RESEARCH THAT MATTERS

World under glass

By Tim Vanderpool
Photographs by Jacob Chinn

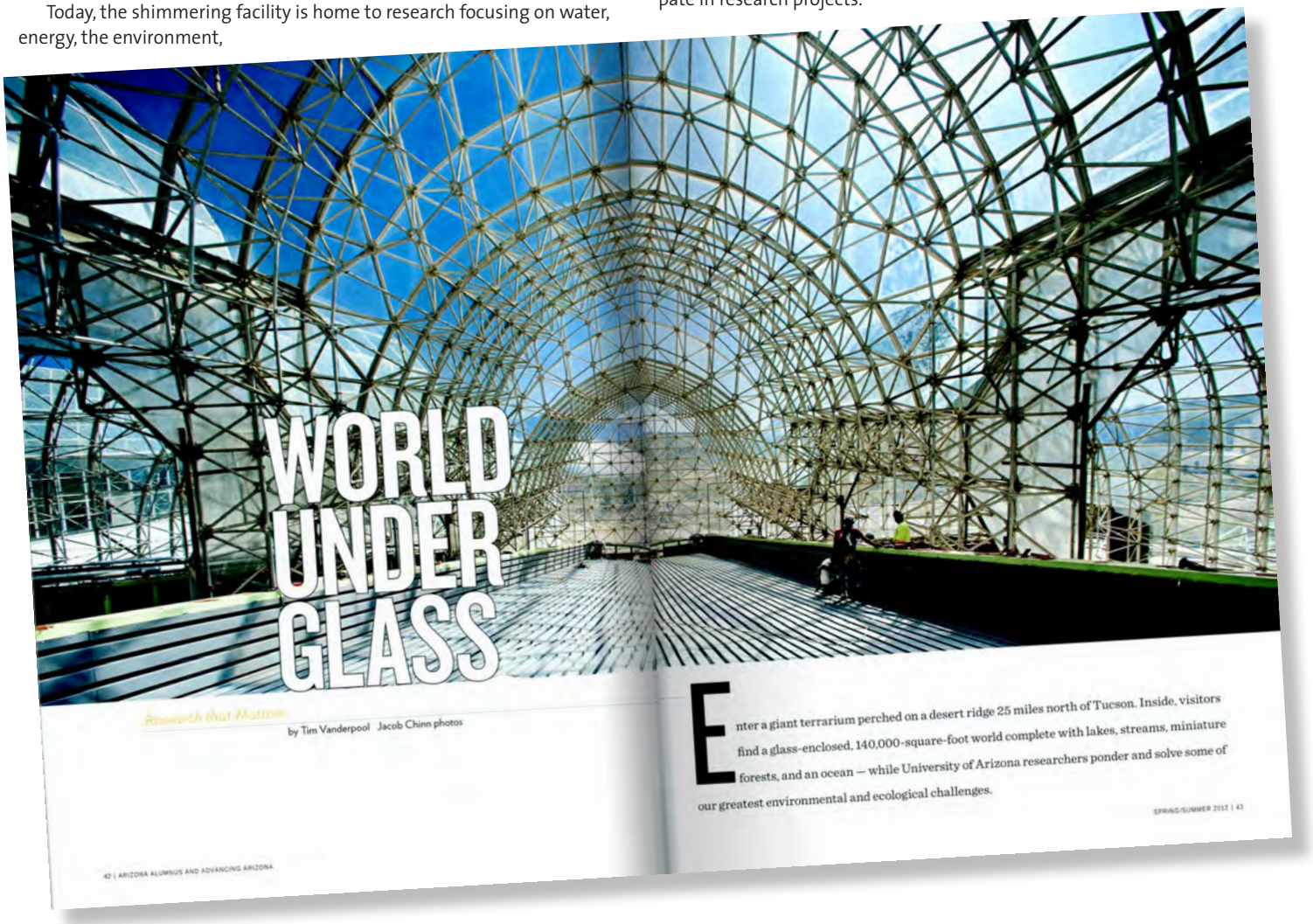
Enter a giant terrarium perched on a desert ridge 25 miles north of Tucson. Inside, visitors find a glass-enclosed, 140,000-square-foot world complete with lakes, streams, miniature forests, and an ocean — while University of Arizona researchers ponder and solve some of our greatest environmental and ecological challenges.

No mere novelty or tourist attraction, Biosphere 2 — so named because it is a model of Earth, the first biosphere — ranks among the leading research centers on the planet. It was donated to the UA College of Science in 2011 by Texas-based owners CDO Ranching and Development. The gift was accompanied by $20 million from the Philecology Foundation, a nonprofit created by Ed Bass, the same Texas businessman who funded construction of the Biosphere in the late 1980s.

Today, the shimmering facility is home to research focusing on water, energy, the environment, and the consequences of global climate change. One project studies the effects of global warming on an already parched American Southwest, while another tests the cooling capacity of rooftop gardens filled with native plants. A third gauges the environmental impacts of new military munitions. Yet another is studying the effects of drought on rainforest ecosystems.

Biosphere 2 is also home to three massive slopes under greenhouse glass, designed to reveal how carbon, energy, and water move through — and change — the terrain. Called the Landscape Evolution Observatory, it has the ambitious mission of revealing how climate change might affect those complex processes.

And though Biosphere 2 may be enclosed, it's hardly cloistered. The facility offers ongoing tours and outreach programs such as Science Saturdays — fascinating, often hands-on forums where scientists discuss their special areas of study — and Citizen Science, which encourages visitors to participate in research projects.



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Those programs are a hit; thousands of visitors explore the Biosphere 2's 40-acre campus each year; they leave with a glimpse of cutting-edge science. "We're trying to use Biosphere 2 as a model city for testing innovative energy and water management strategies," says Hassan Hijazi, director of external affairs. "By applying this research on a smaller scale at the Biosphere, we can take the lessons we learn on the inside — in this controlled system — and apply it to the outside world."

Advancing deserts

As temperature and weather patterns change, invasive plants are often quick to move into newly hospitable areas. Their presence, in turn, can transform once-fertile regions into permanent deserts, as each new species battles for resources — from nutrients to soil moisture — in a constantly shifting landscape.

This looming threat is the focus of recently completed research by Sujith Ravi, an assistant research professor at Biosphere 2. Though he and his colleagues are still sifting through mountains of data, Ravi believes the project will ultimately offer insights into this daunting global pattern — thanks to the exclusive capabilities of Biosphere 2. "The Biosphere is a unique tool," says Ravi, "in that we can actually repeat the experiment in different climates."

Under the dome's protective cover, he monitored plant behavior in two settings, one of which was kept three to four degrees warmer than the other. Ravi's experiment used native grasses and an invasive species currently plaguing the American Southwest called buffel grass. "We wanted to look at how those two species interact," he says, "how they use water, how they cycle carbon, and how those interactions changed in a warmer climate."

Of course, those various climates don't just happen accidentally at Biosphere 2. Like Oz behind his curtain, support engineers and a bank of computers control the biome systems. "We just let the engineers know what conditions we need," Ravi says. "They can even create rainfall in different areas of the biome and maintain certain levels of humidity."

Such precision has made it clear that nonnative plants fare better than their native cousins in the hotter climate. And in drought's aftermath, exotics are far quicker to bounce back.

The result, Ravi says, "is that you could end up with a one-species landscape." And that is not a good omen for dry times. "Normally, if you have a landscape with more biodiversity, it adapts better to drought conditions."

Gauging the rainforest

Global climate change researchers predict that the Amazon basin will grow much drier in coming years. But if so, how will the vast forest be changed? That's a question being addressed by Joost van Haren, a doctoral student at Biosphere 2.

Because the facility is enclosed, he's able to subject its rainforests to specific conditions and gauge the results with remarkable precision. "The

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Biosphere is actually the only rainforest we have where we can control the precipitation in great detail," van Haren says. "We can make it rain when we want it to rain, and we don't have to wait for Mother Nature to do her thing."

Working under glass also allows researchers to closely monitor how plants and the soil respond to specific changes in precipitation — and to exclude many factors found in the outside world that can skew research results.

Much of the Amazon Basin's precipitation cycle is sparked by the trees themselves. Since huge swaths of that forest are being decimated each year, predicting the full impact of changes in precipitation has proved elusive. But by taking advantage of Arizona's seasonally shifting light cycles — which don't exist along the Amazonian equator — researchers are able to monitor changes as varying levels of sunlight reach the formerly shaded and increasingly dry forest floor.

"It allows us to get more at the question: What is really driving the response of the plants to drought?" says van Haren. "Is it a response driven by precipitation? Or is it a response that's driven by the light?"

Cool rooftops

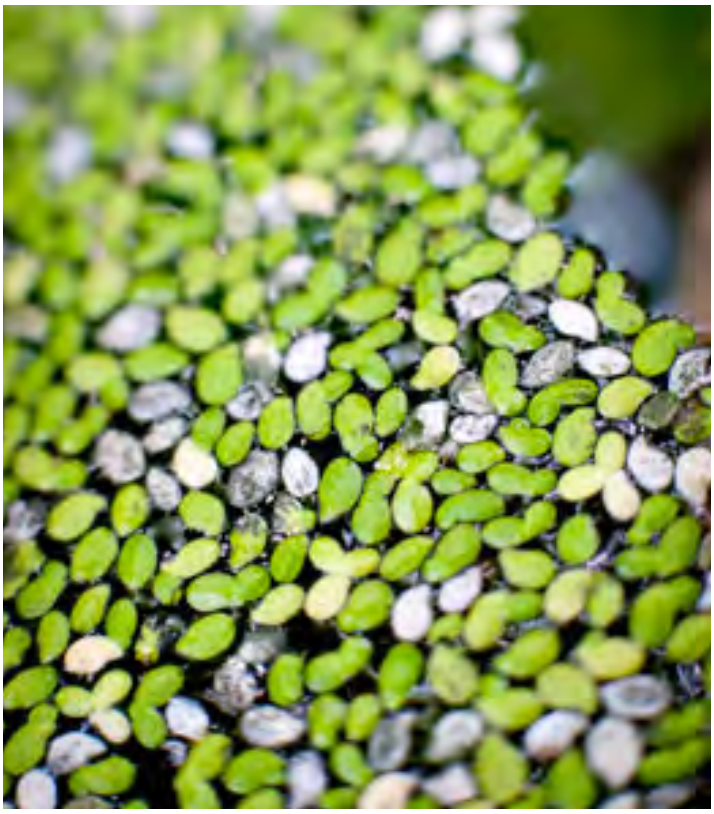
Emerging science views cities as urban ecosystems. That means we need to understand how metropolitan systems operate — and find strategies for keeping them healthy.

One goal is reducing the "heat island" effect caused by an abundance of pavement and asphalt rooftops. Another is reducing home energy use. Both are the focus of Biosphere 2's Green Roofs Project, which aims to turn residential roofs into cooling green spaces by populating them with native plants.

The rooftops in the project adorn miniature homes stretching in colorful rows along the Biosphere's perimeter. The project is directed by Assistant Research Professor Mitch Pavao-Zuckerman, with help from citizen scientists who assist in plant and soil monitoring.

Their goal is to answer one big question, says Pavao-Zuckerman. "Can you cool a building by having a layer of soil (on top) that acts as insulation and plants that provide the evaporative movement of water, almost like a living swamp cooler?"

His team aims to find out by monitoring the miniature houses, each fitted with a rooftop planting box. But success also depends on one key element: assistance from Biosphere visitors — or, as the Biosphere calls them, citizen scientists. "We've had people out there collecting data with handheld sensors," Pavao-Zuckerman says, "measuring soil temperature,



soil moisture — things like that to help us characterize the energy and water use."

So while these homes may be charming and tiny, their task is quite serious. Indeed, studies from the Midwest demonstrate that planted roofs can cool building interiors by up to 30 degrees. It's Pavao-Zuckerman's task to determine whether we can achieve similar results in simmering, southwestern summers.

Military impacts

Biosphere 2 is on the U.S. Department of Defense's radar. That became clear recently when the DoD awarded a $1.35 million grant to UA researchers to study how the latest generation of munitions reacts in the environment. Not surprisingly, that's a huge concern for communities near military training facilities.

Known as "insensitive" munitions, these new weapons are much less likely to detonate by accident. Less clear is how they react when dissolving, unexploded, into the soil. That's where Biosphere 2 comes in.

The project was designed in part by Assistant Research Professor Katerina Dontsova. "Just like many other manufactured chemicals, munitions can present environmental concerns if they enter the groundwater," she says, "and the military has had previous problems with that. So they want to be sure, when they create new munitions, that they have as little impact as possible."

The project is a collaboration between the UA Department of Soil, Water & Environmental Science and analysts at Biosphere 2. Dontsova calls it a perfect fit. "The Biosphere has a mission of outreach," she says, "and a part of this outreach is focused on the understanding of environmental issues that our planet is facing. A lot of our activities deal with the choices that humans make and how those choices are reflected in their impacts on the earth."

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International oasis

If water is precious everywhere, that's doubly true in the world's most arid regions, like the Sonoran Desert of southern Arizona and the vast Middle Eastern dunes of Oman.

By necessity, desert dwellers are expert at stretching — and sharing — this life-giving resource to the ultimate degree. And few are more adept than the people of Oman, a nation bordered by United Arab Emirates, Saudi Arabia, and Yemen.

For centuries, the Omanis have used an ingenious distribution system called falaj, which employs subterranean channels to deliver water to farmers and villagers. Typically, those channels emanate from a main well, dispersing water along a course dotted by side channels. The efficiency of the falaj offers valuable lessons for us all.

Fortunately, that worthy example of water cooperation just became a lot more accessible to us here in the Sonoran Desert, with a $298,000 grant made possible by the Sultan Qaboos Cultural Center (SQCC) to create a model falaj at Biosphere 2 called Water Oasis.

This generous gift not only offers a bridge between cultures, but also reveals the international reach of UA alumni. A significant boost for the project came from Sultan Hamdoon Al Harthi, mayor of Muscat, Oman's capital city, and 2011 College of Architecture and Landscape Architecture Alumnus of the Year. Discussions leading to the gift were furthered by Peter Smith, a prominent professor in the UA Department of Lunar and Planetary Sciences with professional ties to the Middle East.

The project is likewise a team effort here at home, tapping the expertise of Biosphere 2 and the design skills of students in the UA Landscape Architecture program.

Ultimately, the falaj has become a model in more ways than one. "All of this is generated through international collaboration," says Hassan Hijazi, Biosphere 2's director of external affairs. "It sends a great message. There are so many ways that people can work together, especially on this most precious commodity, which is water — and now a country that has this simple method to distribute water can show it off to the world."

And show it off they will. "The Biosphere gets about 100,000 visitors every year," says Hijazi. "Everybody will be exposed to this water exhibit and its importance in the world."