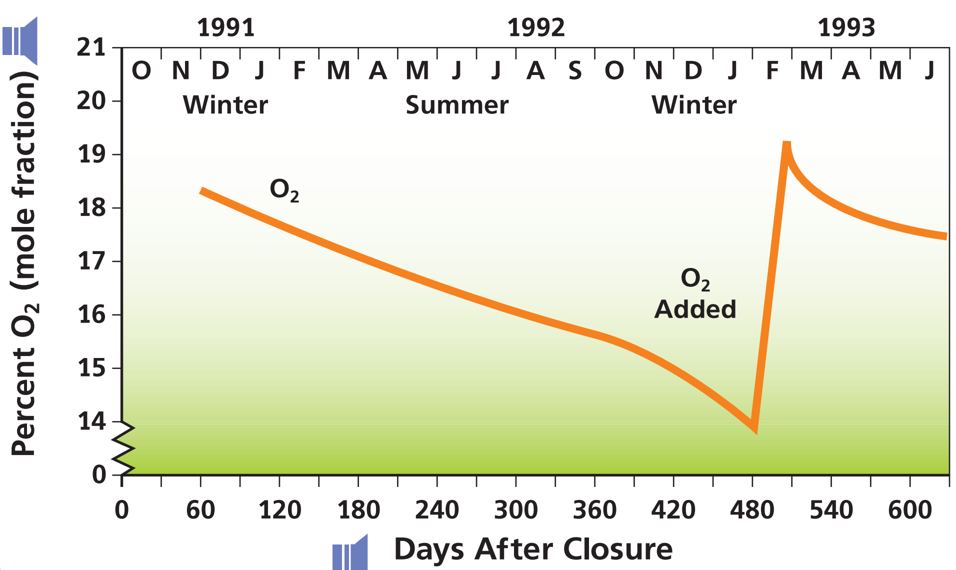
"How about oxygen—did they have enough to breathe?" asked Ann.

"Take a look at this graph of oxygen levels," said Sally, pointing to a display panel. "As you can see, oxygen levels fell steadily to a point at which the biospherians began to feel some effects. Some of them had trouble sleeping and felt tired. When oxygen levels reached 14.2%, the outside managers decided to pump in pure oxygen, increasing the oxygen level so that the biospherians could complete their two-year stay. Nevertheless, the experiment proved humans could do well at lower oxygen levels."

"Didn't the plants make enough oxygen for the people to breathe?" Mr. Green asked.

"Yes, the plants (and bacteria) did make enough oxygen. It was a mystery to everyone involved in the two-year project where all that oxygen went. The mystery wasn't solved until some time later. Let's walk over to the other mini-ecosystems, and I'll show you what happened."

Oxygen Levels Inside Biosphere



The students followed Sally to the main enclosure and entered the rain forest zone. They walked along wooden walkways through the thick foliage.

"This is one big greenhouse!" exclaimed Ann.

Sally smiled. "Yes, it is sort of like a gigantic greenhouse. This is the tallest part of Biosphere 2. It's about 91 feet high. As you can see, there is a stream that cascades down the mountain into the rain forest's center, through a flood plain on the forest floor, and into the savanna ecosystem. From there the stream travels down to the marsh ecosystem, and then to the ocean ecosystem.

The Rain Forest

"There is one big difference between Biosphere 2 and a greenhouse," Sally continued. "A greenhouse is not airtight. This structure is tightly sealed, so no air can get in or out unless someone intentionally opens an airlock. That means the plants and animals living inside must be in perfect balance. Do you all understand what that means?"

Ann's hand shot up. "If the plants don't get enough carbon dioxide from the animals, the plants will die. And if the animals don't get enough oxygen from the plants, the animals will die."

"That's right," said Sally. "The designers of Biosphere 2 calculated that introducing a variety of plants and animals, in a variety of mini-ecosystems would cause a natural balance between the plants and animals to evolve on its own inside Biosphere 2. But as I told you before, there was a slow decline in the oxygen level. A clue to the mystery of why that happened is under your feet. Take a look at the soil."

"It looks like good, rich soil with lots of organic matter in it," said Jen.

"Good, Jen. Now, does anyone know what happens to organic matter in soil?" asked Sally.

"Think about the compost pile that we built at school," Mr. Green suggested.

"Bacteria and other microbes in the soil grow and use the organic matter for food," answered Mike.

"Exactly," replied Sally, "and besides organic matter, what else do bacteria need to grow and reproduce?"

"They need oxygen and water," answered Sue.

"Right again," said Sally. "Like all living things, bacteria need to burn food for energy. They need oxygen to burn food, and they produce carbon dioxide as a waste product."

"Oh, I get it!" exclaimed Jen. "The bacteria in this rich soil used up lots of oxygen and gave off lots of carbon dioxide inside Biosphere 2."

"But shouldn't the plants have used up the extra carbon dioxide to produce more oxygen through photosynthesis?" asked José.

"Mr. Green, you have taught your group well!" exclaimed Sally. "That was what the scientists thought, too. So why didn't the plants use up the excess carbon dioxide? A clue to that mystery is in the concrete walls over there," she said, pointing. "Some scientists had the idea that perhaps the carbon dioxide was getting locked up in those walls. You see, concrete contains a chemical called calcium hydroxide. Carbon dioxide can react with calcium hydroxide to form calcium carbonate and water. The scientists tested the walls and found out that the walls did, indeed, contain about ten times more calcium carbonate on their inner surfaces than on their outer surfaces."

"So the carbon dioxide got locked up in calcium carbonate, instead of being available for plants to use during photosynthesis, " offered Mr. Green.

"That's exactly it," said Sally. "Remember that carbon dioxide is made up of carbon and oxygen. So the walls locked up much of the original oxygen inside Biosphere 2. There was an imbalance between how fast the soil microbes consumed oxygen and how fast the plants produced oxygen, so the oxygen slowly became less and less. The humans needed the oxygen to be made up."

"This was an exciting discovery. The designers knew in advance that the carbon dioxide levels would vary much more than in nature. But the role of bare concrete in the balance of the atmosphere was one of the most important lessons learned from Biosphere 2 and shows us how to do it better the next time."

"What about temperature and light levels?" José asked. "Could they be regulated?"

"The temperatures inside Biosphere 2 were well controlled," replied Sally. "The natural light levels were less than expected due to the extra shading by the space frame structure and by unusual El Niño weather patterns during the two-year period."

"What about the plants and animals in the mini-ecosystems? Did they stay in balance?" asked Jen.

"It was quite astounding," said Sally. "All of the ecosystems maintained an incredible amount of diversity, an ecological engineering accomplishment, and Biosphere 2 became the world's largest 'Laboratory for Global Ecology.' There the functioning of ecosystems could be studied and experimented with. Taking small pieces of large ecosystems and putting them all together in an artificial enclosure changed the way the ecosystems functioned. Cycles occur more frequently in smaller environments. Biosphere 2 recycled itself 2000 times faster than Biosphere 1."

"How many of the 3800 species actually survived?" asked Mike.

"Not everything made it through the first two-year experiment. The designers allowed for a 30% extinction rate. Of the 40 small vertebrates with which the project began, only 6 did not become extinct. The hummingbirds died and the bees didn't make it."

"Bees pollinate flowers," said Jen. "So if no bees were around, that meant that no flowers were pollinated, right?"

"Not exactly," said Sally. "The plants that relied on bees for pollination had to be hand-pollinated; however, they found that cockroaches and other insects became effective pollinators."

"Amazingly, though, the coral reef ecosystem did quite well. At the end of two years, there were 87 baby coral colonies identified. It's right next door. Let's go see it now."

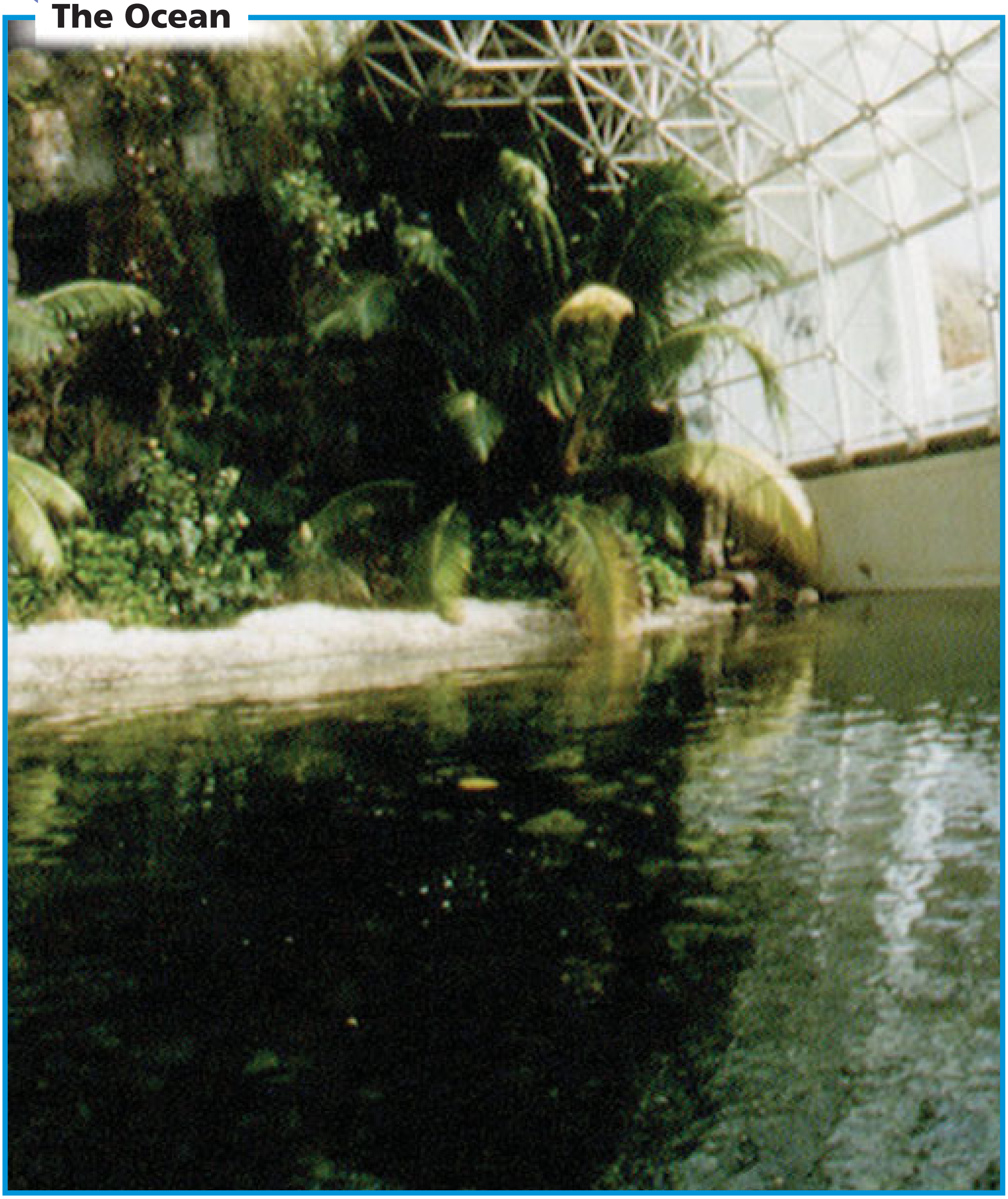
They arrived at the mini-ocean just as Heidi, the manager of that section of Biosphere 2, walked in wearing a wet suit. Sally introduced her to everyone.

"Welcome to our mini-ocean," Heidi said. "It's 25 feet deep and includes a functioning coral reef. Wave action, which is required for the coral reef ecology, is generated mechanically.

"Most of the reef animals in Biosphere 2 are from the Caribbean, with some special species, such as the Giant Clams, brought from the Pacific Ocean. Part of the ocean water came from the Pacific.

"Inside Biosphere 2 we can change environmental factors, such as temperature and carbon dioxide levels, and then measure and record the coral's growth response. We wouldn't be able to do that experiment on a real coral reef. The advantage of doing research here in Biosphere 2 is the fact that we can change these environmental factors, closely monitor the changes, and then measure the effects of these changes on coral reef animals."

The Ocean



The students thanked Heidi and then walked with Sally through the savanna which has grassland plants and animals from Africa, South America, and Australia. Sally held up a picture of a passion vine. “Passion vines lived in the upper savanna. After the two-year experiment, the passion vines grew so vigorously that they were taken out of the system to allow more incoming light.”

As they walked through the desert ecosystem, Mike said, “This doesn’t look anything like a desert.”

“The desert ecosystem,” Sally explained, “was originally designed as a coastal fog desert, but abundant winter moisture and mild summer drought in the mini-ecosystem favored plants found in a high desert chaparral ecology, like in California, so it was allowed to change — another example of ecological engineering.”

“Throughout Biosphere 2, carefully engineered machines make waves for the coral reef, circulate the air as wind, distribute the water as rain, and help monitor air and water quality. It is an engineering marvel designed to help us learn more about how our Earth works and how to build life-support systems for human exploration of space.”

The Desert

"In 1994," Sally began, "Columbia University came on board, bringing together a group of scientists to discuss how Biosphere 2 could continue to be used to further ecological research. Researchers decided to utilize the unique facility to mimic an atmospheric nightmare."

"Are you talking about global warming?" asked Sue.

"Yes, that's exactly it. The scientists intended to retool Biosphere 2 and use it to research global warming," answered Sally. "They realized they could use the facility to see how different plants and animals could survive at different levels of carbon dioxide and at different temperatures. Therefore, they cleared out old growths and animals. They subdivided the agricultural area into three experimental plots, each with different temperatures and levels of carbon dioxide. The rain forest, savanna, and desert were also subdivided into three zones. In all, the scientists built six atmospherically distinct areas. Plantings in the six areas were to be as uniform as possible, but the areas were not necessarily parallel to natural systems."

“What is Biosphere 2 doing today?” asked Ann.

“Biosphere 2 is still being used for research and education and continues to have much to teach us. Those lessons help scientists who are making self-sustaining ecosystems that could someday be used to colonize other planets.”

“Actually, I think we *all* have a lot to learn from Biosphere 2,” said Mr. Green. “What do you think we can learn, fellow Earthspherians?” he asked.

“I think Biosphere 2 teaches us a lot about Biosphere 1—our own Earth,” said Ann. “I think we take all the natural balances in our ecosystems too much for granted. Biosphere 2 shows that it’s not so easy to build balanced ecosystems like those that already exist on Earth.”

“I think that the most important lesson to be learned from Biosphere 2 is that humans are able to survive apart from the well-balanced ecosystems that already exist on Earth,” said Sue.

“And I think Biosphere 2 shows us that we need to take care of Biosphere 1, because we need to understand Earth’s biosphere to best protect her,” said Mike.

“You’re absolutely right!” replied Sally. “We simply cannot do the job that our planet does.”

When the members of the ecology club stepped out of Biosphere 2, they all took a deep breath of Earth’s biosphere air. They looked at the distant mountains, the desert, and the clear blue sky, and they thought about all the ways that Earth keeps everything in balance.

Think and Write

1. How does a biosphere stay in balance?
2. Why did oxygen levels inside Biosphere 2 steadily decrease? What effect did the decreased oxygen have on the Biospherians?
3. What is the most interesting thing that you learned about Biosphere 2? Explain your answer.
4. **Persuasive Writing** The two-year experiment in Biosphere 2 has much to teach us about Earth. Write a paragraph that persuades people to take better care of Earth's natural biosphere. Use the lessons learned from Biosphere 2 to make your case.

Hands-On Activity

Build a Biosphere You'll need a glass jar with a tight-fitting lid, some stones, pond water at room temperature, pond snails (from a pond or pet shop), aquatic plants such as duckweed or elodea (from a pond or pet shop), and duct tape. Place the rocks in the bottom of the jar. Fill the jar with pond water. Add some aquatic plants. You may want to anchor them on the bottom. Add one or two pond snails. Add more water to bring the level to within 2.5 centimeters of the top. Put the lid on the jar and seal it tightly with duct tape. Keep the ecosystem in bright, but not direct, light. Explain the cycling of carbon dioxide and oxygen in your closed ecosystem.

School-Home Connection

What's New? With a family member, visit www.biospherics.org where there is a photogallery tour of Biosphere 2. Find out about the ongoing work in biospherics by the team who designed and built Biosphere 2, by going to www.biospherefoundation.org. Look for plans for building biospheres in space by going to www.nasa.gov and visiting the National Aeronautics and Space Administration (NASA) web site.

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