BioView

Fall 2012 | Science Journalism Project | University of Arizona

ROCK PORRIDGE

Postdoc thrives on stone soup

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A photo tour of Biosphere 2

Nestled in the foothills of the Santa Catalina Mountains, Biosphere 2 offers picturesque views of sunsets.
Photograph by Alison Dorf

SCICATS: Bio 2

One of the key goals for any researcher is to link findings, ideas, concepts and goals to a story. These stories are old, begun centuries ago when the first methodical inquiries into the natural world were put forward by thinkers like Descartes, Newton and Kepler. The stories have changed over the years, but the need to link them to research is vital to improving our understanding of the world around us.

A similar need drives our understanding of place, of history and of identity. On Oct. 5, 2012, the University of Arizona Science Journalism class taught by Carol Schwalbe set out to find Biosphere 2's story. What we found, I'd argue, is a place still working out its self-understanding, a place trying to figure out its history as it strives to become an active interface between science and the public.

What follows are threads in this ongoing process of self-understanding—the third incarnation of a 20-year-old experimental laboratory under the Arizona sun.

By Brandon T. Bishop

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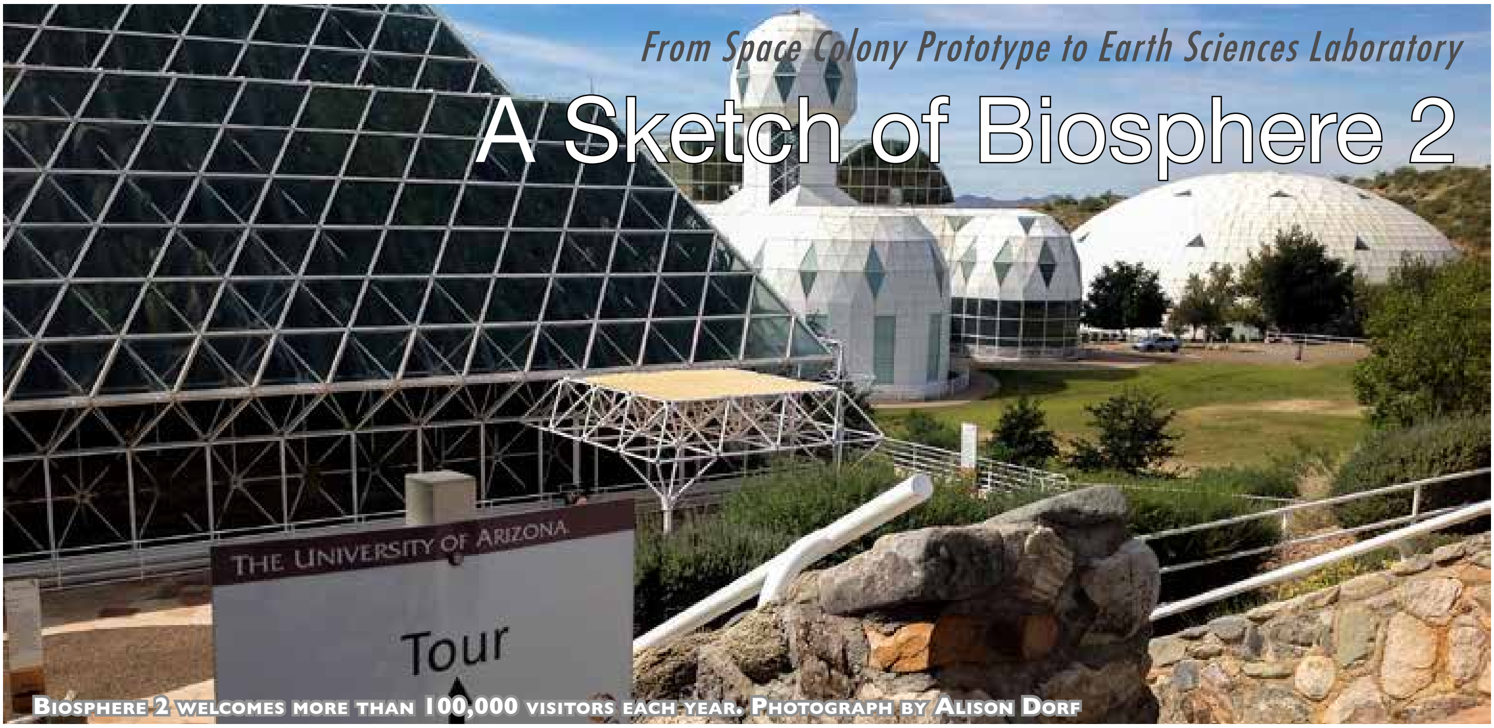
Photograph by Julian Ybarra

From Space Colony Prototype to Earth Sciences Laboratory

A Sketch of Biosphere 2



Biosphere 2 welcomes more than 100,000 visitors each year. Photograph by Alison Dorf

By Brandon T. Bishop

Biosphere 2 sits on a 1,600-acre piece of land that has passed through the hands of an eclectic collection of owners. Matt Adamson, associate director of K-12 education at Biosphere 2, has detailed knowledge of this land's obscure history.

Little is known about the first two owners of the property that would one day house Biosphere 2. In the early 1920s John Lackner of Tucson bought 1,600 acres of land and built a ranch house not far from where the glass pyramid of Biosphere 2 now rises from the semi-desert grassland turned mesquite savanna. In the 1950s the land was sold to Margaret Howard, an American heiress who married into a British noble family and become the countess of Suffolk. The countess had become reclusive after the death of her husband in the First World War and the death of one of her sons in the Second. To fulfill the terms of her father's will, she spent four months every winter in a secluded home she had built on her property north of Tucson.

Following the widow's death in the late 1960s, Motorola purchased the land and built a hotel and conference center for its staff. In the late 1970s Motorola gave the parcel to the University of Arizona as part of a land swap. The university did little with the property before selling it in 1984 to Space Biosphere Ventures—a for-profit organization led by John Allen. Depending on whom you listen to, the group was either a cult or an intentional community similar to the utopias of earlier decades. This purchase marked the beginning of Biosphere 2 and an oral history passed down from successive generations to this day, blurring the line between old rumor and historical fact.

Space Biosphere Ventures begun in the 1960s as a group inspired by space exploration and the potential for-profit that it promised. To see how people might survive in a closed system, the group began to build Biosphere 2 in 1987. With funds from Texas billionaire Ed Bass, the group completed the project in 1991. That September, eight people were sealed inside the glass-and-metal structure and given no more food, water or oxygen other than what they could provide for themselves from the diverse habitats inside.

The experiment ultimately failed. Oxygen had to be pumped in to compensate for the depletion of atmosphere caused by the slowly curing concrete that made up much of the complex's bowels. The project's secrecy lost trust of the public and the scientific community.

After a second failed mission in 1995, Bass abandoned the idea of a space colony prototype. He repurposed the facility for research and education. Bass brought in Columbia University, and for almost 10 years, Biosphere 2 was used to research the effects of CO2 levels on ecosystems. Researchers found many unexpected effects of high CO2 levels, ranging from stresses on plants to the inability of corals to grow their skeletons. Columbia added casitas to house undergraduate students engaged in the research.

Columbia changed focus in 2003 and left the Biosphere. Four years later the UA took out a 10-year lease and repurposed the complex for water and energy research. In 2011 Bass and other owners of the site donated the complex to the UA, along with $20 million in material support for the facilities and reconstruction needs.

Biosphere 2's third incarnation as a research facility is now focused on two large goals. The first is completing the Landscape Evolution Observatory (LEO), which will become the main focus of new research. The second goal is giving the public the chance to interact with researchers and see science in action. Pursuing both goals is important to Biosphere 2's continuation, as the facilities require at least 150,000 visitors per year to break even as well as funding from research grants to modify the complex for new experiments.

Adamson's telling of Biosphere 2's history shows how much the values and goals of the project have changed across the last three decades. Secrecy has been replaced by openness. An attempt to create an artificial habitat for space explorers has transformed into a tool for understanding the processes and problems of Earth's living systems.

New Slopes for Earth Scientists

By Holly Bryant

Biosphere 2 prides itself on going big. As you stroll the boardwalk through the rainforest, past the ocean into the savanna, you get a sense of the Biosphere's grandeur. The biomes represent different landscapes on Earth, which is the first biosphere.

Although one section is off-limits to the public, it's clear that something big is brewing there too. Inside a greenhouse the size of an airplane hangar, construction workers, scientists and engineers are putting the final touches on LEO—the Landscape Evolution Observatory.

LEO is the brainchild of earth scientists wanting to learn more about the effects of climate change in a controlled environment. A very large, controlled and measured environment. On three huge, man-made hillslopes, scientists will study how water, carbon and energy move through the landscape.

Each of LEO's slopes is exactly the same, measuring 40 feet wide by 100 feet long and weighing 1.6 million pounds. That's the weight of more than 300 African elephants.

Why build three identical slopes? That number was driven by ecologists, said Steve DeLong, LEO's lead scientist and a University of Arizona assistant research professor. Sample sizes from fieldwork are typically small, with many variables. Ecologists want to verify that the same conditions will

PHOTOGRAPH COURTESY OF PAUL INGRAM/LANDSCAPE EVOLUTION OBSERVATORY

Steve DeLong, the lead scientist of the Landscape Evolution Observatory, stands on the first hillslope built inside the LEO space. DeLong has left Biosphere 2 to take a new position with the U.S. Geological Survey in California.

Blue Barrels: The End of a Critical

By Cecelia Marshall

Ten bright blue barrels stand on display on a platform overlooking the grassland. Mesquite trees stretch from half the barrels, their branches reaching toward the neighboring Egyptian thorn tree. Scraggly grasses dangle over the sides of the other barrels, like dreads falling over a Rasta man's head.

The blue barrels project has come to an end at Biosphere 2.

Each barrel is a biological test bed that holds a mesquite tree or grasses. Researchers can peer at the plants' roots with cameras and measure the effects of mini-climate changes with sensors that will be used later in Biosphere 2's main project, the Landscape Evolution Observatory (LEO).

Greg Barron-Gafford, an assistant research professor and associate research scientist at Biosphere 2, designed the blue barrels project to find out whether mesquite trees or grasses would become the dominant species as the climate changes. Models predict that the temperature of the Earth could increase by 7 degrees Fahrenheit over the next hundred years, according to Biosphere 2 researchers. Many plants, animals and microorganisms will either flourish or die.

Woody plants, for example, are invading and changing the grasslands in southern Arizona. "The mesquite won't be going away," Barron-Gafford said. Grasses bake in the rising heat, but deep-rooted mesquites can tap into pockets of water. "We're probably not going back to a grasslands landscape," he said.

To test this hypothesis, Barron-Gafford conducted experiments in the blue barrels inside Biosphere 2, where it is easier to control the variables than it is out in the field. The barrels were distressed every two weeks by a controlled "drought." For days, the barrels went through a mini-drought until their soil became dry and crusty. Just when there was almost no hope of survival, researchers drenched the plants with a simulated "monsoon."

Researchers studied how the plants responded to the lack of soil moisture. Sensors were buried in the soil from the top to the bottom of each barrel, recording yield the same responses by repeating experiments on the three slopes.

Geologists, however, would have preferred comparing soil and water reactions on three different platforms with varying gradients, such as steep, gentle and in between.

Earth science has long been a field of … well, fieldwork. It's about collecting data in the field and putting together the puzzle pieces of Earth's evolution—weather, water, carbon, energy and soil. Many of the pieces are missing. LEO brings fieldwork into a controlled environment and will help fill in those missing pieces.

By controlling rainfall, temperature and vegetation, LEO adds a new dimension to the study of soil evolution. "[There are] lots of small details about what water does in the soil and how it reacts and moves," said Paul Ingram, a science writer with the project. "It's understood but not as well as it could be, and LEO gives scientists an apparatus to experiment on a much larger scale."

PHOTOGRAPH BY JOSE SERRANO

Special watering systems were designed for the Landscape Evolution Observatory to simulate different types of rainfall on the hillslopes.

Critical Zone Observatories, sponsored by the National Science Foundation, are the current model for collecting in-the-field measurements of climate, soil and water. If geologists want to know how water moves through soil, for example, they go into the field and put in a flow meter, CO_2 sensor and moisture sensor. Then they have to wait for something to happen … and that could take a while.

LEO brings these field laboratories into a setting where researchers can control the variables. "[Scientists] often aren't able to make systems of this scale and degree of control," DeLong said. "Natural systems are complex and kind of messy…. Scale and control are the important parts [of LEO]."

Each slope is covered with 3 feet of soil and laced with more than 2,000 sensors that measure the water content, temperature, gas and chemistry of the soil as well as the surface temperature.

Built-in sprinklers will allow researchers to simulate weather changes, from a gentle English rain to a monsoon storm. "There are big applications for that data," Ingram said. The interactions of the water, soil and carbon will help researchers understand how landscapes form and evolve under extreme weather patterns.

DeLong is looking forward to the future of LEO "as new scientists get involved. They may influence how efforts go forward and what questions get asked." Researchers all over the world will be able to use data from LEO to test and refine large-scale climate models.

Component of Biosphere 2 Research

data every five seconds around the clock. The sensors showed how the mesquite roots pulled the water in the soil up from the bottom of each barrel and distributed it evenly to the top and middle levels.

Every week Maggie Heard, a research assistant on the blue barrels project, took nearly 550 pictures of the roots of the grasses or mesquites in each barrel. Foil-wrapped tubes plunged inside the barrels. A camera fit down into the tube and displayed a frame of the plant roots and soil.

Early on, researchers encountered problems with the soil pressing on the sensors. "This is generally what you would expect with an experiment," said Katerina Dontsova, an assistant research professor at Biosphere 2 who studies soil biogeochemistry. "It doesn't usually work right away."

Researchers had to repack some sensors because of the pressure and weight of the soil. "They're relatively fine instruments," Dontsova said.

The sensors in the blue barrels served as prototypes for LEO, where Biosphere researchers will study how landscapes react to climate change. LEO's three man-made hillslopes are packed with 2 million pounds of soil inside an enormous greenhouse.

LEO contains $750,000 worth of sensors. The 20 blue barrels, on the other hand, were fitted with $70,000 worth of sensors.

PHOTOGRAPH BY CECELIA MARSHALL

Maggie Heard, a research assistant with the blue barrels project, relaxes after talking to a tour group. Heard took hundreds of pictures inside the blue barrels each week to document water absorption and photosynthesis by grasses and mesquite trees.

If a sensor stopped working in a blue barrel, it could be replaced. But if a sensor stopped working on a LEO hillslope, buried under tons of soil, it could mean the end of an experiment or the loss of hundreds of thousands of dollars, said Stephen DeLong, an assistant research professor and lead scientist for the LEO project.

By serving as prototypes, "the blue barrels built confidence in the sensor systems used in LEO," DeLong said. "It's a nice trade-off."

Photographs by Jason Hill

Researchers can control temperature, rainfall and humidity inside the rainforest biome at Biosphere 2. Joost van Haren, an assistant research professor, will soon conduct experiments here designed to improve on field studies in the Amazon rainforest.

What Happens to Rainforests Without Rain?

By Brandon T. Bishop

As global temperatures increase and weather patterns change, drought is emerging as a major threat to the world's rainforests. If nations want to make policies to cope with this potentially devastating threat, scientists must develop a better understanding of rainforest plants and how they respond to drought.

Joost van Haren, an assistant research professor at Biosphere 2, has a perfect laboratory for studying these plants—the Biosphere's rainforest biome. Under the immense glass pyramid, van Haren will soon carry out a series of studies designed to improve on field studies in the Amazon rainforest.

In the past, researchers would redirect rainfall from small patches of forest to prevent it from reaching the soil, van Haren said. There was no way, however, to block rain from reaching the forest's upper canopy or to remove the high levels of moisture found in a rainforest's air, making these studies incomplete. Within Biosphere 2, researchers can control both the temperature and humidity of the rainforest biome to simulate the hotter, drier conditions of the tropics anticipated in coming decades.

Biosphere 2 offers more than improved control. Researchers can also monitor how the biology and ecology change the atmosphere as an experiment progresses. Trees and other plants emit specific compounds at low levels. These compounds react with the ozone in the atmosphere produced by ultraviolet light and, therefore, are extremely difficult to collect in the wild.

But at Biosphere 2 the concentrations of these compounds are much higher. The Mylar sheets that strengthen the windows block out the sun's ultraviolet light, and the abundant plant life inside the rainforest biome lead to much higher gas concentrations, letting van Haren and his team more easily measure them.

The rainforest biome "acts like a magnifying glass that lets us see how biology affects the atmosphere," van Haren said.

Van Haren can also monitor how changes in the atmosphere affect plants. By adding CO_2 from fossil fuels to the Biosphere's atmosphere, he can track the pathways by which trees extract CO_2 from the atmosphere, use it to produce sugars in the leaves and transport those sugars to the roots. There, microbes consume some of the sugars and add the carbon from the CO_2 to the soil. The CO_2 from fossil fuels acts almost like a dye, van Haren said, because it has different isotopes—atoms of an element with a different weight than usual—compared with the typical CO_2 in the atmosphere.

Van Haren's team will soon be able to study the full effect of drought on a rainforest ecosystem, from treetops to deep roots, to a degree that is impossible in the wild. What van Haren discovers might be vital to learning how to deal with a changing climate in the tropics.

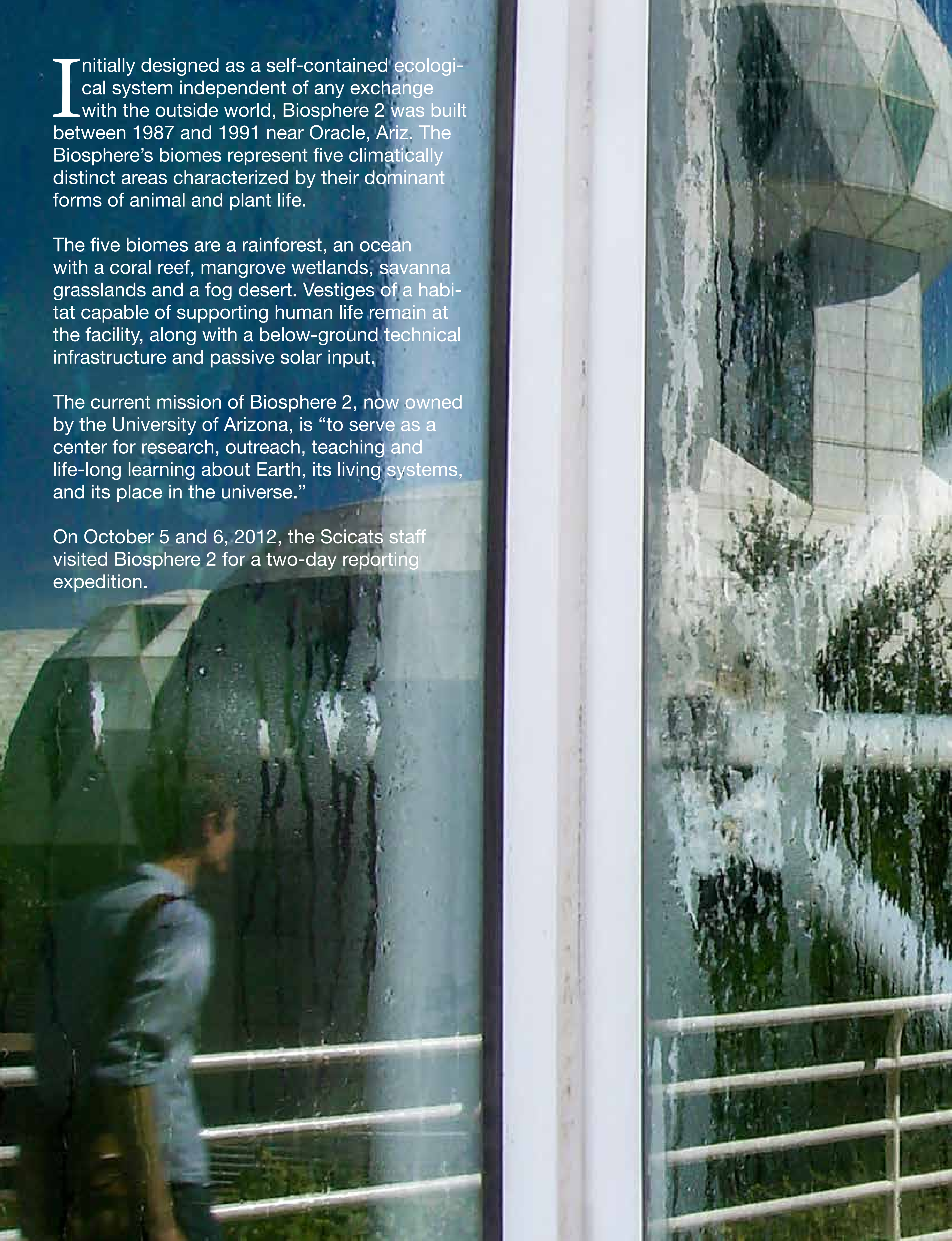
About a hundred types of plants grow in the rainforest biome.
Photograph by Jason Hill

Initially designed as a self-contained ecological system independent of any exchange with the outside world, Biosphere 2 was built between 1987 and 1991 near Oracle, Ariz. The Biosphere's biomes represent five climatically distinct areas characterized by their dominant forms of animal and plant life.

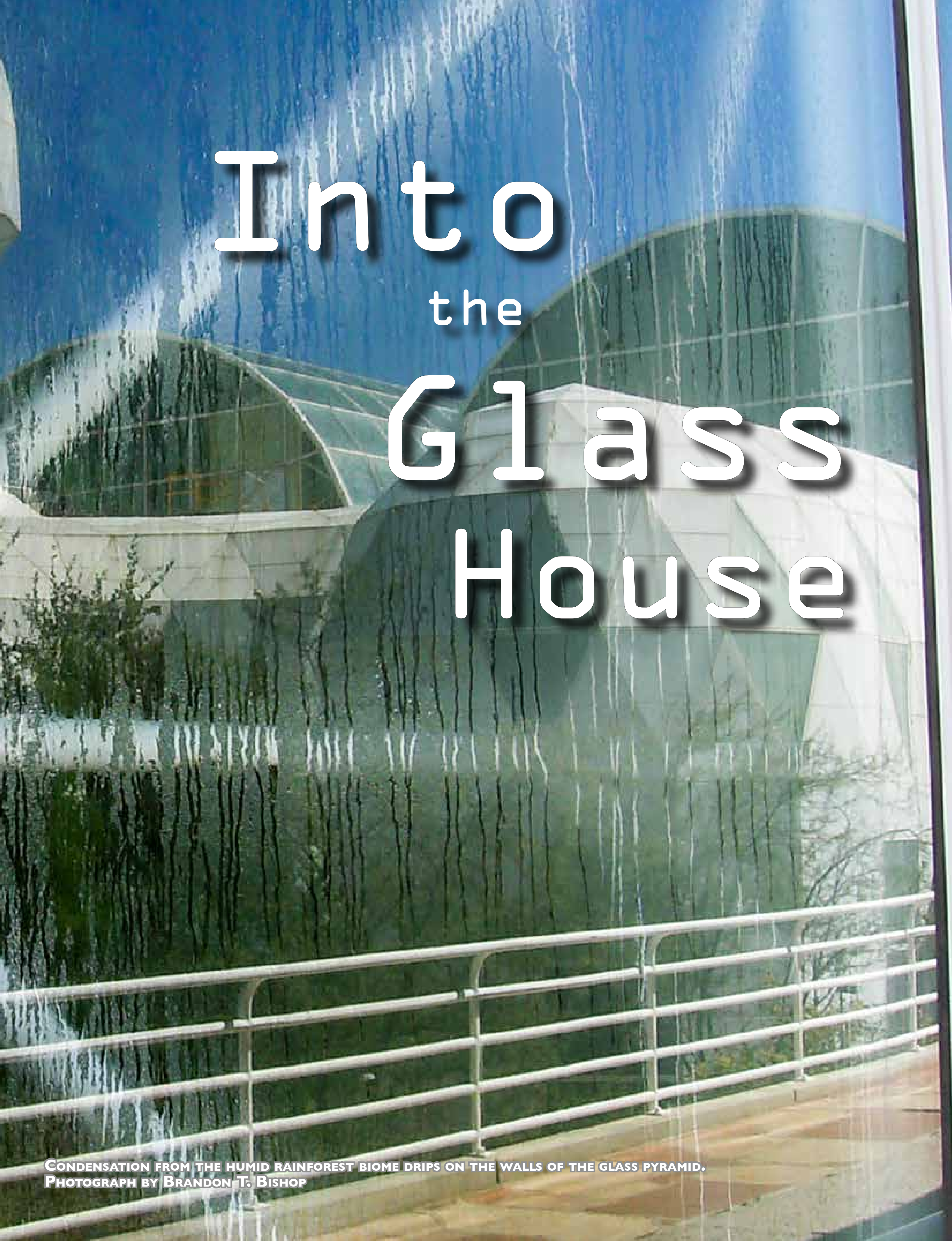
The five biomes are a rainforest, an ocean with a coral reef, mangrove wetlands, savanna grasslands and a fog desert. Vestiges of a habitat capable of supporting human life remain at the facility, along with a below-ground technical infrastructure and passive solar input.

The current mission of Biosphere 2, now owned by the University of Arizona, is "to serve as a center for research, outreach, teaching and life-long learning about Earth, its living systems, and its place in the universe."

On October 5 and 6, 2012, the Scicats staff visited Biosphere 2 for a two-day reporting expedition.



Into the Glass House



Condensation from the humid rainforest biome drips on the walls of the glass pyramid.
Photograph by Brandon T. Bishop

Photograph by Brandon T. Bishop

Photograph by Emily Berkson

Photograph by Cecelia Marshall

Top: The Biosphere's 6,500 windows rise 91 feet at the highest point. **Above:** Steve DeLong (right), the lead scientist for the Landscape Evolution Observatory (LEO), and Shipherd Reed, a multimedia producer at Flandrau Science Center, ride over one of the three LEO hillslopes. **Left:** Cactuses and other arid-adapted plants thrive in the desert biome. **Below:** Scientists conduct interdisciplinary research in the space age-looking structure, which houses five distinctive biomes.

Photograph by Tyler Stenzel

Chris Stump, a Scicats staffer, inspects a tree leaf in the rainforest.
Photograph by Holly Bryant

Located near Oracle, Ariz., Biosphere 2 overlooks mesquite savanna.
Photograph by Alex Wainwright

Rock Tasting at Biosphere 2

By Susan E. Swanberg

With a mischievous grin and gleaming dark eyes, Dragos Zaharescu raises a small spatula to his lips and tastes. At his feet are four containers, each filled with a different type of ground rock—granite, basalt, rhyolite or schist. Zaharescu will blend this rock with bacteria or fungus, creating a sandy medium for seedlings he grows here under the glass dome of Biosphere 2.

The dark-haired scientist cleanses his palate with water and tastes another sample. He won't tell us his opinion yet but dares us to participate as he serves sand like a sommelier.

"Which one do you want first?" he says.

After we sample the ground rock, Zaharescu agrees that granite tastes like salt.

Photographs by Susan E. Swanberg

Above: Nicknamed "rockubators," Plexiglas growth chambers nurture seeds in ground rock as part of an experiment by Dragos Zaharescu, a post-doctoral researcher at Biosphere 2. **Opposite:** Buckets contain ground-up rock samples in Zaharescu's laboratory, ready to be tested in his "rock soup."

A version of this story ran on the Scientific American Guest Blog on Dec. 11, 2012.

Biosphere 2, where Zaharescu does his research, is about 35 miles north of Tucson, Ariz. The dome of Biosphere 2 rises from the mesquite savanna like a cathedral for the celebration of science. A long line of biospherians and scientists has studied within this glass vivarium. The enthusiasm for discovery has not waned since the original crew of biospherians lived here two decades ago. Their mission: To survive for two years sustained only by the food they grew beneath the dome.

Birth of the biosphere concept

The word "biosphere," meaning the place on Earth's surface where life dwells, was coined in 1875 by Edward Seuss, an early ecologist. New life was breathed into the biosphere concept in the 1960s, a fertile era for the melding of ecological principles and New Age philosophy. It was in this rarified atmosphere that the idea for Biosphere 2 was born.

In the early 1980s a team of scientists, architects, adventurers and dreamers decided to build an artificial biosphere—a geodesic-like structure within which they would create a self-sustaining community. Ground was broken for Biosphere 2 in January 1987, and four years later the infrastructure was complete.

During construction, in a mysterious process more akin to a vision quest than the vetting of a team of scientists, eight individuals were chosen to inhabit Biosphere 2 for two years. The biospherians survived the experience, living almost entirely without assistance from the outside world. In the process, they learned as much about human relations as anything else.

"It makes me want to stay in the science field just to know that there are a lot of people [in science who] are personable and social."

Biospherian for the 21st century

Dragos Zaharescu is an intellectual descendant of the original biospherians. He says, without hesitation, that he would go back in time and join them in their grand experiment—if he could. Zaharescu came to Biosphere 2 as a research associate in 2011 after graduating from Vigo University in Galicia, Spain, where he investigated the interface between high-altitude organisms and their environment.

Here at Biosphere 2, Zaharescu sprouts seeds in ground rock, studying the interaction among the organisms living in his unique growth medium. He hopes his research will demonstrate how plants, microbes and fungi contribute to biological weathering, part of the process that changes rock into a living ecosystem and, ultimately, soil.

Some of the rocks that Zaharescu uses come from Arizona or New Mexico. Other rocks are sent to him by mountaineers and explorers affiliated with Adventurers and Scientists for Conservation (ASC). This organization pairs adventure athletes with scientists who need help collecting samples or data from extreme environments. Mountaineers associated with ASC collect bedrock for Zaharescu from the tops of mountain ranges.

The arrival of a new rock in the mail renews his excitement. "I open the package, and it might be a rock from Kilimanjaro. Whoa! Kilimanjaro."

He feels a close bond with these citizen scientists, who risk life and limb to collect samples for him. "Anything can happen to them. They can die."

Zaharescu plans to bring his team of mountaineers to Biosphere 2 for a conference once his research is complete, perhaps within the next five years. "They will be co-authors on the papers," he says.

This is the highest honor a scientist can confer on a colleague.

Life in a bottle

Zaharescu's work harkens back to the studies of Clair Folsome of the University of Hawaii—a "historic figure in the Biosphere lineage," according to Jane Poynter, one of the original biospherians. In her book *The Human Experiment: Two Years and Twenty Minutes Inside Biosphere 2,* Poynter describes Folsome's life-in-a-bottle experiments. In 1968 Folsome sealed an amalgam of beach sand, bacteria and algae into flasks, sealed the flasks and sterilized them. "[No matter what he did to the flasks, unless he heated them to the point that the proteins broke down irreparably, or deprived the systems of light for a long time, life always persisted inside," Poynter wrote.

Decades later, Zaharescu carries out his own "life-in-a-bottle" project. In his exquisitely designed and executed experiments, he grows grass and ponderosa pine seedlings within specially designed chambers, using rock that he or his collaborators collected and his young associates ground into a sandy mixture.

Zaharescu smiles ruefully as he describes how he burned through at least 20 assistants during the rock-crushing phase of the project. To avoid contamination, any living matter had to be ground off the rock with a drill. Then the rock was crushed and sterilized in an autoclave. Each grain of sand had to be the same size, so the growth medium would be uniform.

Zaharescu didn't spare himself the hard labor, but he wouldn't demonstrate the process for us. "Don't ask me to crush rock again," he says.

"No more," echoes Andrew Toriello, one of the few student assistants still with the project.

Toriello, a nutritional science undergraduate at the University of Arizona, joined the project in March 2012. Toriello helped denude and grind rock for months.

PHOTOGRAPHS BY SUSAN E. SWANBERG

TOP: Dragos Zaharescu examines a series of cylinders through which his plants send their roots. Zaharescu collects runoff and metabolites from these cylinders to study how well the plants survive on a minimal medium.

ABOVE: Zaharescu "taste-tests" the sterilized rock he will use to grow his plants. Granite, he said, tastes like salt.

In spite of these monotonous tasks, Toriello enjoys working with Zaharescu. "It makes me want to stay in the science field just to know that there are a lot of people [in science who] are personable and social."

Jennifer Presler, also a University of Arizona undergraduate, started on the project as a National Science Foundation summer intern and was hired on when her internship ended. "I wasn't in charge of the grinding," she says. "I was in charge of the cleaning, thank goodness."

Presler also helped to assemble a watering system for the seedlings. "It's a lot of fun," she says. "His [Zaharescu's] excitement makes me excited, too."

After mastering rock grinding and cleaning, Zaharescu designed and built "rockubators"—hexagonal Plexiglas incubators where seedlings grow in the ground rock medium. These cradles for infant plants are kept as clean as possible during each experiment.
Rows of tubes carry water to the seedlings. Gloves dangle from portholes opening into the rockubators. If plants must be handled or tubes adjusted, only gloved hands will enter the clean environment.

To the sandy medium, Zaharescu adds a rich mixture of bacteria and fungus that will jumpstart his plants. As water drains through the Plexiglas columns containing the seedlings, he will collect the runoff and analyze it for nutrients, bacteria, fungi and the chemical metabolites of plant growth. In this way he hopes to learn how plants, bacteria and fungi transform a rocky environment into a living ecosystem. This knowledge will help us understand how the Earth evolved from a rocky, uninhabitable planet into the green, fertile biosphere it is today.

With his experiments, Zaharescu has shown himself to be a consummate scientist with a creative approach worthy of the original biospherians. As he says, "Don't think outside of the box. Just get rid of the box."

PHOTOGRAPH BY SUSAN E. SWANBERG

Postdoctoral researcher Dragos Zaharescu points to the tubes that carry water to seedlings growing in "soil" made of crushed, sterilized rock.

Life on the Rocks

By Sean Fleming

Biosphere 2 is a disorienting place. A tour through the space age structure takes you from one biome to another within seconds. At one moment you're on sand next to a small ocean, and the next in a lush rainforest so dense you can't see the geometric ceiling.

But visit the fog desert area, and you might notice something a bit strange as you follow the fenced path—a scientist conducting research before your eyes.

On a vaulted platform Dragos Zaharescu tends his rock garden—six sealed hexagonal modules nicknamed "hex-boxes" or "rockubators." The modules look like something straight out of a *Star Trek* movie, with their geometric shape and myriad small tubes sprouting from every opening.

As Zaharescu talks to the crowd, he wears the symbol of science—the white lab coat. But under this coat are not a tie and slacks but shorts and a T-shirt, a must in the stifling Arizona heat. His shoes are covered with blue booties that prevent the dirt on his shoes from contaminating the spotless hex-boxes.

His casual attire and accessible speech put visitors at ease as they learn about his research in the Biosphere, a gigantic laboratory that models the world around us. Located about 35 miles north of Tucson, Ariz., the Biosphere houses experiments that seek to understand landscapes, climates and sustainability.

A closer look inside each hex-box reveals a grid of small circles. Some appear empty, while tiny seedlings pop out of the soil in others. The needles of the ponderosa pine seedlings form a cage as the plants germinate.

The "soil" the seedlings are growing in is pure ground rock, much like the sand on a beach. You can't grow tomatoes in this stuff. Well, you can. Eventually.

Soil-creating colonists

Plants, bacteria and fungi are the first settlers of desolate landscapes of only rock, such as an island after a volcanic eruption or the Earth of eons ago. Over thousands of years, these organisms change the rocks into soil—a mix of inorganic and organic material. It is this soil that supports us all.

Zaharescu is researching this interaction between life and pure rock. How do plants, bacteria and fungi get nutrients from the rocks? How do the rocks become weathered over time? How do these processes affect the water that flows through the rock sand?

Zaharescu has placed four types of

colonists in the untouched environment inside the hex-boxes. The ponderosa pine and buffalo grass, already seedlings, are doing just fine in their new rocky home.

The other two organisms require a microscope to see. The third type—bacteria—is used to living on rock. The bacteria have been collected from the surfaces of rocks found in nature.

The fourth—a type of fungus called mycorrhiza—lives in the root network of 80 percent of the world's plants. The mycorrhiza exist in a symbiotic relationship with the plants, sharing food, water and minerals.

These four organisms are changing the rock they live in, and it's the job of analytical chemist Ed Hunt to determine how much and in what way.

To the laboratory

A vista of the Santa Catalina Mountains opens up as Hunt walks down the hill to his on-site lab adjacent to the Biosphere. He takes a shortcut flanked on both sides with native flora. As a budding herpetologist, Hunt is always on the lookout for Gila monsters.

In the lab the research posters of Zaharescu and his adviser, Dr. Katerina Dontsova, line the walls. The low hum of analysis instruments resonates throughout the building. Save for the thousands of tiny plastic vials scattered around, the lab is uncluttered, if a bit empty. It's ready to grow. "My goal is to do more research with a lot of different analytical capabilities," Hunt said. "And hire more people."

Hunt analyzes the water runoff from the rock soil every day. When rock particles are dissolved by water, they leave as charged ions. It is these ions that Hunt analyzes.

Surprisingly, Hunt found dissolved carbon, nitrogen and organic molecules in the water runoff. These nutrients aren't found in the rock. The rock sand is watered with ultra-pure water, so the nutrients aren't there either. But they're essential for survival. By fixing the carbon and nitrogen in the air and by discarding some of their own organic molecules, the

The Scientist and the Daredevils

By Bethany Barnes

Some people have pen pals.

Dragos Zaharescu has explorers.

These adventurers are working with the Biosphere 2 scientist to collect rocks from high elevations for his research. Sometimes their journeys take them to harrowing heights, where they snag snapshots or videos of themselves holding up rocks before mailing them to Zaharescu, a research associate.

"You open [the package] and say 'Wow! This came from Kilimanjaro," Zaharescu said.

He has received rocks from around the globe, including the Alps, Russia, Alaska and Tanzania. He contacts the explorers through Adventurers and Scientists for Conservation, a group that pairs researchers with outdoor enthusiasts who are in a prime position to help with research.

Zaharescu is collecting rocks from extreme environments so he can strip off the thin veneer of weathering and study how microbes contribute to the process that changes rock into soil. Analyzing the microbes will also provide clues as to how the environment is changing in remote mountainous regions.

Perfect Partners

It's a perfect partnership. The explorers like the challenge of reaching daring heights, and that's where they find rocks with the least amount of weathering.

While the adventurers would undertake the extreme trips anyway, Zaharescu is acutely aware of the dangers. He is quick to point out that these men and women are risking their lives. "It's not easy, and I know that," he said as he stressed his gratitude.

It's clear that he's in awe of the adventurers when he tells the story of Lonnie Dupre. The explorer reached 17,200 feet climbing Denali, North America's highest peak, in the dead of winter. Dupre huddled in a snow cave for several days before bad weather forced him to abandon his journey, according to a post he wrote on the University of Iowa's Sustainability Blog.

Dupre ended up with frostbite, yet he was concerned that he wasn't able to retrieve any rocks.

Zaharescu laughed as he explained that he had to reassure Dupre it was OK that he didn't bring back the rocks—that his life was more important. The two are still collaborating.

Finding Meaning Through Science

For many of the explorers, partnering with Biosphere 2 adds purpose to something they love to do. "My husband and I like to climb, and most people climb for pretty selfish reasons," said Lisa White, 39, who lives in the Seattle area and works for a medical device company. "[Working with the Biosphere] helped to give a little more purpose to what we're doing."

Talking with Zaharescu about her adventure on Denali made the research even more real. "When I really thought about [the research]," White said, "it was kind of mind blowing."

Whitney Metzger, a 31-year-old elementary school teacher in Bozeman, Mont., also thinks that adventurers tend to be selfish. Working with Zaharescu gave her expedition to California's Mount Whitney a "bigger, broader" purpose.

Zaharescu contacted Metzger as soon as he received the rocks, and that reinforced the positive feeling of helping. "I care about the environment and I care about science," she said, "but I would not have had the first clue of how to connect with [scientists]."

Some of the explorers are knowledgeable about science and eager to share their passion.

That's how it was for Hari Mix, who partnered with Zaharescu during a journey to the Pamir Mountains of central Asia. Mix has a background in geology and studies paleoclimatology at Stanford University's Department of Environmental Earth System Science, so he was naturally interested in Zaharescu's work. He describes himself as someone who is "blown away by the scale and beauty of earth processes."

For Mix, contributing to research gives scientists a better understanding of the places he loves. Although he has an interest as a scientist himself, he thinks that all adventurers would appreciate this sort of stewardship because of their deep emotional connection to remote places.

Rock Steady

Photograph by Tyler Stenzel

Photograph by Bethany Barnes

Photograph by Bethany Barnes

Dragos Zaharescu explains the inner workings of “rockubators,” the sealed chambers where the Biosphere scientist grows plants in rocky “soil.” Zaharescu enjoys speaking to tour groups about his experiments.

organisms are changing the rock to soil before our eyes.

Zaharescu and Dontsova plan to do a comprehensive genetic analysis of the plants, bacteria and fungi. Their genetic code will adapt as the organisms' environment changes from pure rock to something more soil-like. “The organisms have the genetic information to make the carbon and the nitrogen,” Zaharescu said. “We can extract the DNA and see how a primordial organism might have evolved.”

“For the first time, we'll be able to watch the transition from nutrient-poor rock to the nutrient-rich soil that supports us all.”

All these processes are interconnected in the ecosystem, Zaharescu said. “If I were to put a grasshopper in the module and if it were to eat the plants and if I ate the grasshopper, I would be eating the rock.”

Savoring the rock sand

Zaharescu opens his large buckets full of ground rock. He sticks a tiny spatula in the sand, opens his mouth and starts to chew with gusto. He doesn't swallow, thankfully.

The rocks come in four “flavors” that represent primordial geology: volcanic black basalt, shiny metallic schist and speckled granite and rhyolite. The granite and rhyolite are chemically similar, and they taste the same too.

Grinding these rocks to fine sand was no easy task. Technicians had to strip the rocks of their weathered surface to reach the purest material in the center. Then they ground the rocks to the fine sand that Zaharescu now handles carefully.

The two-year, labor-intensive process “burned through 20 people,” Zaharescu said. “But first I burned through myself.”

Zaharescu's two undergraduate research assistants, Andrew Toriello and Jennifer Presler, are glad their rock carving and smashing days are over. Nevertheless, Presler said, “It was an awesome moment when I saw the finished ground rock.”

From hex-box to hillside

Katerina Dontsova, a soil scientist by training, is very supportive of Zaharescu's efforts. Her office overlooks the Landscape Evolution Observatory (LEO), which consists of three massive, sloping platforms covered in ground black basalt.

LEO's platforms represent an untouched environment of pure rock, much like Zaharescu's hex-boxes—if they were the size of a football field. But these rocks aren't ready for life just yet. Other scientists want to investigate earlier stages of the evolving landscape, such as the effect of water flowing down the hillsides.

Two years down the line, Dontsova hopes to introduce plants onto LEO's fabricated hillsides. When she does, she'll already have an idea of the chemicals that the colonists will add to the basalt, which is one of the “flavors” Zaharescu is growing his seeds in. “For the first time, we'll be able to watch the transition from nutrient-poor rock to the nutrient-rich soil that supports us all,” Dontsova said.

No tasting required.

Biosphere 2 and IBM Team Up

By Kyle Johnson

Advances in technology have produced new gadgets that are smarter, sleeker and more efficient. Smartphones, tablets and other mobile devices harness Internet capabilities and bring information to the user instantly.

Now this smart technology is being applied to one of the world's biggest waster of energy—buildings. Commercial and residential buildings accounted for 41 percent of U.S. energy consumption in 2011, according to the U.S. Department of Energy. Their abundant energy use inspired IBM to collaborate with the University of Arizona's Biosphere 2 to research the capabilities of smart buildings.

Although residential buildings consume more energy (22.5 percent) than commercial buildings (18.6 percent), the Biosphere's smart building project focuses on commercial buildings since they more frequently waste energy, said IBM Vice President David Bartlett. "The way we've managed these environments is so wasteful, and it doesn't have to be," Bartlett said. "We just haven't focused on [saving energy]."

Better designs, management and automation of buildings could produce savings worth $340.8 billion worldwide by 2020, according to a 2008 study conducted by the independent climate group Smart 2020.

Photograph by Kyle Johnson

Plants growing on top of the miniature pink houses help insulate and cool the buildings below. The temporary houses are part of the green roofs project within the Model City research program.

Smarter buildings

Commercial buildings waste energy through mismanagement or the lack of information, Bartlett said. While homeowners know when a door is left open while the air-conditioning is running, most businesses don't pay attention to details like these.

In addition to collecting data that show where and how energy is being wasted, smart buildings will also notice things like global shifts in energy demands, said Nathan Allen, Biosphere 2's sustainability coordinator. "[Shifts in demand] affect the price of shipping, which can affect the price of electricity, which can affect the price of any number of things and back the other way," Allen said. A smart building's Internet connection will pick up on this shift in price and adjust its energy use accordingly.

Smart buildings will also notice when something inside the building breaks down, thanks to IBM's Maximo Asset Management software, said Naeem Altaf, the chief solutions architect at IBM. The software will instantly detect a broken-down generator, and someone can fix the problem before much energy is wasted.

"The key is data," Altaf said. "Once we have the data, we have very smart analytic tools which can mine this data."

Smart buildings aren't far off, he added. The computing technology exists, but IBM still needs to work on collecting and implementing the data.

And that's where Biosphere 2 comes into the picture.

Photograph by Sean Fleming

The village of 30 casitas installed by Columbia University plays an important role in the smart buildings project at Biosphere 2.

The intelligent dome

The massive greenhouse near Oracle, Ariz., was built to test human sustainability in outer space by sealing researchers in an enclosed environment. Now owned by UA, Biosphere 2 conducts experiments ranging from drought in the rainforest to innovative energy and water management strategies.

IBM chose to partner with the UA on the smart buildings project because the Biosphere itself now faces issues with the cost and waste of energy that's representative of the worldwide problem,

Photograph by Jason Hill

Above: Guides lead visitors through Biosphere 2. During the early days, when the Biosphere was closed to the outside world, visitors stayed on the perimeter and gazed through the windows at the biospherians living inside.

Photograph by Alex Wainwright

Photograph by Jason Hill

Top: In the basement of Biosphere 2, cables and pipes run through an underground corridor like a nervous system, sending water and energy to each biome. This part of the Biosphere is known as the Technosphere.

Above: Biosphere 2 is a microcosm of an actual city, with different sections comparable to an industrial sector, a commercial business zone and a residential area.

Bartlett said. "When they built the Biosphere, the whole focus was on building an experimental station to study sustainability of humans in a closed environment," he said. "But no one thought about the sustainability of the building itself."

The equipment already in the Biosphere makes it easy to gather data. Hundreds of temperature sensors are scattered around the multiple biomes because of the building's scientific background, Allen said. The problem was figuring out how to apply the information gleaned from the sensors to properly operate the buildings.

"That may sound crazy, right?" Allen said. "I mean, why have all the sensors? It's because we have a lot of sensors that were installed for scientific purposes, not operational purposes. What we're learning is that a lot of those sensors could have valuable information for how we operate."

In the rainforest biome, for example, light sensors gauge the effect of sunshine on the photosynthesis of the plants. The sunlight also affects the temperature and humidity in the giant greenhouse, Allen said. That's something that was ignored before the smart building project.

Now Biosphere 2 is paying attention to the heating of the entire building, he added. While the overall temperature in the rainforest might be 90 degrees Fahrenheit, one side could be 70 degrees while the other is 120 degrees.

A distant plan

Right now the Biosphere is being converted into a smart building. For a truly smart building, the operation system requires autonomic computing, which is a type of artificial intelligence. The computer system will have the capability to learn and make quicker decision in the future, but Allen said the Biosphere has to conduct a feasibility study before investing in that kind of technology.

At the moment the Biosphere is concentrating on the first two steps of creating a smart building—installing new sensors and then processing the information.

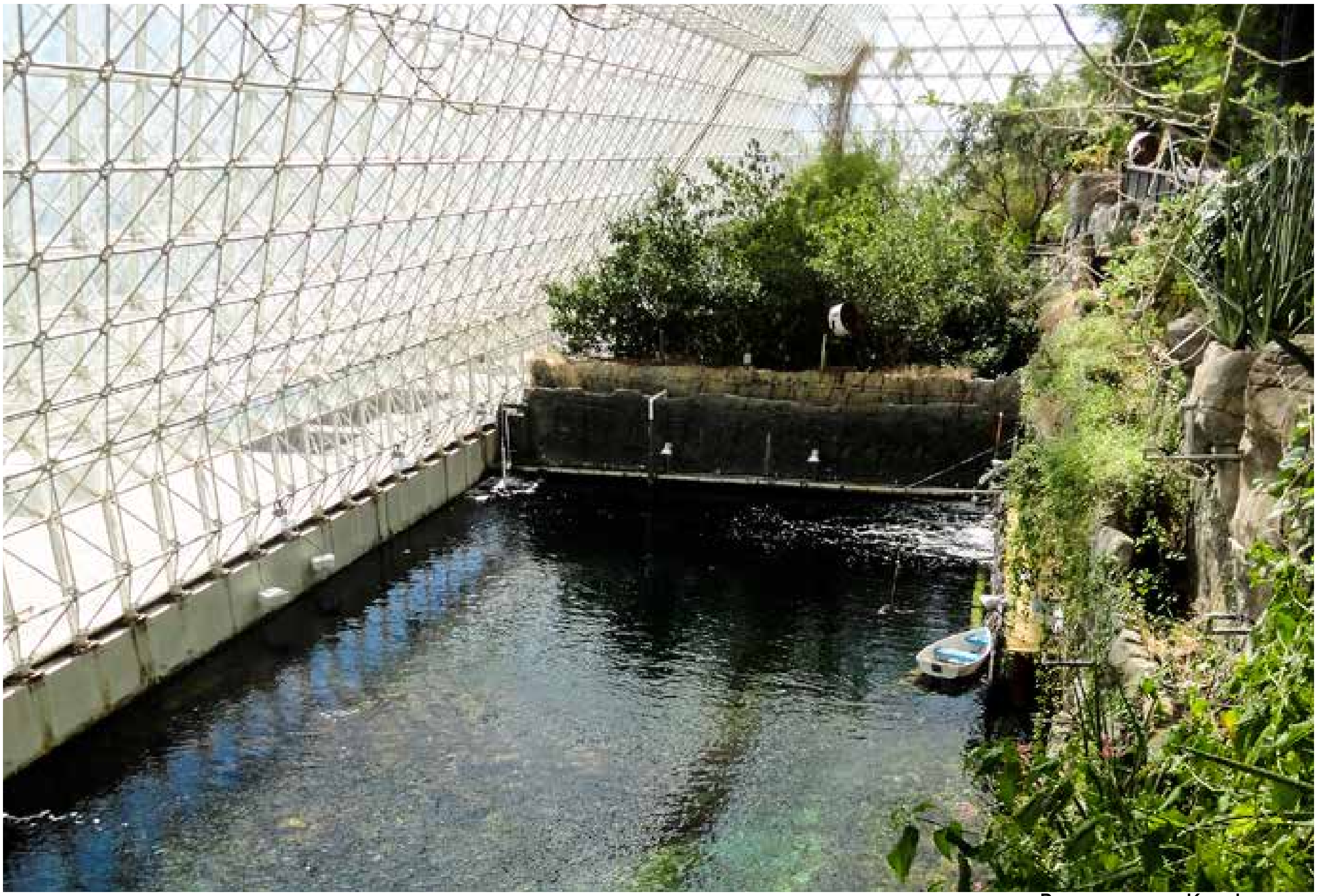
If the Biosphere decides to take the final step and introduce an autonomic system, the buildings' operators won't become obsolete. Their job responsibilities will just change.

Most of these buildings are running off of old controllers, said IBM's Altaf. The building operators don't have the proper information to make quick changes or notice if a system has broken down.

"But now, with the IT-enabled analytics, I still want those people, but I want them to do some more interesting work rather than just sitting there and pressing a button," Altaf said. "Those buttons can be pressed by the computer."

A version of this story ran on the Tucson Weekly's The Range Blog.

An Ocean Under the Heat



PHOTOGRAPH BY KYLE JOHNSON

The ocean biome's 676,000 gallons of water are home to 15 species of fish, 10 species of algae and many types of invertebrates.

"Watergy" Viability Explored for Sustainability

By Hope MIller

Although water and energy tend to be viewed separately, the two are undeniably connected, and researchers at the UA's Biosphere 2 intend to prove it.

Researchers working with the Model City program at Biosphere 2 are exploring ways to synthesize water and energy in a sustainable fashion that can have applications in real cities. Called the "watergy" project by the researchers, it will coordinate the unpredictable demands for water with the production of solar energy.

Biosphere 2 is a microcosm of an actual city, said Nathan Allen, coordinator of the Model City research program. The energy and water usage in the Biosphere itself is comparable to that of an industrial area, while the demands of the administrative building and conference center are similar to those of a commercial business zone. The Biosphere's 30 casitas, which can house researchers or people attending conferences, are akin to a residential area.

"If we know we're going to have a perfectly clear day, let's just take advantage of all that free power we're getting."

"We know that it's not a real city," Allen said, "but we think it's close enough that it allows us to do experiments that we think what we learn will be scalable and applicable to real cities. It's a bridge between desktop research and actual application."

One of the ways that Biosphere researchers bridge the gap between the lab and the real world is by examining the relationship between water and energy and then figuring out real-world applications of their findings. Researchers are studying how to predict the sunny days that power solar panels, which could help them determine when they should or shouldn't run energy-intensive machines like water pumps. This solar forecasting is being conducted because unlike traditional energy sources, renewable energy output is hard to predict and, therefore, hard to regulate.

"When you throw a ton of coal into a generator, it creates electricity that's very even," Allen said. "Renewables are not that way. With solar panels, a cloud goes over, the sun goes down, the wind stops blowing—any number of things [make] the power come on and off and on and off."

At the moment the solar panels at Biosphere 2 can offset about 10 percent of the electrical load at noon on sunny days, said Dani DellaGiustina, a research technician with the project.

DellaGiustina will try to coordinate the variable supply of solar power with the demand for water, which is unpredictable because people don't use the same amount of water at the same time every day. The plan is to eventually create control algorithms for Biosphere 2's water pumping system that will coordinate the variable demands for water with the variable supply of solar energy, DellaGiustina said. This strategy would optimize Biosphere 2's large-scale water pumps, which move water from two wells into reservoirs for a combined capacity of 500,000 gallons.

Although the watergy research is in its early stages, Tucson's many sunny days make Biosphere 2 an ideal testing ground for solar forecasting. "We can start off really, really simply, and why shouldn't we?" DellaGiustina said. "If we know we're going to have a perfectly clear day, let's just take advantage of all that free power we're getting."

Part of the reason that DellaGiustina and other Biosphere 2 researchers are doing solar forecasting is because Tucson Electric Power wants to incorporate more solar energy into its portfolio, she said.

Getting the prices right on renewable technologies is the key to their success, said assistant economics professor Derek Lemoine. Making solar energy cost-effective for companies as well as residents doesn't mean subsidies, though. Instead, policy changes will help cast renewable energy in a more positive light.

"Prices need to push on every dimension at one time," Lemoine said, referring not only to monetary costs but also to the effect of energy use on the environment.

Photograph by Holly Bryant

At noontime on sunny days, photovoltaic panels installed on the lawn outside the Biosphere help generate power that offsets about 10 percent of the electrical load of the campus, according to Dani DellaGiustina, a research technician for the Model City project.

DellaGiustina echoed Lemoine's view. She cited Idaho Power as a company whose energy output is partially dependent on wind energy. Policies were changed to accomplish that goal, she said. "There's a lot of really interesting regulations that make it very difficult to incorporate renewables, because you have to have so much confidence in the amount of power that you're going to have available."

If there's an unexpected power outage, for example, a company such as TEP can quickly buy power from another company, DellaGiustina said. Drops in solar and wind energy, however, are not considered true power outages by many power companies. If they were, renewable energy would be more attractive on a commercial level.

To create a brighter, greener future, researchers at Biosphere 2 recognize that they have to find a way to make their technology widely accessible. "We think [the research] will be a compelling way to make progress in making cities more intelligent, more sustainable, improve services and quality of life for the citizens and hopefully renew the environment a little bit," Allen said. "What drives the economy is innovation, not austerity.

A version of this story ran in the Arizona Daily Wildcat.

A Model City

Photograph by Cecil Schwalbe

Nathan Allen, the sustainability coordinator at Biosphere 2, oversees the Model City program.

Biosphere research bridges the gap between the lab and the real world. The Model City program is looking at ways to coordinate the unpredictable demands for water with the production of solar energy. Nathan Allen is working with university researchers and private companies.

Postscript from Futures Past

A Final Note on Biosphere 2

Photograph by Emily Berkson

Biosphere 2 has served many uses since it was created. Now with the UA at the helm, research has become the primary focus.

By Brandon T. Bishop

At night the silhouette of the Biosphere is terrifying—a form that blots out the horizon like a monument of black obsidian. There is something inhuman about it, some after-image of a failed techno-utopian dream trapped within glass and steel and concrete. We stick close to the floodlights at the glass pyramid's base. We pass back and forth stories about the intrigues that went on inside years ago, not sure if they are true, and reports of madmen at the 1893 Chicago World's Fair, hoping they are not true. Perhaps thwarted dreams evoke our darker fears.

Is Biosphere 2 such a dream? Is that its story? There's a degree of truth to this, emphasized by the original Biosphere's oxygen issues. The symbolic value of a building slowly suffocating its inhabitants with their own CO_2 is many leveled. Thwarted dreams also seem characteristic of Ed Bass, Biosphere 2's builder and bankroller, and his long search to find a use for this truly one-of-a-kind laboratory. I suspect members of Columbia University, former tenants of this laboratory, could also recognize some element of truth in this.

* * * * *

In the morning light, as I sit on a rock at the edge of the casitas north of the vast laboratory, things seem different. I feel natural light filtering through my skin uninterrupted by Mylar sheets. I listen as bumblebees buzz in the flowers next to me, not knowing the tragic fate their kind suffered under that nearby pyramid of glass. I feel wind—real wind—brush against my skin, carrying the dry scent of the desert and whispering of mountains close at hand. It feels nothing like the violent gusts that pass back and forth through airlocks inside the monument of glass in lieu of wind.

The smell is also different. Here the subtle scents of diverse plant life from naturally neighboring ecologies harmonize and call to mind both the stifling heat of the desert and the crisp coolness of nearby mountain slopes. It's a welcome change from the strange, complicated scents of ocean, desert, rainforest and grassland that blend into an unrecognizable stinking musk within the glass building to the south. These things that I feel now as the sun clears the mountains give comfort to some ancient, animal part of me that was unnerved by that dark monument in the night.

With primal fears quieted, it becomes possible to re-evaluate this place. The casitas, painted in the bright colors of children's blocks, are just as much a part of Biosphere 2 as the glass laboratory. They seem now like the unrealized waking dream of a half-remembered past—a past equally part of Tucson's Spanish and indigenous heritage and of the ancient village of Çatal Hüyük, where humanity first began to consider urbanism.

There are differences, of course. The birds singing in the desert scrub beside me are New World natives quite unlike their Anatolian counterparts singing in the ruins of that ancient village half a world away. The casitas here are temporary homes of technologists—specialists who share little in common with the Spanish and Tohono O'odham agriculturalists who once called this valley home. But the idea, the concept of creating a community integrated with its environment—and responding to it—is fundamentally the same.

* * * * *

Both halves of the Biosphere 2 grounds have a part in any full telling of this place's story—a retelling of one common in our culture and deeply part of it. One part speaks of our search for a technological solution to our needs, a level of control that is by turns wonderful and terrifying. That is the theme found written in the glass and steel of Biosphere 2 itself. The other part tells of our connections to our traditions and historical forms, the ideas of conservation and unending cycles that derive from old agriculturalist ideals. That is the theme outlined by the plastered walls of the casitas.

The tensions between these themes pull back and forth on the protagonists of the Biosphere 2 story. These tensions exist in Biosphere 2's early history, between John Lackner's ranch and hunting lodge on one side and Motorola's business interests on the other. They exist in the differing views of Biosphere 2's initial crew. They exist now in the scope and focus of different research projects carried out here by today's scientists. They exist even in me as I sit here on a rock writing with pen and paper while knowing this draft will be edited and published on a laptop.

It is unlikely that this place will resolve these tensions even after 20 years of active research and unrelenting change. I can't be too hard on this place for this failure, however. We have yet to settle these tensions as a culture after 20 centuries. What hope could there be for Biosphere 2 to resolve them so quickly?

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For information about Science Journalism courses at the UA, email Carol Schwalbe, cschwalbe@email.arizona.edu

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Photograph by Drew McCullough