



Biosphere 2 NEWS

Life Names Biosphere 2 "Man-Made Wonder"

The UA's Biosphere 2 has been recognized as one of the world's "50 Must-See Natural and Man-made Marvels." A new publication released by Life Books lists the Biosphere 2 alongside the likes of the Eiffel Tower, Sydney Opera House, Burj Dubai, Hubble Telescope and International Space Station.

Edward P. Bass Receives Honorary PhD Degree from The University of Arizona



June 2007 was an auspicious month for The University of Arizona. On that date the UA undertook management of Biosphere 2. Since then, we have been engaged in research that would be difficult, if not impossible, to do anywhere else. The capabilities of Biosphere 2 make this facility a unique laboratory in which scientists can observe the consequences of a changing climate. We have also created programs that are educating our community about the challenges we will face with a changing climate.

Edward P. Bass

Human endeavors have now surpassed natural processes and humans are affecting our globe in unimaginable ways. We have altered the chemistry of the atmosphere, we have altered the chemistry of the oceans, and we have altered the regimes of water, erosion and fire. The planet's response to this is difficult to evaluate, but Biosphere 2 is extraordinarily equipped to work on these critical issues.

Edward P. Bass was the visionary who built Biosphere 2 in 1984 with the goal of better understanding the complex feedback mechanisms that control the Earth's environment. As a committed conservationist, he must be thrilled to see Biosphere 2 become a center for global climate research. I am pleased to announce that on May 15, Mr. Bass will be presented with an honorary degree of Doctor of Science from The University of Arizona. Please join me in congratulating Mr. Bass for his extraordinary accomplishments. ■

Joaquin Ruiz
Dean of the College of Science
The University of Arizona

Letter from the Provost

The University of Arizona has emerged as a world leader in many disciplines over the past decade. But given our Southwest desert location there is probably no field more critical to the state and our nation's future than UA's work on issues impacting sustainability and the environment.

Becoming a leader in all aspects of environmental research is an absolute priority for our University, and Biosphere 2 plays a central role in that effort. No other facility in the world provides the unique laboratory environment of Biosphere 2. It gives the UA a one-of-a-kind platform to expand what the world knows about our planet, and how we can survive and prosper in the face of global climate changes.

Every day, in labs all across our campus, UA scientists are shaping the future. There is no better example of that than what you see at Biosphere 2. It is a tremendous symbol of our commitment to world-class research that makes life better for the people of Arizona. ■



Meredith Hay, PhD
Executive Vice President
and Provost
The University of Arizona

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Arizona Center for STEM Teachers: Off to a Great Start

The Arizona Center for STEM Teachers (ACST) was created in December 2008 through a three-year, \$1.5 million grant by Science Foundation Arizona (SFAz) to The University of Arizona's B2 Institute to establish a resource and training center that will expand the quality and retention of science, technology, engineering and mathematics (STEM) teachers in Arizona. The Center's mission is to enhance and deepen the skills of Arizona STEM educators to ensure that their teaching translates to successful graduates who can effectively compete and prosper in the 21st century marketplace. The Phileology Foundation is partnering and providing a matching grant to fully fund the Center.

Biosphere 2 and the Arizona STEM Center at Science Foundation Arizona (STEMAz) hosted the Arizona Schools Superintendents Summit on December 3. Educators from across the state along with local, state and federal elected officials attended the event.

ACST also recently held its first two short courses for science and math teachers from around the state of Arizona.

The first short course, "Discovering Darwin Days: Teaching Evolution in the K-12 Classroom," was held during the weekend of February 13-15 and was attended by 44

active K-12 teachers. The inaugural workshop kicked off programs that are slated to engage more than 300 teachers statewide within three years. The weekend was dedicated to taking a close look at evolution, in celebration of Charles Darwin's 200th birthday.

"Being able to collaborate with other educators and to hear from experts in cutting-edge research was a renewing and inspiring experience," said participant Retta Ward, science department chair at Cactus Shadows High School in Scottsdale. "After 18 years as a teacher, and with ever-growing challenges and a shrinking budget, it is easy to become discouraged with the current state of education, particularly in Arizona. I have already begun to incorporate some of the new things I learned into my classroom, and I definitely have a more positive outlook this week," she added. "The whole event was spectacular from start to finish."

The Arizona K-12 Science Teacher Symposium, ACST's second short course, was hosted in partnership with the University of Arizona's BIO5

Institute during the weekend of April 17-19 and was attended by more than 150 science teachers from around the state. Topics covered included water quality, microclimate, plant matrices, DNA electrophoresis, and environmental justice.

The goal of all ACST programming is to help teachers ensure that their teaching prepares students to succeed in the 21st century world, said Pierre Meystre, B2 Institute director and principal investigator for ACST. "The unique aspect of ACST is that it is teacher driven," Meystre said. "Part of this process is to treat teachers like the valued professionals that they are. That's why stipends, room and board, and other perks will be included in all ACST programs."

During the symposium, ACST's Education Committee composed



Karen Moore (far right) and fellow teachers experimented with prisms during the Galileoscope workshop at the recent Arizona Science Teachers Symposium at Biosphere 2.



Dr. Matthew Kaplan of the Human Origins Genotyping Laboratory led a breakout session on human DNA for teacher participants at the ACST-sponsored Darwin Days short course at Biosphere 2 in February.



Science teacher Julia Guerrero (left) handled a giant cockroach during the Insect Discovery workshop at the recent Arizona Science Teachers Symposium at Biosphere 2.

of six veteran, master K-12 teachers from around the state, selected 35 teacher participants for the next program, the Summer Institute. The Institute is an intensive residential program that incorporates research projects, formal lectures, and

curriculum development. The inaugural Institute will take place July 8-25.

Biosphere 2's initial ACST efforts appear headed in the right direction, Darwin Days participant and Tucson

second-grade teacher Jennifer Valentine, of Gallego Elementary School, agreed. "It was definitely one of the very best professional development experiences I've had in my 11 years as a teacher," Valentine said. ■

Federal and state elected officials address school administrators attending the Arizona School Superintendents Summit on December 3. Top left: Congresswoman Gabrielle Giffords; top right: Congressman Raul Grijalva; bottom left: State Representative David Bradley; bottom right: State Representative Olivia Cajero Bedford.



B2 Announces the Science and Society Fellows for 2009-2010!

Initiated in 2008, The University of Arizona Biosphere 2 Science and Society Fellows Program was created for UA graduate students undertaking research in the areas of ecology, earth, and environmental sciences. The goals of the program are to increase the skills of the Fellows in communicating their research outside an academic setting through public outreach events, blogs, and displays; and to advance the understanding of scientific information and the scientific process by members of the general public. Research areas for the new fellows include the science of ecosystem restoration, drought and climate change in the Santa Catalina Mountains, trace organic contaminants in wastewater, monsoon season rainfall across the southwestern United States, and the behavior and survival of aquatic insects, specifically giant water bugs. ■



Chris Goforth



Daniel Griffin



Alandra Kahl



Rebecca Lloyd



Bryan Morovec

Featured Research Projects

Trace Gas Research

Investigating the exchange of volatile organic compounds and carbon dioxide between the Biosphere and the atmosphere



Instruments in the trace gas isotope lab at Biosphere 2 (from left): proton transfer reaction mass spectrometer (PTR-MS), quantum cascade laser absorption spectrometer (QCLAS), and gas chromatograph-ion trap mass spectrometer (GC-ITMS).

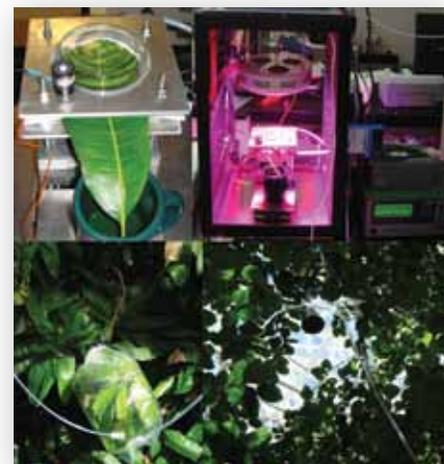
During photosynthesis, plants take carbon dioxide (CO_2) from the atmosphere to form organic matter, allowing them to grow. They release a fraction of it back in the form of CO_2 and volatile organic compounds (VOCs). While CO_2 directly influences climate by acting as a potent greenhouse gas, VOCs do so indirectly by influencing the oxidizing capacity (the ability to remove trace gases such as methane and carbon monoxide through oxidation) and the acidity of the atmosphere and by increasing the size of aerosol particles that are suspended there. Although the exchange of these trace gases between the biosphere and the atmosphere has a large impact on the global carbon cycle, air quality, and climate, the underlying biochemical processes that contribute to the primary carbon metabolism of forests remains poorly understood.

To investigate these topics as well as support future studies of land-atmosphere gas exchange, Dr. Kolby Jardine is establishing a world-class trace gas isotope lab at Biosphere 2. The lab is currently managing two newly upgraded instruments (top photo) including a proton transfer

reaction mass spectrometer (PTR-MS) and a gas chromatograph iontrap mass spectrometer (GC-ITMS). These instruments allow for continuous real-time quantification of VOCs in the air at concentrations as low as a few parts per trillion. Another key instrument recently purchased by Biosphere 2 is an Aerodyne quantum cascade laser absorption spectrometer (QCLAS). This instrument allows isotopic ratios in carbon dioxide to be monitored in real-time; it is currently being developed and tested at Aerodyne Research in Massachusetts.

Biosphere 2 is an ideal location for this lab because it provides the combined benefits of a state-of-the-art 21st century analytical chemistry lab and large-scale enclosed systems such as the tropical rainforest biome and hillslopes. By doing this research within the Biosphere 2 facility, we can observe the exchange of gases between the biosphere and the atmosphere at multiple scales. Other key advantages of studying these gases in the tropical rainforest biome are the high species diversity represented there, the full enclosure of the system—which enables the gas concentrations to accumulate

to levels generally higher than observed in natural forest air—and the lack of ultraviolet light and therefore oxidants such as ozone, which destroys these compounds in the atmosphere. These advantages are enabling the discovery of novel VOCs not previously observed in the atmosphere and the characterization of VOCs that are so rapidly destroyed in the atmosphere that they are hard to study. These studies promise to transform our understanding of both primary metabolism in plants and how it influences air quality and climate. ■



Biosphere 2 offers the possibility of studying trace gases at the leaf, branch, and ecosystem scales.

Pinyon Pine Research

The first research paper on work at Biosphere 2 under management by the University of Arizona was published this spring in the *Proceedings of the National Academy of Sciences, USA*. In the study, University of Arizona ecologist and principal investigator Henry Adams and colleagues transplanted mature pinyon pines into several areas of Biosphere 2. With help from B2 staff they created a temperature difference between two areas of the former wilderness biomes: the lower savanna, where temperatures were kept as close as possible to normal for the species range, and the desert biome, which was kept elevated approximately 4°C above the lower savanna area. They started the experiment by withholding water from half of the trees in each of these areas to simulate a severe drought, while the others trees continued to be watered as before. They ran the temperature and watering treatments until all of the trees experiencing drought died.

All of the trees under a warmer drought died before any of the ambient drought trees died, with the warmer trees dying 28% sooner than the ambient trees. This result documented that drought mortality in these trees was highly sensitive to temperature, and confirmed previous speculation that increased temperatures were behind the widespread pinyon die-off that peaked in the Four Corners area in 2002. Detailed measurements of water stress and carbon exchange (photosynthesis and respiration) revealed that carbon starvation was the primary mechanism by which

these trees died from drought, as hypothesized by previous research. The trees closed their pores, or stomata, to prevent water loss and attempted to wait out the drought. Since stomata also serve to admit carbon dioxide into the leaf, their closure curtailed photosynthesis during the drought, yet the trees still needed to respire stored carbon to maintain tissue. When they ran out of this fuel, they died. This mechanism also explains the temperature sensitivity: because respiration rates are higher with warmer temperatures, trees under warmer drought conditions simply spent their stored reserves faster than the ambient drought trees.

The paper goes further, extrapolating the temperature difference in survival time to predict sharp increases in the frequency of widespread die-off events. The 2002 drought that caused widespread pinyon die-off in the Southwest—the only drought in the last 103 years where this was observed—represented a severe 6-month regional drought. If temperatures become warmer by around 4°C in the future, a 28% shorter, 4.3-month drought would be sufficient to cause widespread die-off. Shorter droughts are much more frequent than longer droughts; while the 6-month 2002 drought



A dead unwatered drought tree and a surviving watered control tree inside Biosphere 2 after the experiment was completed.

only occurred once, there were five 4.3-month droughts in the last 100 years. This suggests that with warming, widespread pinyon die-off could go from being a once-a-century event to something that occurs every 20 years! In fact, this prediction was conservative because it didn't include changes in drought frequency and bark beetle populations, which are expected to increase with warming.

These results suggest that other forests may be very vulnerable to global change and could experience sudden, drastic changes, including loss of wildlife habitat, carbon sequestration, and changes to water budgets that could reduce water availability downslope. The media picked up on this story, and the research was featured in over 50 media outlets, including National Public Radio, *Time*, *Scientific American*, and cover stories in the *Tucson Citizen*, *Albuquerque Journal*, and *Arizona Daily Republic*. ■

Biological Invasions and Desertification Research

Desert margins are very sensitive to external forces like climate change and are easily affected by rapid land degradation and desertification. A common form of land degradation at the desert margins is a rapid shift in vegetation such as invasion by

exotic grasses. It is recognized that changing environmental conditions (as from climate change and shifting land management practices) may have favored the invasion by exotic grasses in many dryland ecosystems, such as the Sonoran Desert. But very few studies have investigated and

compared the interactions between native vegetation and invasive grasses in these changing scenarios. Many arid regions around the world—including the North American deserts—are expected to more frequently be affected by recurrent

Biological Invasions, cont. on 6

New Science Research Program Leaders

Biosphere 2 welcomes Dr. Alex Cronin and Dr. Matt Sullivan as B2 Chief Research Scientists



Alex Cronin

Dr. Cronin, Associate Professor of Physics and Optical Sciences, is a leading University of Arizona

researcher on solar energy. His current research on solar photovoltaic performance includes collaborations with ASU, UA and Tucson Electric Power. He also has received support for further research and outreach efforts from Science Foundation Arizona, AZRISE, a Graduate Incentive for Growth

Award, and a NASA Space Grant Graduate Fellowship. Cronin has been pivotal in bringing solar to Biosphere2 as well as unmatched expertise and enthusiasm to Biosphere 2's growing research program.



Matthew Sullivan

Assistant Professor Matthew Sullivan aims to understand the influence of viruses on the microorganism-driven biogeochemical cycles that fuel

life on Earth. For example, ocean viruses that infect the dominant photosynthetic cells of the planet (cyanobacteria) often contain the core reaction center genes of photosynthesis; these genes are expressed during infection, and alter at a global scale the evolutionary path of photosynthetic protein complexes.

Sullivan's work in the UA Department of Ecology and Evolutionary Biology pairs a model-systems hypothesis-driven approach with exploratory genomic studies to open new windows into ocean virus-host biology in the Biosphere 2 Ocean and other real-world, climate-sensitive, and "extreme" ocean regions. ■

Biological Invasions, cont. from 5

droughts, further compromising the capacity of these landscapes to adjust to human-caused increases in atmospheric CO₂ and associated global warming. Thus, understanding the interactions between native and invasive grasses, in the context of rising temperatures and recurrent droughts, is fundamental to global change research.

At Biosphere 2, we are investigating how the altered ecohydrological feedbacks from exotic grass invasion may cause irreversible desertification. We hypothesized that two major drivers of global environmental change—biological invasions and climate change—may act in concert to amplify each other's impacts on land cover and soil resources. In the Sonoran Desert, invasion by exotic grasses can increase fire frequency, shrub mortality, and soil loss, thereby destroying the heterogeneity of resources typical of desert shrublands and favoring their conversion into exotic grasslands. Many invasive grasses have the ability to alter their morphology and physiological processes in response to environmental changes even in low-resource environments, allowing them to survive in unfavorable environmental conditions and to

invade these landscapes in years of high resource availability. However, the long-term persistence of invasive grasses may be limited by low-frequency recurrent droughts, which displace these plant species that have not evolved under this regional climatic context.

To validate this desertification hypothesis, we are designing experiments under the Biosphere 2 dome to investigate the impact of drought and rising temperatures on native and invasive grass communities. How do these communities use and distribute resources such as soil moisture and nutrients under changing environmental conditions? We are specifically interested in understanding the above- and below-ground features that may allow invasive grasses to out-compete the natives in taking up nutrients and soil moisture and in consistently maintaining larger densities. The experiment will involve growing patches of native grasses, invasive grasses, and mixed communities in two locations with a temperature difference of 4°C. One location will be maintained at the ambient conditions of the Sonoran Desert and the other will be maintained

at a warmer temperature (+4°C) to simulate a future-warming scenario. We are planning to compare the physiological responses (photosynthesis, respiration, water use) and root growth responses (using root observation cameras) of native and invasive grass communities. Further, we will investigate with isotopic tracers how the plant communities use and distribute resources like nitrogen and how this pattern changes with rising temperatures. Finally, we will monitor the physiological responses, resource use patterns, and mortality of these plant communities under moisture stress conditions to simulate a global-change-type drought.

This research project has implications for issues ranging from desertification, sustainable management of dryland ecosystems, and the response of these systems to climate change and disturbances. Through cross-disciplinary collaborations, this project will relate earth-surface science to the dynamics of biological systems to help us better understand and model the complexity of ecohydrological processes in arid and semi-arid regions. ■



The First Annual UA/Biosphere 2 Earth Day Celebration

Despite rain, hail and cold weather, 1,400 people—a record crowd—visited Biosphere 2 to celebrate the first University of Arizona Biosphere 2 Earth Day. People young and old, science-inclined and not, came to celebrate earth in the mini-natural world of Biosphere 2. The event was a combination of art, science, green technology, and businesses with “green music” as a key element. The Kontomble Percussion Quartet played instruments made of natural non-metallic materials. Two Steel Bands, Falcon Steel and Apocalypso, demonstrated to listeners that recycled oil barrels never

sounded so good. Tucson Symphony Orchestra harpist Patricia Harris performed soothing music on the little “troubadour” harp, and the inner world of the Biosphere was explored by Native American flutist and vocalist Mary Redhouse.

With Earth Day 2009 at the UA’s Biosphere 2, we joined thousands of schools across the United States and the world to educate students of all ages about making informed decisions on protecting our planet and using our natural resources. ■



Biosphere 2 staff grilled up an array of tasty food for hungry visitors.



Over 40 vendors gathered at Biosphere 2 to participate in Earth Day.



Visitors gathered under the tent to enjoy the festival sounds while enjoying a bite to eat.



The Falcons Steel Band with its tropical sounds warmed up visitors.



Guest speakers Jane Poynter and Taber MacCallum discussed the history of Biosphere 2.



Visitors view the NASA Astronomy Exhibit on permanent display in the Biosphere.

Music of the Sphere

On January 25th of this year, music for the first time filled the Sphere, both inside and out. Visitors were greeted in the Rainforest Pavilion by the Reville Mens Chorus, singing songs from around the world. Under the glass, the dynamic guitar duo Brazukas performed on the ocean beach. In the Exhibition Hall, Biosphere’s newest inhabitant, a grand piano, made its debut under the hands of pianist Simone Gorete Machado in a unique joint presentation with Amazonian specialist Scott Saleska, who provided the science. In this musical-scientific

dialogue, audiences were treated to information about the tropical rainforest along with visual imagery complemented by classical piano works by Brazilian composers. At the end of the afternoon visitors literally danced their way out to the infectious sounds of the Brazilian dance band Sambalanço. This event was funded by the College of Fine Arts Dean’s Fund for Excellence.

Far from being just a concert venue, Biosphere 2 is well on its way to becoming “the place where science and the arts meet.” ■



Guitar duo Brazukas play on the beach at Biosphere 2.

B2 Plans to Go Solar, Thanks to SOLON Corp. Gift

SOLON Corp., a Tucson solar panel manufacturing firm, has donated 500 photovoltaic modules valued at more than \$200,000 to provide nearly 50 kilowatts of energy to UA's Biosphere 2.

The panels to be installed over the summer will provide power to the B2 Institute Conference Center and serve as an education and public demonstration site.

The array will also serve as a research site for exploring the performance of photovoltaic technology in Arizona, in a project led by Dr. Alex Cronin.

We are grateful to SOLON for their generous donation and leadership in promoting research for the advancement of solar technology at The University of Arizona. ■



Olaf Koester, CEO of SOLON, and Travis Huxman, Director of Biosphere 2, discuss the benefits of solar.

Sustainability Tip

Biosphere 2 was built to leak only 10 percent of its air per year. The space shuttles leak 2 percent per day.

Weather sealing is usually something we think about doing in the winter. But weather stripping, caulking, and insulation are just as important in the summer to efficiently keep your house cool.

How You Can Help

Biosphere 2's cutting-edge work depends on people who care about our environment and the science that helps us make informed choices. We hope you will consider becoming involved, in any of the following ways.

- 1. Learn more** about the many research projects taking place under the dome. You can also see some of our ongoing research through our live webcam.
- 2. Take a tour** of Biosphere 2. We are open every day from 9:00 to 4:00 except Thanksgiving and Christmas.
- 3. Become a member.** There are many different levels of membership that provide benefits for you and support of our work.
- 4. Attend a Science Saturday** for a hands-on experience in science! You could learn about bird species in the

Southwest through an on-site birding experience, gain a new appreciation for insects and experience at handling live insects, or participate in physics activities and in demonstrations that show how water moves in urban environments.

- 5. Make a donation.** Any gift is appreciated and can be designated to the Biosphere 2 activity or research project that matters most to you.

For more information on any of the above, visit our website, www.B2science.org. ■



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