Water, Energy, and the Arid Environment Strategic Planning Workshop Sept 15-16

Name	Email	Title	Affiliation
John R. Adams	jadamsb2@email.arizona.edu	Deputy Director	Biosphere2
David Allen	davida@tla.arizona.edu	Vice President	Tech Launch Arizona
Parker Antin	pba@email.arizona.edu	Associate Dean, Research	College of Agriculture and Life Sciences
Neal Armstrong	nra@email.arizona.edu	Associate VP for Research	Office for Research & Discovery
Bob Arnold	rga@email.arizona.edu	Professor	Chemical and Environmental Engineering
Diane Austin	daustin@email.arizona.edu	Director	School of Anthropolgy
Laura Bakkensen	laurabakkensen@email.arizona.edu	Assistant Professor	School of Government and Public Policy
Ardeth Barnhart	ardethb@email.arizona.edu	Program Director	Renewable Energy
Greg Barron-Gafford	gregbg@email.arizona.edu	Assistant Professor	Biosphere 2 & Geography and Development
Jennifer Barton	barton@email.arizona.edu	Associate VP for Research	Office for Research & Discovery
Arnoldo Bautista	abautista@email.arizona.edu		Center of Mexican Studies
Dennis Beal	dwbeal@email.arizona.edu	AVR Business Development	Office for Research & Discovery
Eric Betterton	betterton@atmo.arizona.edu	Department Head	Atmospheric Sciences
David Breshears	daveb@email.arizona.edu	Professor	School of Natural Resource & Environment
Heidi Brown	heidibrown@email.arizona.edu	Assistant Professor	Public Health
Paul Brown	pbrown@ag.arizona.edu	Associate Director	Agriculture Extension Administration
Jim Buizer	buizer@email.arizona.edu	Research Scientist	Natural Resources and the Environment
Jeff Burgess	jburgess@email.arizona.edu	Associate Dean	Public Health
Shane Burgess	sburgess@cals.arizona.edu	Director	College of Agriculture and Life Sciences
Jim Buzier	buizer@email.arizona.edu		
Chuck Cairns	cairnsc@email.arizona.edu	Interim Dean	College of Medicine
Christopher Castro	castro@atmo.arizona.edu	Associate Professor	Atmospheric Sciences
Jan Cervelli	jcervell@email.arizona.edu	Dean	College of Architecture-Landscape Architecture
Elliot Cheu	echeu@email.arizona.edu	Associate Dean	College of Science
Karletta Chief	kchief@email.arizona.edu	Assistnat Specialist	Solil/Water and Environmental Sciences
Jon Chorover	chorover@email.arizona.edu	Department Head	Soil/Water and Environmental Science
Chris Cokinos	cokinos@email.arizona.edu	Associate Professor	English
Bonnie Colby	bcolby@ag.arizona.edu	Professor	Agriculture Resource Economics
Julia Cole	jecole@email.arizona.edu	Professor	Geosciences
Anne Cress	cress@email.arizona.edu	Deputy Dean, Research Affairs	College of Medicine
Pierre Deymier	deymier@email.arizona.edu	Department Head	Materials Science & Engineering
Peter Ellsworth	peterell@cals.arizona.edu	Specialist	Entomology / Bio 5
Kirsten Engel	engel@law.arizona.edu	Professor	Law
Kimberly Andrews Espy	kespy@email.arizona.edu	Senior Vice President	Office for Research & Discovery
Regis Ferriere	regisf@email.arizona.edu	Associate Professor	Ecology and Evolutionary Biology
George Frisvold	frisvold@ag.arizona.edu	Professor	Agriculture Resource Economics
Laura Galindo	galindoislas@email.arizona.edu		Center of Mexican Studies
Caroline Garcia	cmgarcia@email.arizona.edu	Associate VP for Research	Office for Research & Discovery
Gene Giacomelli	giacomel@ag.arizona.edu	Director	Controlled Environment Argriculture Program
Robert Glennon	glennon@law.arizona.edu	Regents Professor	Law
Jeff Goldberg	jgoldberg@arizona.edu	Dean	College of Engineering
Lucio Guerrero	luciog@email.arizona.edu	Director, Communications	Office for Research & Discovery
Kristin Gunckel	kgunckel@email.arizona.edu	Associate Professor	Teaching/Learning and Sociocultural Studies
Iman Hakim	ihakim@email.arizona.edu	Dean	Public Health
Adam Henry	adhenry@email.arizona.edu	Assistant Professor	School of Government and Public Policy
Bonnie Hurwitz	bhurwitz@email.arizona.edu	Assistant Professor	Agricultural-Biosystems Engineering
Kathy Jacobs	jacobsk@email.arizona.edu	Director	Center fir Climate Adaptation Science and Solutions
Bruce Johnson	brucej@email.arizona.edu	Department Head	Teaching/Learning and Sociocultural Studies
JP Jones	jpjones@email.arizona.edu	Dean	Social and Behavioral Sciences
Tom Koch	tlkoch@email.arizona.edu	Dean	College of Optical Sciences
Ray Kostuk	kostuk@email.arizona.edu	Professor	Electrical and Computer Engineering
Lloyd Lacomb	llacomb@email.arizona.edu	Research Professor	College of Optical Sciences
Kevin Lansey	lansey@email.arizona.edu	Department Head	Civil Engineering - Engineering Mechanics
Frank Lederman	FrankLederman@comcast.net	Facilitator	
Derek Lemoine	dlemoine@email.arizona.edu	Assistant Professor	Economics
Peiwen Li	peiwen@email.arizona.edu	Professor	Aerospace and Mechanical Engineering
Brian Liesveld	brianliesveld@email.arizona.edu	Program Manager, DSRI	Office for Research & Discovery
Diana Liverman	liverman@email.arizona.edu	Co-Director	Institute of the Environment
Laura Lopez Hoffman	lauralh@email.arizona.edu	Assistant Research Professor	Udall Center
Raina Maier	rmaier@ag.Arizona.edu	Professor	Soil/Water and Environmental Science

Stuart Marsh	smarsh@email.arizona.edu	Director	School of Natural Resource & Environment
Ann McGuigan	amcguigan@email.arizona.edu	Director, Research Development	Office for Research & Discovery
Cecile McKee	mckee@email.arizona.edu	Associate Dean, Research	Social and Behavioral Sciences
Kenneth McLaughlin	mcl@math.arizona.edu	Department Head	Mathematics
Sharon Megdal	smegdal@email.arizona.edu	Director	Water Resrources Research Center
Tom Meixner	tmeixner@email.arizona.edu	Associate Head	Hydrology
Kathleen Melde	melde@ece.arizona.edu	Professor	Electrical and Computer Engineering
Oliver Monti	monti@email.arizona.edu	Associate Professor	Chemistry and Biochemistry
Chris Nelson	acnelson@email.arizona.edu	Associate Dean, Research	Planning
Melynda Noble	melnoble@email.arizona.edu	Administrative Associate	Office for Research & Discovery
Kim Ogden	ogden@email.arizona.edu	Professor	Chemical and Environmental Engineering
Jonathan Overpeck	jto@email.arizona.edu	Co-Director	Institute of the Environment
Kim Patten	kjpatten@email.arizona.edu	Associate, Research Development	Office for Research & Discovery
Jeanne Pemberton	pembertn@email.arizona.edu	Professor	Chemistry and Biochemistry
Ian Pepper	ipepper@ag.arizona.edu	Director	Environmental Research Lab
Nasser Peyghambarian	Nasser@optics.arizona.edu	Professor	Optical Sciences
Gary Pivo	gpivo@email.arizona.edu	Professor	Planning
Mary Poulton	mpoulton@email.arizona.edu	Director	Lowell Institute for Mineral Resources
Jeff Pyun	jpyun@email.arizona.edu	Associate Professor	Chemistry and Biochemistry
Tauhudur Rahman	tauhid@ag.arizona.edu	Associate Professor	Agriculture and Resource Economics
Pete Reiners	reiners@email.arizona.edu	Department Head	Geosciences
Stan Reynolds	reynolds@eller.arizona.edu	Professor	Economics
Robin Richards	robinr1@email.arizona.edu	Associate, Research Development	Office for Research & Discovery
Cecilia Rosales	crosales@email.arizona.edu	Associate Professor	Public Health
Joaquin Ruiz	jruiz@email.arizona.edu	Dean	College of Science
Chris Scott	cascott@email.arizona.edu	Research Professor	Water Resources Policy - Udall Center
Jeff Silvertooth	silver@ag.arizona.edu	Associate Dean	Cooperative Extension / Economic Development
Kelly Simmons-Potter	kspotter@ece.arizona.edu	Professor	Electrical and Computer Engineering
Shane Smith	shaneida@email.arizona.edu	Assistant Professor	School of Architecture
Shane Snyder	snyders2@email.arizona.edu	Professor	Chemical and Environmental Engineering
Young-Jun Son	son@sie.arizona.edu	Department Head	Systems and Industrial Engineering
Armin Sorooshian	armin@email.arizona.edu	Assistant Professor	Chemical and Environmental Engineering
Brian Ten Eyck	bteneyck@email.arizona.edu	Assistant Dean, Research Developme	College of Engineering
Jessica Tierney	jesst@email.arizona.edu	Associate Professor	Geosciences
Robin Tricoles	robintricoles@email.arizona.edu	Science Writer	University Relations, Communication
Peter Troch	patroch@hwr.arizona.edu	Science Director	Biosphere 2
Virinchipuram Viswanathan	vkv@email.arizona.edu	Associate Professor	Animal & Comparative Biomedical Sciences
Justin Walker	juswalker@email.arizona.edu	Associate Dean, Business Developme	College of Optical Sciences
Margaret Wilder	mwilder@email.arizona.edu	Associate Professor	Udall/Geography & Development
Andre-Denis Girard Wright	adwright@email.arizona.edu	Director	Animal & Comparative Biomedical Sciences
Austin Yamada	akyamada@email.arizona.edu	Director, DSRI	Office for Research & Discovery
Michele Zacks	mzacks@email.arizona.edu	Associate, Research Development	Office for Research & Discovery
Tom Zega	tzega@email.arizona.edu	Assistant Professor	Lunar and Planetary Laboratory
Xubin Zeng	xubin@atmo.arizona.edu	Professor	Atmospheric Sciences
Zhiping Zheng	zhiping@email.arizona.edu	Professor	Chemistry and Biochemistry

Attendees' names in green; other invitees in red

WEA Strategic Planning Workshop
Whiteboard Notes – Sept. 16

Physical Infrastructure:

- Single-particle aerosol mass spectrometer

Opportunities for Collaboration (not a thorough list):

- Apply oceanic microbiome methods to earth microbiome
- Focus, funded center on WEA
- Multi-scale problems
- Conservation and ecosystems
- Connectivity of processes and systems
- WFE Policy Inst. (emphasis on SW region) – within Udall Center?
- Subsurface management
- Study special environmental needs of SW peoples

Needed Expertise:

- Aquatic toxicologist
- Energy use and municipal waste
- Dust
- Combination of neuroscience with design & architecture
- Access to special data sets

Other Issues:

- Need faculty incentives to participate in interdisciplinary proposals
- Need to be mindful of both basic science and integrated systems (and how to translate)
- Need to create interdisciplinary networks (with mission focus)
- Consider Liaison Group to connect north and south campuses
- Need networking tools
- Need to enhance current network of graduate students (formalize and with increased funding)

Strategic Planning Workshop

Water, Energy, Arid Environment

September 15-16, 2015

Frank Lederman

---

imagination at work

noranda ALCOA

CRAY THE SUPERCOMPUTER COMPANY

BLASCH PRECISION CERAMICS

ARIZONA PITT UT DALLAS CARNEGIE MELLON UNIVERSITY ILLINOIS

2

Goals for Day Two

- Breakout sessions for each program theme (2 x 80 min)
- Report-backs to entire group
  - What are the most exciting ideas?
  - Summarize key results & issues
  - What items need further work?
- Group discussion
  - Review strategic issues and common resource needs
  - Develop action plan

Breakout Sessions - Key Topics

- What makes (or could make) us unique?
- What grand challenges are addressed?
- What new strategic technical capabilities?
  - What new competitive advantage?
  - What can we demonstrate in the short-term?
  - How can capabilities be extended to other parts of the university?
- Specific opportunities for external funding
- Resources required
  - Program-specific
  - Infrastructure
- What partnerships can help us?
- Other program risks
- Strategic issues

We Need a Strategy to:

- **Support the vision and/or strategy of parent organization**
- **Guide allocation of resources**
  - — **What will grow and what will shrink?**
- **Show focus**
- **Inspire objectives that are *required* to achieve the vision**
- **Help unify the organization around a common set of goals**

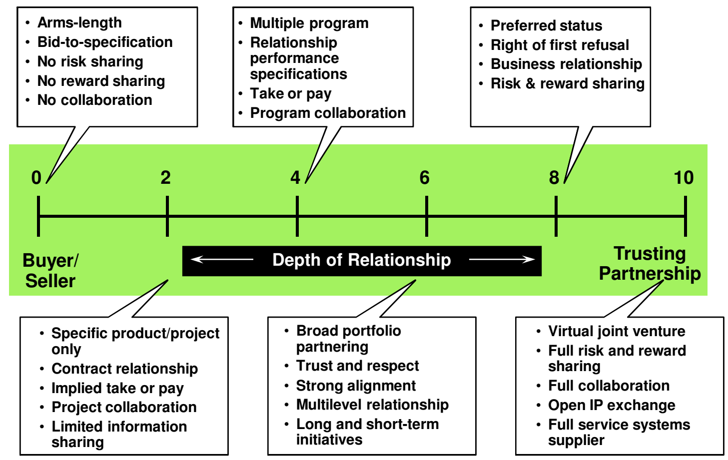
Strengths and Weaknesses

- **Internal focus – emphasis on competitive capabilities**
- **What are our core competencies?**
  - — **Transcend several departments or groups**
  - — **Provide true competitive advantage / differentiation**
  - — **Produce a barrier for others to enter**
- **Examples**
  - — **Unique facilities difficult and/or expensive to duplicate**
  - — **Unique skills, such as a critical mass of talent in one area that took years to establish**
  - — **Local climate / ecology**
  - — **Key partnerships / relationships**
  - — **Weaknesses: resource limitations in required areas**

What can we do?

Sources and Partners

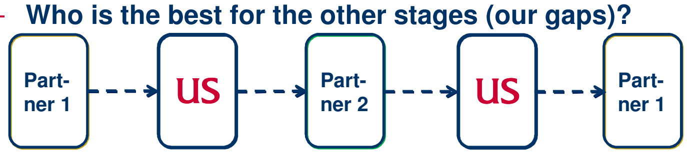
Classifying the nature / depth of a relationship



How deep of a relationship do you need?

Strategic Relationships

- Analyze the "supply chain" of your technology
  - For what capabilities / stages are we truly the best?
  - We can afford to be the best for only one or two stages
  - Who is the best for the other stages (our gaps)?



- Analyze the strategy for possible partners
  - What is *their* strategy for their gaps (why they need us)?
  - If they won't tell us, put ourselves in their shoes & guess

A mutually-strategic relationship
is a competitive advantage

Opportunities and Threats

- External focus
- What are the external forces affecting your organization?
  - What changes have you seen and do you envision?
- Examples
  - Evolving model for competing for federal funding
  - New budget constraints
  - Changing demographics for students, legislature, philanthropy, …
  - Changes in partners and / or their strategies
- What are the strategic options to respond?
  - What strategic capabilities are required?
  - Which programs should grow? Which should shrink?

What should we do?

Breakout Sessions – Key Topics

- What makes (or could make) us unique?
- What grand challenges are addressed?
- What new strategic technical capabilities?
  - What new competitive advantage?
  - What can we demonstrate in the short-term?
  - How can capabilities be extended to other parts of the university?
- Specific opportunities for external funding
- Resources required
  - Program-specific
  - Infrastructure
- What partnerships can help us?
- Other program risks
- Strategic issues

Breakout Session Locations

A. Water for Food, Energy, and Resilient Natural Systems
— Visitor Center Conf. Rm. 1
Greg Barron-Gafford, Sharon Megdal

B. Integrated Technical Solutions for Energy, Water, and Food
— VC Conf. Rm. 2 Ardeth Barnhart, Kim Ogden

C. Scaling: Molecules to Ecosystems and Earth Microbiome
— Sahara Room Raina Maier, Jon Chorover

D. Environ. Systems & Population Health
— Casita 1900 Shane Snyder, Jeff Burgess

Breakout Session A

Water for Food, Energy, and Resilient Natural Systems (WFERNS)

Sharon Megdal and Greg Barron-Gafford

This discussion group focused on the grand challenge as stated in our focus: Having sufficient water to meet the needs of the world's growing population. Both groups noted UA strengths, which include but are not limited to: interdisciplinary research, for which there are low barriers; ecosystems analysis; social sciences; broad and deep water research; energy; education; paleo-science; and arid lands. Our location makes us unique. Arizona is crossroads of physical types, border region. B2 is one scale of laboratory. WEST is another. The broader region is an arid lands living laboratory, with international borders and borders with Native Nations.

This location positions us to be a leader in many areas of research, including examination of issues related to social equity and economic development. Crises abound in arid lands across the globe. Organizations look to AZ for arid lands work, but UA depth/breadth in this has been weakened some. Need to exercise the strengths we have and also revitalize.

UA has the opportunity to <u>study arid landscapes at the global level</u>. We should look to upscale some of the more localized UA research.

A key to research opportunity is <u>preserving natural ecosystems given the pressures of demands for water, food, and energy</u>. But we have not formed a center or institute devoted to this research.

We have unique skills to research the <u>cascading effects of quick/abrupt climate change</u>; have governance, economic and science capacity; scalable issue. This work would bring together researchers from throughout UA campus, coupling natural and human systems talents.

Pursuing research on achieving <u>net-zero water communities</u> was discussed.

Grand challenge is adequate science education at k-12 level. Look at things in a broad and connected way. Should do more research on <u>how people learn science</u>.

Discussion noted getting the people on campus together as process-related grand challenge. We noted the GIDP strengths of the UA, but they do not provide a vehicle for faculty dialogue.

Another process related challenge: How we go about identifying and developing funding matches. Develop relationships with stakeholder partners that enable us to deliver the deliverables that they want, such as seasonable water resource projections. Make a pitch to them to fund something.

Discussion highlighted the need for more workshops and sustained discussions related to key topics to lead to development of proposals.

Strengths associated with Land Grant University, Experiment Station, and Extension. Our professional degree programs are strengths, including our work on STEM education.

We did not talk about specific faculty positions in the discussion groups; that would have to be a follow up discussion. The important role of post docs and grad students was duly noted. Graduate Assistant, Outreach position can be written into proposals; this position is available throughout the UA. We should take our existing programs that train students to take their science to action to a larger scale.

Need to be organized so that we can assemble the capabilities. Need to find the right people to pull the team together to go after funding that has been identified by the funding agency for a specific purpose. There was mention of the opportunity to bring GIDP faculty together for discussing research. iPlant, big data analysis, and computational facilities were mentioned multiple times.

A water and energy institute (one-stop shop) could be very helpful. Need to match interests/needs of funders with what researchers can/want to do.

Our research strengths in paleo-science, coupling natural and human systems, governance and policy, and social sciences research form a very strong foundation for understanding how climate change manifests itself over time and at different scales, including consideration of effects on low-income populations and different economic activities.

Opportunities to build upon particular strengths, such as interactions with Native American (Indigenous) communities and Spanish language skills, can assist in achieving the goals of upscaling the geographic scope of UA research, as well as coverage of the breadth of human-natural systems interactions.

Additional note from WFERNS Discussion Facilitator Sharon Megdal related to groundwater/aquifer health. This could be a topic for additional discussion among interested individuals.

Summary: Funding opportunities, including Department of Defense, USAID and private foundations, could be pursued through a groundwater/aquifer health center or institute. Groundwater utilization is a growing concern at all geographic scales. Because groundwater is invisible, modeling and characterization of groundwater supplies, including their replenishment, relationship to surface water supplies, and quality, require sophisticated analyses, including use of satellite imagery and GIS mapping. Groundwater supplies affect and are affected by ecosystem health. Formation of a groundwater center or institute could build upon its research strengths in groundwater modeling, groundwater quality and remediation, water storage and banking, groundwater governance, GIS, and community landscapes at many scales. Coalescing around our interdisciplinary groundwater research could distinguish the UA and enable the UA to build upon its core research strengths and academic programs and position the UA for additional substantial research dollars going forward.

Breakout Session B

Integrated Technological Solutions for Energy, Water & Food

Kim Ogden and Ardeth Barnhart

The UA is very well poised to work in the area of Energy, Water and Food in Arid environments because of our location, facilities, regional expertise and willingness to work across disciplines. Many of our existing projects and capabilities can easily be extended into the Energy, Water, and Food (EWF) Nexus and the environment and a focus on better coordination and collaboration across disciplines is required to successfully identify challenges and produce solutions in this area. Increased exposure to extreme events and other changing environmental factors will make us more of a test bed for the world where securing energy, water and food is a global challenge as well as a local one.

Exciting ideas

- We have a diverse set of researchers working in materials in basic science, engineering, architecture (chemistry, planetary, acoustic, molecular, material science, building) that can be coordinated to help find solutions in EWF Nexus such as the development of **new materials** for energy storage technologies, biological and chemical processes to reduce scaling in water treatment systems, sensor materials to determine health of agricultural fields (crop, ecosystem, etc), and food safety and conservation.
- The UA has over 50 years of history in understanding the arid environment and an extension school working with traditional agricultural processes, energy and water production and mining. There is an opportunity to **bring new technological processes, ideas and coproduction of knowledge** to produce more sustainable outcomes in these areas like treating waste streams, purifying water, integrating renewable energy and recovery of materials (rare earths) from waste/water and controlled environment agriculture and precision agriculture (provide more efficiency in the field sensors, irrigation, harvesting).
- We can develop energy, water, food technologies at scale; nano-scale, single unit, community, large-scale and in a distributed system to produce and deliver energy, water and food at the point-of-use to reduce costs and waste. The UA has many facilities such as the Biosphere 2, Solar Zone, West Center and others that can be used to as **test beds for the research, development and demonstration** of these technologies with key partners.
- Utilizing the **Southwest as a template for spatial, high-fidelity modeling**, we can begin to understand how energy, water and food systems interact – how much water in energy/food, energy in water/food, types of energy and water, etc. These models can reflect the situational scarcity of resources and institutional interaction (government, industry, consumer) in the decision-making process. The UA can create a repository of these types of models that can be integrated into research efforts.
- The UA faculty has **culturally diverse knowledge in food, energy, and water systems** and expertise with local government collaboration and change agents in the Southwest. There is an opportunity

to incorporate this knowledge of social capital interaction into research efforts to develop new ideas about working with Mexico, the Middle East and others with similar environmental, economic and social circumstances.

- The development of technological solutions can begin with **the integration of ecosystem and sustainability science in our research approach** to reduce the time to understand the impact of energy, water and food system and technology development on the environment. Examples include: reducing animal mortality in wind energy system deployment in the initial phases of development and creating technologies that increase adaptability in the face of extreme events.
- Create a "Laboratory" where stakeholders (inside and outside of the University) and researchers work together to find and implement solutions and integrates a "**social science" testbed** that includes direct stakeholder and community involvement.
- The UA is a world-leader in light management and we can utilize the expertize **in hyper-spectral optical management** in the development of new solutions for energy, water, food materials and systems.
- Build on the **world-class research in energy and water policy** to integrate social science in basic and applied research approaches from the beginning of research efforts.
- Increase **remote communications capabilities** to reach communities, industrial/agricultural partners or other researchers similar to tools used in telemedicine that will take advantage of the advances in sensor networks.

Items That Need Further Work

- We need to understand how to **facilitate targeted and accelerated development** and implementation of necessary innovations from basic science to societal issues and amplify on the strengths that we have. The time-scale to roll things out to address big challenges is an issue to be considered, everything will not happen overnight and we need to avoid having them happen in a haphazard way.
- Create more ways to **coordinate faculty collaboration** by providing opportunities to interact like this workshop. Design mechanisms to assemble competitive interdisciplinary teams and incentivize faculty to work on interdisciplinary projects to craft meaningful outcomes.
- In the process of technology development, we need to focus on **affordable and accessible technologies that allow us to meet the needs of the more vulnerable sectors of society**. This may be an area of development for the University and an opportunity to bring in faculty with expertise in this area.
- The development of partnerships takes time and we need to **maintain and build up key competencies** and maintain and keep sustained research projects that are not always tied to the current buzz phrases.
- **Expand capabilities by linking to public health, applied math, big data (iPLant**), **climate adaptation** and other areas that enhance the efficacy of solutions developed for the EWF nexus.
- We want to be known for our quality of research, our used inspired basic research by enhancing our capabilities in the "**Science to Action**" space, looking holistically at the EWF nexus.

Breakout Session C

The Impact of Earth's Microbiome on Global System Function and Dynamics

Session co-leaders: Raina Maier, Peter Reiners, Jon Chorover

Session participants: Arnoldo Bautista, Dave Breshears, Pierre Deymier, Lloyd LaComb Diana Liverman, Tom Meixner, Oliver Monti, Ian Pepper, Robin Richards, Shane Smith, Armin Sorooshian, Jessica Tierney, Michelle Zacks, Tom Zega

Preamble – Why the Earth's Microbiome?:

We have learned about the human microbiome, the trillions of microorganisms living in and on our bodies that are essential to our health and well-being but which can become compromised by antibiotics and other trappings of industrialization. Earth too has a microbiome, a quadrillion quadrillion microorganisms living in the earth's crust and waterways, which is analogous in terms of keeping our planet healthy—and it is similarly threatened by human activity.

Earth's microbiome created just the right conditions on the planet to support higher forms of life, and eventually humans. Early planet Earth had zero oxygen and 98% carbon dioxide. Our breathable air came about because microbial photosynthesis evolved almost four billion years ago, resulting in the consumption of most of the carbon dioxide and led to the production of oxygen. By the time humans came on the scene, Earth's atmosphere had 21% oxygen and 0.03% carbon dioxide. Without microbial development of photosynthesis, Earth would be nearly as hot as Venus, and airless. Even today, though we usually think of plants as responsible for photosynthesis, about 50% of global photosynthesis is still carried out microbially, primarily in the oceans.

It took the Earth's microbiome 4 billion years to slowly turn the carbon dioxide-oxygen ratio around; in the last 150 years, humans have increased the amount of carbon dioxide in the atmosphere, from 0.03 to 0.04%. This change has happened 2,700 times faster than what occurred in the previous 4 billion years. The scientific community is working to understand how our planet will respond to this change. The question we are not asking is how will the Earth's microbiome respond? After all, microbes have no vested interest in the status quo. The best conditions for some of these microbes may be very different from those that favor human health and welfare.

A good example is the acid mine drainage that results from mining (think Gold King Mine spill). When we dig past the top layer of soil and vegetation, oxygen penetrates the sulfide-containing coal or metal rich ores beneath the surface. This awakens and feeds dormant microbes that oxidize iron and sulfur deposits that coexist with coal and metals. In the process, the microbes make acid, which leaches into the soil and ultimately the waterways. Once this process has started, it is very difficult to stop, and treatment must go on in perpetuity.

Everything we do, from mining to burning of fossil fuels to large-scale agriculture changes the earth's microbiome, sometimes in ways that we cannot currently predict. Understanding the Earth's microbiome is a challenge that rivals going to the moon or developing cures for cancer.

Grand challenges –

1) Defining the earth's microbiome across the planet – Earth Microbiome Project at PNNL and Argonne has a good start on this grand challenge but it is an underfunded effort.
2) How does the microbiome contribute to global environmental change and vice versa – the role of the microbiome in the major biogeochemical cycles both in the past and in the present. What are the low frequency functions you can model? How do these processes scale from the molecular scale to pore scale to landscape scale to global scale.
3) How does the microbiome change through time and what are the drivers and feedbacks – we note that current climate models don't include microbial response and what will happen to organic matter in a changing climate
4) How do we observe the microbiome-environment interaction at different time scales and what the tools we use to analyze and interpret

Solving these grand challenges will lead to:

1) Fundamental science relating to understanding earth processes
2) Information and opportunities for decision-making and management strategies
3) Science that leads to applied and commercial applications – sustaining and improving agriculture, built environment, geoengineering, etc.

Understanding the microbiome will allow us to:

Manage the Earth's microbiome in the Anthropocene – need to know how to manage and at what scale it should be managed, need to understand patchiness and flashiness in microbial action, hot spots and hot moments, fertility islands, and relationships to scaling

Geoengineer the planet – need to understand how this will change the Earth's microbiome as well as the reverse – can the microbiome be changed to geoengineer the planet

Create designer microbial megacommunities and understand their unique structural requirements e.g., for agriculture, space travel, terraforming other planets

Agriculture – improving soil fertility

Understand and predict the response of Earth's microbiome to extreme events – megadrought, heat waves, disease - how resilient is the microbiome and how do you make it more resilient?

Understand and predict the impact of Earth microbiome changes on human health, perform cost-benefit analysis

Understand and predict impact of a changing Earth microbiome on wilderness areas

Manage the Earth's microbiome to restore ecosystem function to disturbed lands

Manage the microbiome for local productivity, human health, etc. – the microbiome is at the base of the pyramid, we need to consider more than just the large charismatic mammals e.g., the base of the pyramid that we take for granted and is at risk

<u>What makes the University of Arizona unique?</u>

1. **Unique collection of researchers in a wide variety of disciplinary sciences that understand biological, physical, and chemical aspects of arid environments:**
    - Astrobiology
    - LPL - remote sensing of other planets, terraforming Mars, the microbiome of space travel
    - Geosciences – organic biomarkers to observe the molecules that represent early and present microbiomes , authigenic minerals (e.g., carbonate) in desert soils, paleoclimate reconstruction, paleolimnology reconstruction
    - Hydrology – defining physical boundary conditions both historical and modern
    - Environmental and soil science – microbiome analysis, earth ecosystem modeling, evolutionary biology, earth surface to atmosphere interactions, preliminary work in the Atacama Desert
    - Chemistry – can address a second highthroughput challenge - identifying chemicals and chemical signals (chemiome) in environmental systems – can the microbiome be controlled through these signals?
    - Materials Science – artificial materials, plastics, metals etc – how do these influence the microbiome (again think space travel), microscale resolution of redox
    - Math and applied math – modeling earth systems – current models don't consider Earth microbiome
    - Architecture - built environment linking spatial and material information to microbiome
    - Research translation and communication – have someone like Chris Cokinos raise awareness of the importance of the microbiome as the sustainer of ecosystem health.
    - Big data, (managing big data, sequencing and other highthroughput analysis)
    - Remote sensing capabilities – cluster hire focus
    - Ecosystem genomics – cluster hire focus
    - Big data cluster hire focus – these three cluster hire groups should talk with each other

2. **What makes us unique - facilities?**
    - Combination of medical school and public health, land grant, science and liberal arts, social sciences –
    - The large number of faculty with expertise in paleo environments.
    - B2 Leo lab
    - Yuma (and other) Experiment Station
    - CEAC – production under glass
    - LPL, remote sensing
    - BIO5
    - IPlant, iEarth
    - Critical zone observatory

- Institute for Mineral Resources
- Genomics Core - Itag and genome sequencing capabilities
- Mass spec facility (chemistry) and proteomics facility (BIO5)
- Artificial intelligence lab - data mining monitoring disease
- WEST Center

Possible partnerships

- Scripps for oceans
- Argonne Earthmicrobiome Project
- Strong partnerships already developed with UNAM, Mexico – national center for genomics, national lab of advanced microscopy
- Corporations interested in agricultural genomics, e.g., Monsanto

Possible funding sources

NASA – to understand how to make other planets habitable, exobiology, inorganic-organic interactionos e.g., what the effect of microbial activity on the inorganic framework of rock

NOAH – extreme events

NSF – food energy water, PREVENTS – natural hazards, Belmont forum (ICS)

Sloane – inventory, microbiology in the built environment

NIH – human health

USDA – NIFA

Gates foundation – extreme events hit the poor more strongly than wealthy nations

International Council for Science – Future Earth - New Future Initiative

DOD – check with Dennis

DOE – Subter program, talk with IMR, spent fuel storage,

Mining industry

Breakout Session D

Environmental Systems and Population Health

Shane Snyder (Engineering) & Jeff Burgess (Public Health)

Breakout Group #1:
Shane Snyder and Jeff Burgess moderating, Ian Pepper, Robin Tricoles, Shane Smith, Armin Sorooshian, Michele Zacks, Kristin Gunckel and Ann McGuigan attending (Jennifer Barton and Neal Armstrong observing)

Introductions

Shane Snyder – analytical chemistry/metabolomics and biomarkers, sensor systems, mixture toxicity, treatment systems. Resource recovery. Membrane systems. Oxidation. Activated carbon and IX. Singapore. Distributed systems/POU – aquaculture – WHO/EPA Biosolids – land applications.

Jeff Burgess – public health/occup. & environ. medicine, New NIH "Center for Indigenous Environmental Health Research" with focus on water, food and air contamination. Other research comparing vehicle emissions and health effects from diesel and biodiesel use, cancer reduction in firefighters

Ian Pepper: Pathogens – ebola, model viruses, water treatment, and biosolids.

Robin Tricoles: Science writer for university and CALS, DC freelance writer, 5-weeks at UA, NPR.

Shane Smith: Architecture – 1 year – Building technology research, solar water metabolic processes. Air to water-water to air, biopolymers in building systems. Correlating environmental building with human health response. WEES exploratory grant – adoptive prototypes

Armin Sorooshian: 7 years as UA faculty (28 on campus), aerosols – how they impact clouds and rainfalls, how particles interact with water vapor. Air and health – aerosol pollution. Suggested center that relates dust/airborne pollutants to health, climate, hydrology, visibility, etc.

Michele Zacks – ORD Office, worked in infectious disease and epidemiology, public health.

Kristin Gunckle – education, students understanding water environment, 6-8 graders how their perceptions change over time – NSF grant to integrate computer modeling in HS courses.

Ann McGuigan – ORD (Director of Research Development Services). Prior to coming to the UA, she was Assistant VPR at Texas A&M. Head of group for proposal development.

What Makes us Unique:

WEST (Shane Snyder and Ian Pepper)– new Center, built by Pima County, access to reclaimed effluent, industry donations, international connections. Aquatic toxicology laboratory already there. Next door to Pima County laboratory. **Major focus**: indirect potable reuse, also thermotolerant pathogens, legionella, brain eating amoeba, ability to detect in real time. Warraby – influenza strains for earlier indicators of disease. Also chemical exposure issues such as toxicity of disinfection byproducts, and municipal waste reuse. Dermal transport (could benefit from interaction with Georg Wondrak in the Cancer Center)

Education: UA has experts in education who could help develop programs for potable reuse education for high-school (or younger) students

Action item: 1) This group should make an ERC "type" list of faculty to circulate to Tucson Water/Pima County, AZ State regulators, and Shay Stautz; 2) Shane will circulate a draft for each person to which each interested person can add their inf; 3) Combine with green energy by Kelly Simmons-Potter and energy modeling by Young-Jon Son; and 4) Hiring need: aquatic toxicologist

Dust (Armin Sorooshian) – other programs are at CalTech, Georgia Tech, Carnegie Mellon – dust from biosolids (Shane would like to work on this too), dust in arid in environment. Infrastructure here: Armin, Eric Betterton, Paloma Beamer. Major questions include: 1) aerosol-cloud interactions as part of climate change (reduce error bar) also addresses precipitation; 2) visibility (DOD) concern; 3) public health consequences. Need: single-particle MS. Neal said they have new technology that could help. Also need senior leadership.

Green buildings and design (Shane Smith) - catalysis and decentralized. Could work with Berkeley. Could use WEST forum for her to meet our companies. Could benefit from collaboration with existing UA assets including 3D technology (virtual cave). Need critical hire across design/architecture and neuroscience. http://www.greenhoustontx.gov/greenbuilding.html (Michele Zacks sent link to greenbuilding)

GROUP #2

Jean Pemberton, Kelly Simmons-Potter, Robin Tricoles, Cecile McKey, Jan Cervelli, Young-Jun Son, Bruce Johnson, Chris Scott (again with Shane Snyder and Jeff Burgess moderating)

Introductions

Jean Pemberton – energy conversion projects. New sustainable materials – for water treatment and recovery of rare earth elements. Strong mining connections. Studied at U. Penn in Philly.

Kelly Simmons-Potter: Optical sciences – Reliability and degradation – TEP test yard and storage systems, dusty hot facility for solar research. Environmental chamber, humidity control, FULL spectrum lamps up to 1-sun – very large – (could do UV collimated beam experiments) for solar panels. Could do photolysis experiments to minic the sun!

Robin Tricoles – Science writer (also from Group 1).

Cecile McKey – social sciences and linguistics and young children studies

Jan Cervelli - Dean of Architecture – joint center – place for well-being, physiological, ester sternberg is the lead. Biosensoring for physiological response to light, sound, pattern, stress indicators and hormones and reactions in real time. Principals to show clients. For the consumer.

Young-Jun Son – Department head of systems engineering – modeling. Could help with buildings (architecture) for emergency exit models. Policy decisions

Bruce Johnson – education – dept. head. Help kids understand ecological concepts. Co-director of STEM University learning center. Community access to the University. Broader impacts sections of larger grants.

Chris Scott: Geography and Udall Center – policy work. International work. Water Reuse. Chronic exposures and acute pathogens. Treatment systems – land limited systems. Unreliable power. Nexus questions. Driving policy through health endpoints (air quality, heat, drivers from climate change).

Concepts:

Jeanne Pemberton – with Raina – question REE harvesting. She has new technologies that use sustainable materials based on biosynthesized glycolipids. Can chemically synthesize these components now to make them more economically viable. Works great for REEs – tie to Kim Ogden. Expertise in mining and sustainable mining could be very valuable to make us competitive. Can help produce better quality water for use for agriculture and green technology pieces. This is a global issue.

Jan: Place and well-being. GSA $3M headquarters in DC. Comparing the old building to the new one. Is Green building more healthy. Strengths – consultancy! Professional consultation, DOD, etc. Investments needed in functional MRIs around colors, associations with objects, wait times!, 3-d visualization, sweat patch to monitor physiological responses. Need more neuroscience connections. Critical hire in an integrative area. Veterans admin, DOD, etc. Please let us know if there are chemical contaminant exposures. Son is interested in emergency evaluation and optimization.

Kelly: TEP battery storage and reliability and degradation. Could use the 1-megawatt solar at WEST. TechPark and monitor their output and utilization - migrating to physics department. Data infrastructure to more robust location. Research tool helps with Public Perceptions – Education on retrofitting buildings – kids can come out and see the systems work, ENERGY. Could we do this for that for WEST – kids could watch the water process from home via internet (idea – use sensors systems)

Son – modeling of energy for Tucson Water well operations (Shane could turn Son to TW for some discussion).

Chris Scott – phosphorus – recovery of P from waste. Energy required for nitrogen is huge for agriculture. What are the energy dynamics around food systems. Larger scale systems for food…

Jeff Burgess – Larry Head (SIE Department) has vehicle to vehicle communication technology – implications for traffic and human health. Pool technologies – could we coat the pool with TiO2 and get an oxidation potential? Maybe UV disinfection through concentrated solar?

Robin: Better international relations to work with companies and agencies from other countries – middle east – asia – mexico -

Added from report-back: (Diana Liverman): Need for bridging main campus environmental and AHDS initiatives: Focus group on this area?

Supplemental Report

A UA Network on *Conservation, Communities and Connectivities*

A topic originally titled "Conservation, and Ecosystems" was raised specifically or in part in sessions of the workshop, particularly in the "Water for Food, Energy and Resilient Natural Systems" session. Although ecosystems, biodiversity, and conservation have strong connections to the four breakout themes there is also an excellent case for the potential of a more unified UA effort in this area to capture additional grants from federal and international agencies, the private sector, foundations, and individual philanthropists. This was noted in the plenary session and a group of those workshop participants took the opportunity to develop such a concept further for inclusion in the workshop notes immediately following the plenary. Those participants included: Greg Barron-Gafford, Dave Breshears, Paul Brown, Jim Buizer, Chris Castro, Laura López-Hoffman, Diana Liverman, Stuart Marsh, Tom Meixner, and Chris Scott.

The group also identified an example list of many other relevant faculty who could contribute to an expansion of funding in this area, many of whom have substantial individual grants but who could come together for much larger collaborations (several of whom interest in such an initiative was confirmed within the limited timeframe available, indicated by an "*"):

ANTHRO: Diane Austin, Ben Colombi*, Tom Sheridan **AREC:** George Frisvold*, Bonnie Colby*; **Biosphere 2**: Kevin Bonine*, **EEB:** Brian Enquist*, Scott Saleska, **Journalism**: Carol Schwalbe; **LTRR:** Tom Swetnam, Valerie Trouet*, **Public Health**: Stephanie Rainie*, Palomoa Beamer, Jeff Burgess*, **SGD:** Tracey Osborne*, **SNRE:** George Ruyle*, Randy Gimblett*, Rachel Gallery, Dave Moore*, Dave Christianson*, Melanie Culver, Bill Matter, Bill Mannan, Bill Shaw, Bob Steidl*, Michael Bogan, Wim van Leewuen*, Cecil Schwalbe*; Shirley Papuga; **Southwest Center:** Gary Nabhan; Jeff Banister*. These are examples from a what would potentially be a much longer list.

We propose development of a UA Network focused on ***Conservation, Communities and Connectivities***

UA has unique and distinctive strengths
UA has strengths that collectively place us in a strategic position to approach ecosystem and biodiversity conservation in innovative ways attracting new sources of funding:

- *Our location and expertise in arid ecosystems*
- *Our focus and location in a world region of high biodiversity across an international boundary*
- *Faculty excellence in providing interdisciplinary natural and social science research for the management of natural resources and ecosystem services (parks and wildlife, farms and ranches, urban land use)*
- *Additional faculty expertise in understanding climate impacts and other stresses on ecosystems (e.g., drought, plant die-off, temperature stress, wildfire), reconstructing past ecosystems, analyzing ecosystem genetics/ genomics, agroecosytems, linking food security and ecosystems, linking public health and ecosystems, ecosystem services assessment and valuation, payments for ecosystem services conservation incentives, ecohumanities, and conservation law, policy and governance*
- *A land grant tradition of serving stakeholders in the sustainable management of landscapes for both ecosystems and economic development*
- *Strong partnerships with regional conservation organizations and ecosystem-based businesses (e.g. tourism)*
- *Unique facilities in which UA has already made substantive investments including research stations, Biosphere 2, Cooper Center for Environmental Learning, Critical Zone Observatory, a NEON node, and many others*

Our proposal is to create a focus area at UA on ***CONSERVATION, COMMUNITIES AND CONNECTIVITIES*** to emphasize the importance of conservation with and for communities, the importance of connectivities (e.g. between agricultural productivity and pollinators, across national boundaries, between natural and social science, between conservation and economics, and between ecosystems and the future of health, energy, water and food) under rapid climate change threats in arid lands, the critical role of broad community engagement in problem solving, and the broad-scale connectivities that need to be accounted for to be effective (e.g., pollinator butterfly habitat in Mexico affecting US agricultural production; large-scale forest die-off in western US potentially impacting climate and plants in the Amazon and boreal zones; economic impacts cascading across regions).

Example **Grand Challenges** that could be addressed by a UA *CONSERVATION, COMMUNITIES AND CONNECTIVITIES* network include:

- How can biodiversity conservation support food security and economic growth?
- How can the conservation of functioning ecosystems support human health and physical and emotional well-being?
- How we can foster large landscape conservation under climate change, including abrupt change and peak temperatures, and severe sustained drought?
- How can effective governance be created for conservation with the participation of multiple stakeholders, across boundaries and under current challenges?
- How can ecosystems and conservation support the sustainable use of arid lands and their rich biodiversity?

Three example of initial projects could include: a) *Agricultural interconnections in a broad spatiotemporal context; b) Conservation of iconic trees and groves for forests at risk*; and c) *Binational U.S. – Mexico conservation challenges;*

A few of the many specific opportunities for external funding include:

- Major private donors, including three specific targeted donors, including an individual donor who has already expressed interest in this concept;
- Federal agencies including DOI, DOD and NIH in addition to NSF (building on the many Federal conservation relations and public lands relations we have in the west, and building on CNH, DEB, NRT, and EF successes);
- Big foundations that fund conservation: e.g., McArthur, Hewlett, Moore, Wilberforce, Walton;
- International institutions: UNAM, CONACYT, IAI.

Notes submitted by Dave Breshears (daveb@email.arizona.edu).