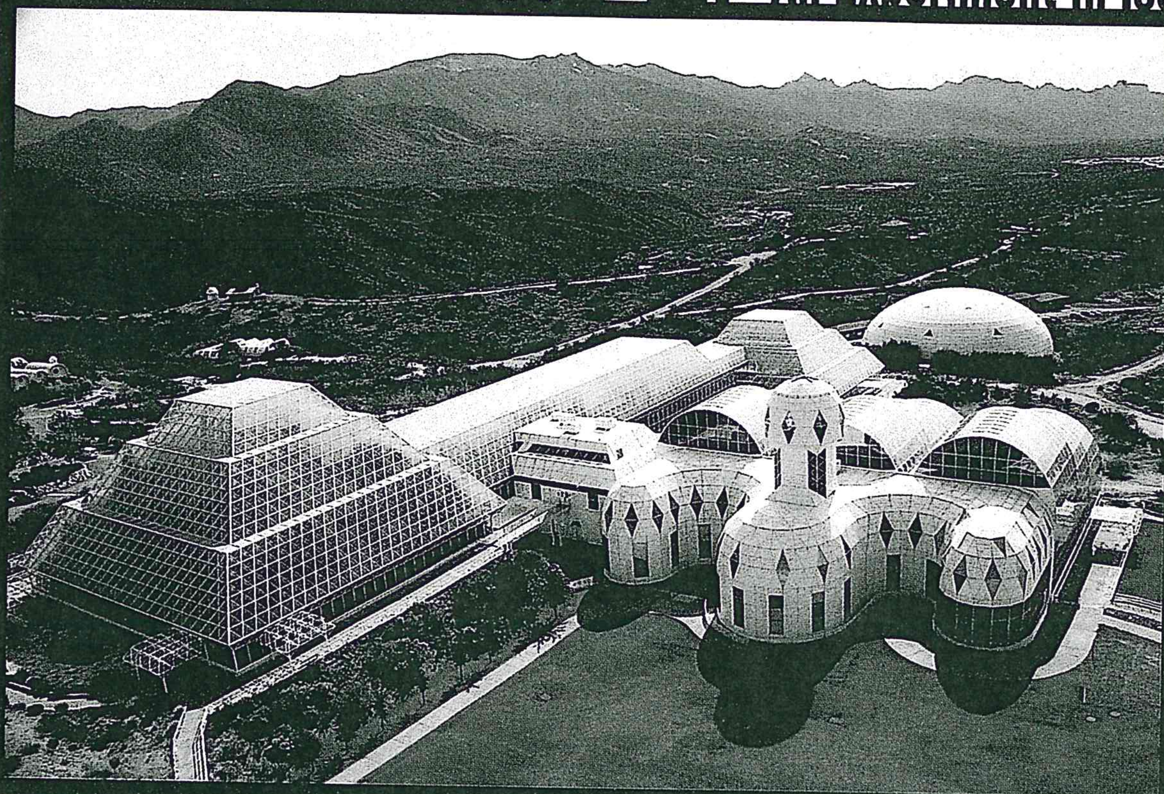
BIOSPHERE 2: An Experiment in Isolation



Can human beings live in an airtight building for 2 years with no life support except for the organisms they bring inside with them? Can they set up an ecosystem that provides for their every need and the needs of the other populations around them?

These were the big questions that Biosphere 2 was built to answer. In 1984 construction began on the world's largest isolated environment. The location was the Sonoran Desert, a short distance north of Tucson in Arizona. This part of the country experiences a high percentage of days without cloud cover. Sunshine is essential for an experimental ecosystem because it is the only energy source to sustain the humans and hundreds of other species in the closed system.

One critically important factor was sealing the 3.1-acre live-in terrarium from the outside environment. That means no gases or organisms entering or leaving the system. First a 500-ton stainless-steel liner was laid down to isolate Biosphere 2 from the earth. Then a massive glass, steel, and concrete greenhouse was constructed on the steel base to isolate Biosphere 2 from the atmosphere. The $150 million chamber was ready for business in 1991.

Four men and four women were identified as the first team. But before they closed the door, they had to populate Biosphere 2 with other organisms in order to turn the newly finished building into an ecosystem. The ecologists working on the project spent a long time selecting organisms. They knew that they needed plants, animals, and microorganisms. They needed to have food for eight people and life support for the organisms that would provide the food. They needed organisms to refresh the air and dispose of waste materials. The planning was complex and detailed—lives depended on getting it right.

The First Mission

In September 1991 the door was closed and sealed with the eight Biospherians and 1800 other populations on the inside. The challenge faced by the humans was the same one astronauts will probably face during our first visits to other planets. The trip to the Moon takes a few days. A trip to Mars might take a year. The most efficient way to make such a journey would be in a miniecosystem, where everything needed for life recycles.

Biosphere 2 had surprises for the scientists inside. Before long they noted that the oxygen concentration began to drop. The oxygen started at 21%, the concentration of oxygen in Earth's atmosphere, but got down to 14%. This was a dangerous level for the people. Where was the oxygen going?

Analysis revealed that the soil in Biosphere 2 was too rich in organic matter. The populations of microbes were growing out of control, using too much of the oxygen. The scientists reasoned that if the oxygen concentration was going down, the carbon dioxide (CO_2) concentration should be going up. But the concentration of CO_2 was not going up as fast as the scientists calculated. It was later discovered that the CO_2 was being taken up by the massive amount of concrete that was still curing.

On the biotic side, a problem came up with ants. An uninvited species, known as crazy ants, got into Biosphere 2 somehow and caused disruptions in the community. Not only did the ants put pressure on other organisms in the ecosystem, they clogged vents and chewed on wiring, creating quite a nuisance.

How could tiny organisms like ants cause a major problem in the Biosphere 2? Crazy ants form "super colonies." Super colonies have many queens and many nests. All of the ants work together to search for food, share food, and distribute resources. Most other species of ants form colonies with a single queen in a single nest and are highly territorial toward other colonies of the same species of ant. Crazy ant colonies, on the other hand, cooperate with one another. This gave them an advantage over other species of ants in Biosphere 2. While crazy ants are not aggressive to others of their species, they are very aggressive in searching out and attacking prey. They can effectively communicate the exact location of the prey to other ants in the super colony. Then they can launch an attack that will overwhelm even a large insect such as a cockroach.

Crazy ants, like other ants and many other animals, communicate with each other by using pheromones. Pheromones are scent chemicals that send signals to other animals of the same kind. For example, ants leave pheromones on the ground to mark a trail for other ants in the colony to follow. While most other ants are thought to have only one trail pheromone, crazy ants have at least three different ones. Some of these pheromones evaporate faster than others, so they stay on the trail for only 2–3 minutes, while other pheromones may last for 24 hours. Crazy ants, with more than one pheromone, can provide more information to other ants so the colonies can adjust quickly to changing conditions. The superior communications and the super colony cooperation seem to be the characteristics that gave the crazy ants the advantage over the other insect species in Biosphere 2 and allowed the crazy ants to displace most of the other arthropods.

The Biospherians made it through the 2-year mission, but just barely, and not without a little assistance. The oxygen problem could be solved only by pumping in extra from outside. A second mission in 1994 lasted 6 months. Following the second mission, a decision was made. Biosphere 2 would no longer be a live-in facility, but would be transformed into a unique ecological research center. In 1996 Columbia University took over management of Biosphere 2 and continues to oversee the important international research going on there.

The Current Research

It is fairly easy to do an experiment with the plants and animals in your terrarium or aquarium. You could add some CO_2 to one terrarium but not the other, to see if it made plants grow faster or slower. You could increase the temperature of an aquarium and monitor the health of the fish. But would your experimental results tell you what would happen in the rain forest or the ocean?

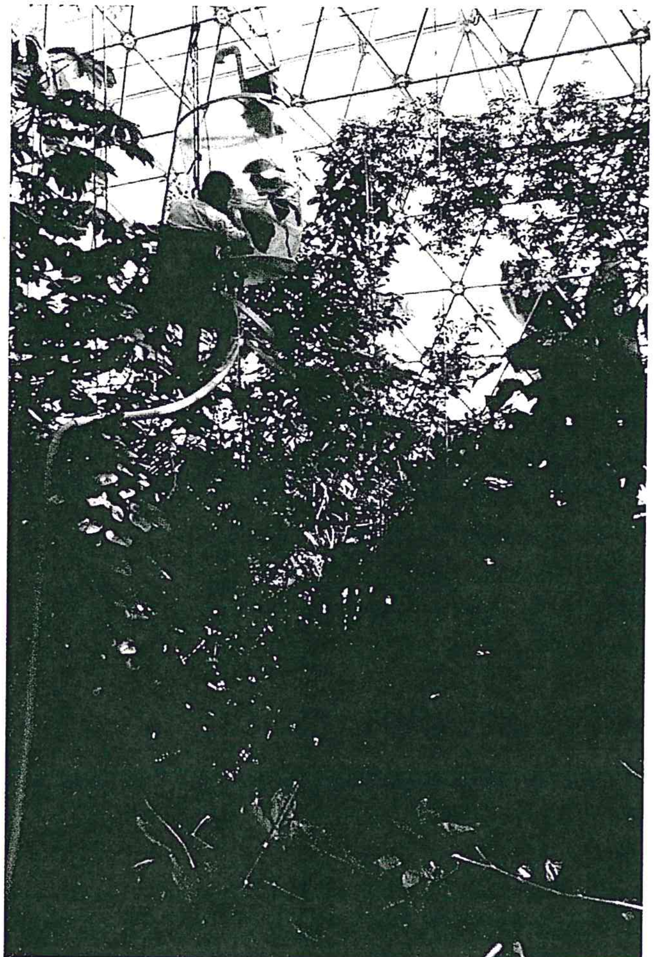
How do you study an entire ecosystem? A real ecosystem is much larger and more complex than the ones you can build in class. To try to answer some of these questions, you could add CO_2 gas to a field or forest to see how plant growth might change, but the wind would soon blow the CO_2 away. You could study the weather over a coral reef for a period of 40 or 50 years to see if there are any patterns, but it would be impossible to control variables. You might notice a difference in plant growth and health when you compare a wet, cold, rainy year to a hot, dry, sunny year. Is the difference because of the rain, the moisture in the air, the temperature, or the amount of sunlight? It is impossible to say with so many variables changing at once.

What you really need is a box like your terrarium or aquarium that is big enough to hold a whole ecosystem. Then you could do experiments and control all the variables except the one you are studying. Where can you find such a box? Biosphere 2.

Biosphere 2 covers almost as much area as four football fields. Inside are seven different environments: rain forest, desert, tropical ocean, marsh, savanna, thorn scrub, and agroforest.

One area of intensive study is the tropical rain forest ecosystem. Tropical rain forests can soak up CO_2, a greenhouse gas that contributes to global warming. Tropical rain forests are sometimes called the lungs of the planet because they take in so much CO_2 and produce so much oxygen during photosynthesis. Dense vegetation and long days of direct sunlight year-round enable rain forest plants to carry out photosynthesis at a higher rate than anywhere else on Earth. Some scientists think rain forests have great potential for controlling the rising CO_2 level.

Another possibility is that more CO_2 in the atmosphere will result in rising global temperatures all over Earth. Warmer temperatures could result in less rain, because less water vapor will cool enough to condense into raindrops. Water and CO_2 are both needed for photosynthesis to take place. If there is less rain, photosynthesis slows down, which means less CO_2 will be removed from the atmosphere. Increased CO_2 heats the atmosphere even more, reducing rainfall even further. Over time this can cause the average global temperature to rise, which can have a significant effect on many ecosystems.



John Adams, senior research specialist, ascends a canopy access system inside the Biosphere 2 Tropical Rain Forest to check leaves sealed in a branch bag.

Inside the rain forest environment in Biosphere 2 scientists are doing experiments to determine how drier conditions affect the amount of CO_2 taken up by rain forest plants. They can control the amount of "rainfall" with the overhead sprinkler system. CO_2 can be pumped in. The temperature can be regulated with huge heating and cooling units. Scientists can change any of these variables one at a time to see what effect each has on the amount of CO_2 taken up by the plants.

What will happen if the CO_2 level and the global temperature continue to rise? Will the rain forests take up more CO_2? Will the rain forests take up less CO_2? How will warmer temperatures or more CO_2 affect the health of the plants? Scientists at Biosphere 2 hope to answer these and many other questions about how the rain forest ecosystem responds to change.

Coral reefs have been called the rain forests of the sea because there is so much diversity of life in coral reef ecosystems. Coral defines the ecosystem. Algae, fish, crabs, and many other kinds of sea organisms live on, in, and around the coral structures.

Microscopic **phytoplankton** (single-celled algae and photosynthetic bacteria) are essential to the health of ocean ecosystems. Phytoplankton, which conduct photosynthesis, are food for coral and other small animals, which in turn are food for larger sea animals. Phytoplankton are the base of marine food chains just like green plants are the base of terrestrial food chains.

Marine biologists report that there are fewer and fewer fish and other organisms living in the coral reef ecosystems around the world and that the growth rate of coral has slowed. During the winter of 1997–1998, one-tenth of the world's coral reefs died. The temperature of the water in the affected areas that winter was 2–3°C above normal, making it one of the warmest periods on record. But was it temperature alone that killed the coral, or was it more complicated than that?

Several scientists are studying the coral reefs in the ocean biome at Biosphere 2. The Biosphere 2 "ocean" holds 2,500,000 liters of water. The depth ranges from 0 meters (m) at the beach to 7 m in the deepest part. Scientists have investigated several factors they think might affect the health and survival of the coral.

When they varied the concentration of CO_2 dissolved in the water, the health of the corals declined. They found that excess CO_2 dissolved in the water prevented coral from getting calcium out of the water to build their skeleton.

The studies of the coral reefs in Biosphere 2 provide evidence that the changes taking place in the ocean environment such as more dissolved CO_2 affect the coral reef ecosystem in negative ways.

As scientists learn more about ecosystems, two things become very clear. The first is that any change in one part of an ecosystem affects every other part of the ecosystem, many times in ways that no one could have anticipated. The second is that the more we learn, the more we realize how complex natural ecosystems are and how little we understand about the way they work or what effect human activity has on them.

Why should we care? What difference does it make if rain forests or coral reef organisms are disappearing? That's not where we live.

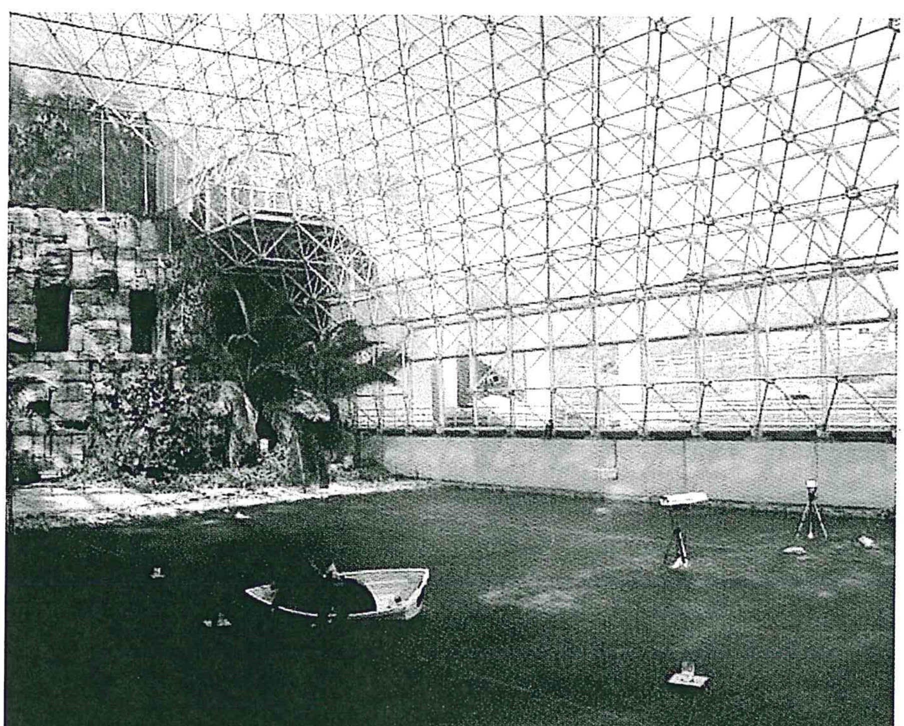
Well, it *is* where we live. Our planet is small. The atmosphere surrounds the planet and the seas wash up on all the continents. Changes in one ecosystem are communicated to the rest of the world by flowing air and water. Everything is connected. Small changes in global temperature can have a huge effect on weather patterns. And weather distributes water, and water is life.

Maybe you can join the small community of people trying to answer some of these tough ecosystem questions. College students from several universities across the country attend classes at Biosphere 2 for a semester to study environmental problems. There is also a summer program for high school students who are interested in studying environmental issues. Maybe in a few years...

More information about these programs is available on the Biosphere 2 website at www.bio2.edu.

Scientists gather at Biosphere 2 to conduct rain experiments at the laboratory's ocean biome.

Six inches of fresh water fell into the saltwater ocean over a 2-hour period to measure the effect a freshwater addition would have on the exchange of carbon dioxide into and out of the ocean. The rain and air-water gas exchange experiment was funded, in part, by a grant from the David and Lucile Packard Foundation.



The Planetary Spheres

One way scientists think about Earth is as a set of nested, interacting spheres. The **lithosphere** is the rocky, mineral part of the planet that extends from the solid surface into the mantle. This is the hard part of the planet that provides a sense of solidity and stability... most of the time. Periodically, we get reminders in the form of earthquakes and volcanic eruptions that the solid Earth is actually restless and dynamic.

Wrapped around Earth is the **atmosphere,** the thin layer of gases that extends, for all practical purposes, no more than 600 kilometers above the surface. The atmosphere is a source of essential gaseous chemicals, an energy-transfer system, a shield protecting us from extraterrestrial radiation, and an insulator. It is also an important medium for water distribution.

Earth is a water planet. Because of the temperature on Earth, water exists naturally in three states: liquid, gas, and solid. All the water on Earth makes up the **hydrosphere.** The hydrosphere includes the oceans, lakes, rivers, streams, and aquifers. It includes the polar icecaps, glaciers, snowpacks, and permafrost. It also includes the aerial water vapor and condensates in the form of clouds, fog, and precipitation.

And finally, creeping, hiding, running, burrowing, flying, slithering, and swimming through, over, under, onto, and into the other three spheres is the **biosphere.** The sum total of all the living organisms on Earth is the biosphere. It is this raggle-taggle, at times improbable, assemblage of millions of different kinds of life-forms that gives Earth its particular flavor.

All four spheres can be bundled into one global sphere called the **ecosphere.** The ecosphere is that portion of a planet that is inhabited by life. Thus, it includes a portion of the atmosphere, a portion of the lithosphere, a portion of the hydrosphere, and all of the biosphere. We focus on the biosphere in this course. However, we will continually consider the interactions between living organisms and the other three spheres to reinforce the idea that life is never disconnected from the physical environment.

THINK QUESTIONS

1. **Give at least two examples of how a change in one variable in an ecosystem can start a chain reaction that affects several other variables.**
2. **Why is global warming considered by some scientists to be such an important problem?**
3. **What are some advantages of doing research on ecosystems in Biosphere 2 rather than in the natural ecosystem? What are some disadvantages?**
4. **Think about the statement "Every decision has an environmental impact." What decisions do you make that add carbon dioxide to the environment? What decisions do you make that would add less carbon dioxide to the environment than you currently add?**
5. **Why should we be concerned about species becoming extinct? What endangered species are found in the area where you live? What has caused them to become endangered? What is being done to help them survive?**