BioInspired!

Volume 6, Issue 2

June 13, 2008

The Biomimicry Institute

Biomimicry Institute Activities *(Bryony Schwan)*

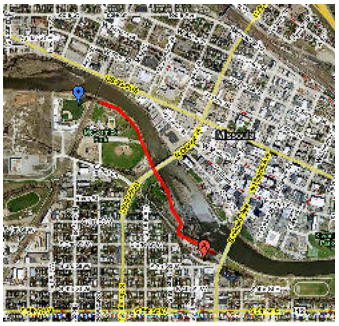
The Biomimicry Institute is off to a running start in 2008! We are pleased to announce that in May, we launched and held the first gathering of our Two-Year Certificate Training in Biomimicry. We had an overwhelming number of applications for the program and the caliber of applicants made selecting the first round of participants for the program very challenging. The first of the five week-long training sessions was held at the Feathered Pipe retreat center near Helena, Montana. Participants included:

From the design world:
Tim Albertson (architect)
Zeynep Arhon (branding consultant)
Jamie Dwyer (architect)
Mary Hansel (sustainability coordinator)
Robert Lichty (mechanical and civil engineer)
Theresa Millard (designer)
Sommer Roefaro (engineer)
Lisa Schmidtke (designer/architecture)
Marie Zanowick (environmental engineer)

From the business world:
Chris Allen (sustainability consultant)
Claire Janisch (sustainability consultant)
Jorge Kanahuati (sustainability consultant)
Erin Leitch (sustainable building consultant)

From the biology world:
Karen Allen
Atrix Oort
Juan Rovalo

Two-Year Certificate Program



As so often happens, an off-handed comment by Janine Benyus has spawned an entire new line of biomimicry projects. After Janine enthusiastically mentioned how neat it might be to have a nature trail with biomimicry signage, a biomimicry interpretive nature trail project is now underway in Missoula, Montana – possibly the world's first.

In collaboration with the Montana Natural History Center and the City of Missoula, The Biomimicry Institute is designing the trail to run right through downtown Missoula along the Clark Fork River. The trail will tell biomimicry stories based on the organisms visitors are likely to see in the area, such as butterflies teaching us safer ways of producing color and kingfishers teaching us better ways to design quieter and more energy efficient trains. TBI hopes this project will spawn biomimicry nature trails in other locations. For more information, contact Sam Stier.

Inside This Issue:

The Biomimicry Guild and Biomimicry Institute in conjunction with the San Diego Zoo are presenting **"Learning From Nature's Best Technologies: An Introduction to Biomimicry"** on Tuesday, June 24 from 6:00-8:00pm. Dayna Baumeister will demonstrate technological and commercial applications that arise when inquisitive humans ask nature for solutions to complex design challenges.

This summer and fall, two workshops will be offered to K-12 teachers interested in incorporating biomimicry into their educational curricula. The first workshop will be offered Aug. 4-6 just north of New York City by the BOCES Center for Environmental Education and The Hudson River Teacher Center. The second workshop will be offered on Oct. 16 in Missoula, Montana as part of the Montana Educators Association Conference. For more information, contact Sam Stier.

Biomimicry Institute Activities *(continued)*

On October 20th, immediately after Bioneers, The Biomimicry Institute and Bioneers will be holding an intensive one-day workshop on biomimetic solutions to climate change, modeled on nature's operating instructions. It is designed for action-oriented professionals from the fields of business, finance and investment, technology, public policy, education, media and civil society. Keynote addresses by Janine Benyus and David Orr will set the stage, while panels will explore:

- Bio-inspired Energy Efficiency and Green Building
- Bio-inspired Alternative Energy
- Bio-inspired Carbon Fixation
- Bio-inspired Biofuels
- Policy, Investment and Social Change

For more details on the conferences and workshops, please see the **Calendar of Events.**

Bryony Schwan

***The BioInspired! Newsletter* publishes material from a wide range of sources. The opinions expressed in articles are entirely those of the authors and do not necessarily represent the views of The Biomimicry Institute.**

Institute of Biological Engineering 2008 Conference *(Norbert Hoeller)*

The Institute of Biological Engineering (IBE) "… is a professional organization which encourages inquiry and interest in biological engineering … (an) emerging discipline (that) lies at the interfaces of biological sciences, engineering sciences, mathematics and computational sciences. It applies biological systems to enhance of the quality and diversity of life."

Denise DeLuca chaired the biomimicry track at this year's conference and kicked off the session with **Biomimicry: Innovation Inspired by Nature.** Other presentations organized by Denise:

- Nick Beck (Terrapin Bright Green, LLC): **Colonies of Jelly: Component Assemblies in Nature and Design**
- Dr. M. Porterfield (Purdue University): **Biometic sensing for root oxygen bioavailability**
- Peter Fiske (PAX Scientific): **Biomimetic Design of Fluid Handling Components and Systems**
- Rolf Mueller (Shandong University): **Thoughts on Embracing Biological Diversity as a Source of Design Knowledge**
- Norbert Hoeller (Sustainable Innovation Network): **Patterns from Nature** (also Feb. 2008 Newsletter)

IBE maintains a Wiki which contains many of the 2008 conference presentations, including three of the biomimicry talks. Peter Fiske's article (below) discusses the key points from his presentation, while Rolf Mueller's article expands on his thoughts on the role of diversity.

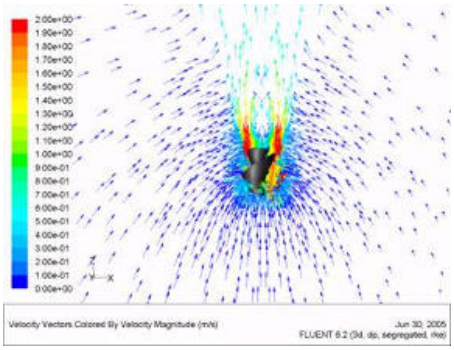
Biomimetic Design of Fluid Handling Components and Systems *(Peter Fiske)*

Peter Fiske is President and CEO of PAX Mixer, Inc., a new company created to commercialize high-efficiency mixing technologies developed by parent company PAX Scientific. He is also a nationally-recognized author and lecturer on the subject of leadership and career development for young scientists and engineers.

Over millennia, Nature has used a common set of geometries to reduce friction and drag in flow structures, plants and animals. Nature developed these geometries through optimization across many constraints, allowing it to use materials and energy in highly efficient and effective ways. Natural solutions are also often very quiet – noise is an indicator of wasted energy.

We can learn much from Nature, not just specific mechanical solutions but also the means by which Nature arrives at these solutions. Engineers are trained to think of design in terms of a superposition of planes and cylinders. These simple geometries are easy to analyze mathematically and (relatively) easy to prototype using conventional machine tools such as lathes and mills. And, like the inebriated motorist who searches for his keys under the streetlight (because that is where the light is), design engineers can similarly become trapped in a "Cartesian mindset" of planes and cylinders and resist exploring the performance of more complex shapes.

Biomimetic Design of Fluid Handling *(continued)*



Today's design and prototyping technologies allow design engineers to break out of the Cartesian mindset and design freeform shapes that are much closer to what Nature achieves. PAX Scientific uses 3D Computational Fluid Dynamics (CFD) and rapid prototyping technologies such as Selective Laser Sintering (SLS) to create biomimetic designs with compound curves in multiple axes that achieve specific flow patterns, often exploiting vortices, dynamic instabilities and "managed turbulence". PAX has developed over 400 impeller designs to date for applications ranging from a drinking water storage tank mixer that homogenizes up to 7 million gallon water tanks using less than 300 watts of power (the equivalent of three typical home incandescent lights) to fans for refrigerator evaporators, air conditioners and computers that use 15-34% less energy, are 50-75% quieter, and are often cheaper to produce.

By escaping from the Cartesian mindset, PAX has been able to work with multiple design variables that traditional, pre-computer analytical solutions simply could not handle. This has opened up new avenues for innovation and has led to biomimetic design solutions that leapfrog current technologies.

Peter Fiske

Biological Diversity as a Source of Design Knowledge *(Rolf Mueller)*

Rolf Mueller is a professor at the School of Physics at Shandong University, and has taught a summer course on Biomimetic Technology to physics undergraduate students.

Biodiversity is one of the most fascinating outcomes of evolution. It is present at all level of biological organization, from the genes carried by the individuals of one species up to entire ecosystems. Estimates of species diversity [1] put the total number of species worldwide at about 13 to 14 million, most of them not yet described scientifically.

To biomimicry, biodiversity offers an almost inexhaustible pool of inspiration. But it also raises questions: what kind of information relevant to technology is contained in this pool of biological solutions and how can it best be accessed?

My research group studies the biosonar system of bats. The approximately 1,000 bat species world-wide have developed a staggering diversity of sensory capabilities that allow them to catch insect prey in the open air as well as in a dense forest, hunt for vertebrate prey on the forest floor, drink nectar from flowers, efficiently pick fruit out of foliage, drink blood, or catch a fish from the water [2]. Mastering all these tasks seems to involve some kind of sonar, either active or passive.

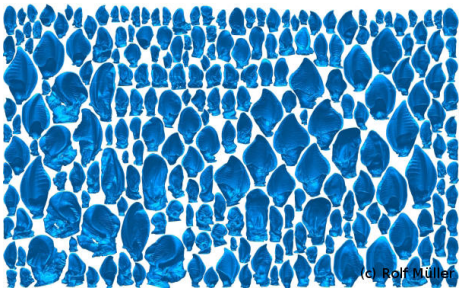
An active sonar system listens to echoes triggered by the sound pulses it emits, whereas a passive sonar system listens to signal that originate from some other source. We would like to understand these capabilities in order to find useful principles for a wide variety of technical sensing and communication tasks that are based on the emission and/or reception of waves. Examples are wireless communication, contact-free sensing and non-invasive biomedical diagnostics. At certain abstraction levels all waves have common features that unify them regardless of their physical nature. Hence, we may get insights on how to handle an electromagnetic wave from studying what biological systems do with an ultrasonic wave.

The most straightforward approach to making use of biodiversity is to search for suitable biological model systems that can inform engineering on a case-by-case basis. If, for example, a reversible adhesion mechanism needs to be found, one could look at different plants or animals one by one, such as by paging through a comprehensive biology textbook until a suitable candidate is found. In this case, the use of biodiversity is limited to increasing the odds of finding a suitable model system and the relationships between the considered biological systems are largely ignored.

Biological Diversity and Design Knowledge *(continued)*

However, being a product of evolution, biodiversity is not a hodgepodge collection of unrelated solutions to unrelated problems. A major force behind biodiversity is an evolutionary process called "adaptive radiation". In adaptive radiation, the same basic set of functional principles is modified to meet the demands of a broader set of ecological niches. In the Darwin's finches, for example, the same basic layout and operation mode of the passerine beak has been modified many times to fit different ways of acquiring food. Likewise, bats use the common principle of shaping the emitted or received sonar beams with physical baffle shapes that surround the sites of sound emission and reception.

The distinctive faces of different bat species with their varied and prominent noseleaf and ear shapes are an indication that this common principle of beamforming shapes has been modified in each species to fit into the specific niche of its sensory ecology.



Examples of the outer ear shapes of bats. The image of each shape is the rendering of a three-dimensional model

The consequence of this process is that the ensembles of related species contain engineering design information that goes beyond what can be learned from an individual biological solution, namely how one basic principle can be adapted to fit an entire set of applications. Such knowledge is of prime technological importance. Customizing technology to the needs of individual users and applications is important because it spreads the benefit of technological solutions more widely and hence can improve the lives of more users and enable a wider range of economic activity around these capabilities. Customized solutions can also operate more efficiently under the constraints of each specific application than a "one-size-fits-all" solution. If this efficiency pertains to the use of energy or other limited resources, it also means that customized solutions can be more sustainable.

Customizing an engineering solution for a particular problem is often a labor-intensive undertaking. An engineer or a team of engineers have to study each new application and then go through the entire cycle of devising a solution, implementing, and testing it. This poses a dilemma for customized technology: to deliver on its promise, customized technology must adapt to many small application niches, but few - if any - of these niches can provide sufficient economic incentives for the customization effort. This dilemma can be overcome by automated customization techniques which cut down on the development cost by employing the same engineering design methodology in each application niche. The most costly step, establishing the general methodology, needs to be performed only once.

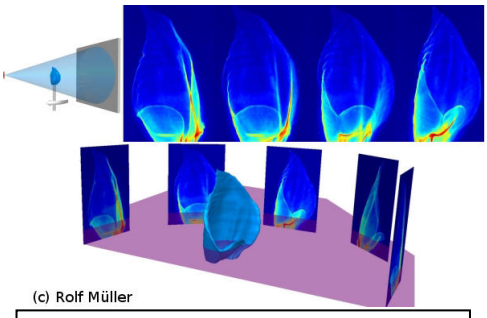
Biodiversity could play an important role as a source of customization knowledge to inform the development of such automated techniques. A group of species that has been adapted by evolution to succeed in a diverse set of ecological niches spans an abstract design space in which each species defines a point. If we can uncover which principles determine where these points are positioned and how their placement relates to the constraints, these insights can be used as design rules. Through interpolation or extrapolation, such design rules can not only be used to pick the most suitable biological solution to an engineering problem, but also to suggest solutions that do not exist in nature but are nevertheless informed by nature's design principles.

Pursuing an agenda of deriving design rules from the study of diverse sets of biological systems poses three major challenges:

1) a data acquisition challenge,
2) a representation challenge,
3) an analysis challenge.

The data acquisition challenge arises from the quantity and quality of the data about the biological systems that is required to elucidate the design rules behind natural diversity: adequate sampling of the biological diversity requires that data is obtained from a large number of species. At the same time, the obtained data should be quantitative and must cover the biological structures or processes themselves as well as their functional significance. In order to perform an analysis of biodiversity, the biological structures and their functional properties have to be represented in an appropriate manner. In particular, the representation must accurately represent all features that are of potential significance. The representations must also be a suitable substrate for the intended technique to describe their variability. If, for example, it is intended to describe the biological systems as a sum of basis functions, then it is important that biological data is represented in a way that can be decomposed into such a sum (e.g., the data cannot be just logical zeroes or ones).

The biosonar system of bats has proven itself as a model system to solve the data acquisition challenge. The main factor that determines how a bat's noseleaf or ear diffracts ultrasound is the geometrical shape of the structure. Other factors such as material



Tomographic reconstruction of a bat ear shape. Top: A sequence of x-ray shadow images acquired from different directions. Bottom: Reconstruction of the three-dimensional ear shape layer-by-layer.

'Biological Diversity *(continued)*

composition have been shown to have much less impact. Digital models of three dimensional biological structures - no matter how complicated - can be obtained using tomographic techniques on resolution scale that can start as small as the resolution of an electron microscope. Once an accurate digital model of the shape has been obtained, its interaction with the sound waves can be described using numerical (computer) models. This means that we can automate the process of obtaining digital models of the biological shapes and characterizing their functional properties. The large number of species is hence not a problem any more (as long as we can get suitable biological material). We are now embarking on work to address the other two challenges.

Despite this progress in our model system, in general all three challenges still require a significant amount of fundamental research until they can be solved. If this research is successful, the result may very well be a transformation of biomimicry from a craft that relies heavily on personal intuition and luck into an engineering discipline with a well-defined methodology.

[1] Global Biodiversity Assessment, R. T. Watson, V. Heywood et al. (eds.), Cambridge University Press, 1996

[2] Bats: A Natural History, J. E. Hill and J. D. Smith, University of Texas Press, 1992.

Rolf Mueller

A Modest Proposal - Expanding Our Ecological Footprint *(Ann Adams)*

Ann Adams is Director of Educational Products & Outreach at Holistic Management International.

There has been a great deal of press about the need for humans to reduce our ecological footprint, implying that Nature would be better off without humans. But, what if humans were actually a necessary part of addressing the key environmental issues of our time?

Holistic Management International (HMI), an international environmental education non-governmental organization headquartered in Albuquerque, New Mexico, works with stewards of large landscapes (agricultural producers, pastoralists and government agencies) to help them partner with Nature to create a positive ecological footprint. Through improved natural resource management practices, these managers improve soil health, which results in a host of benefits including improved water quality, carbon sequestration, drought mitigation, flood resilience, and food security.

The key to this work is understanding how Nature functions in "brittle" and "non-brittle" environments. Humans have taken a one size fits all approach to our resource management practices, which has resulted in loss of biodiversity and desertification. We have assumed that if we just leave Nature alone it will heal itself. While that may be true in non-brittle areas where there is consistent humidity year round that supports biological decay, it is not true in brittle areas where resting the land by reducing grazing pressure leads to greater land degradation. Considering that two thirds of the world is brittle, we had better make sure we look at our assumptions. Brittle areas need the presence of herbivores to cycle the plants through their guts to provide that biological decomposition. If those herbivores are not present, grasses stagnate and soils cap, resulting in poor mineral cycle, water cycle, energy flow, and community dynamics - the ecosystem processes.

These concepts were first articulated by Allan Savory, founder of HMI, as a young park ranger in Rhodesia (now Zimbabwe) 50 years ago. He saw the land continuing to deteriorate even as wildlife was culled to reduce the grazing and browsing pressure from the land. From his observations, he developed the key insights that underpin Holistic Management. In 1984, The Center for Holistic Resource Management (now HMI) was founded. Since then thousands of land managers all over the world have used these principles and practices to positively affect over 30 million acres worldwide.

One of the key insights of Holistic Management is Nature functions in wholes, therefore we must manage the relationships within that whole for the benefit of all. With Holistic Management we accomplish this by determining the whole we are managing and working with all the resources in it through a decision-making framework that encourages that whole to act as a self-organizing system - humans adapting their management in response to the changes happening in their resource base.

Humans often struggle to engage with Nature's complexity. Our tendency toward problem solving leads us to base our objectives on addressing a problem rather than focusing on desired outcomes. With Holistic Management, we strive to

A Modest Proposal *(continued)*

determine what we want in the context of our quality of life and our desire for healthy functioning ecosystem processes and test our decisions toward that desired outcome. Those are our management filters - providing a consciousness that replicates the evolutionary process.

Healthy ecosystem processes also create a resilient landscape that can weather the vagaries of life including droughts, floods, market shifts and government policies. In turn, those who rely on that land base are better situated to survive those fluctuations as well. This resilience buys time for those relying on the landscape to adapt and adjust to changes, staying responsive to early indicators and balancing feedback loops, as they continue to work toward that desired outcome.

One example of how this management process works is at our learning site, The Africa Centre for Holistic Management, in Zimbabwe. There we have worked with the local villagers to help them articulate their desired quality of life and a description of the land base upon which they rely. We then have worked with them to create management systems that help them create a positive ecological footprint within that landscape.

Desertified Lands

As you can see from these two pictures, while neighboring lands remain desertified and riverbeds dry (even in wet years), the land at our learning site is moving in the direction of healing ecosystem processes with more plants covering once bare ground and an increase in plant species diversity. Likewise, riverbeds (photo below) that have remained dry for years are now running again. All this effort has resulted in improved wildlife habitat that will result in additional tourist income for that area. Likewise, villagers can now provide more food security for their families as they have forage for their livestock. In turn, that livestock is also used to increase soil fertility in both rangelands and crop areas, increasing crop yields. Similar results are being achieved here in the U.S. when ranchers manage their domestic herds to mimic the behavior of wild herbivores like the Bison that kept the grasslands healthy before humans removed the predators and the herbivores from this system.

Regenerated Riverbed

These are just two examples of how Holistic Management has been used by a community to create a symbiotic relationship with other aspects within their whole, resulting in improved quality of life for many species and a better economy for the humans involved so they can continue to create a positive ecological footprint.

Research performed by scientists from Montana State University, Ohio State University, and North Dakota State University have verified some of the changes on grazing land where Holistic Management is practiced such as:

- 300% increase in plant species
- 400% increase in stocking rate
- 50% decrease in bare ground
- 800% increase in soil permeability
- 300% increase in profitability
- 500% increase in riparian bird population
- 900% increase in rooting depth of plants

Humans have certainly contributed to environmental problems, but abdicating our responsibility will only exacerbate the problems on over two thirds of the Earth's surface which are brittle environments needing many herbivores to cycle the grasses and create biologically active soil. We encourage resource managers, policy makers, and citizens from every walk of life to recognize our necessary role as part of the self-organizing systems within our communities and within the planet and universe.

Ann Adams

Calendar of Public Events

Date	Location	Event
June 15-27, 2008	California College of the Arts	Summer Institute in Sustainable Design
June 24, 2008	San Diego Zoo, California	Learning From Nature's Best Technologies: An Introduction to Biomimicry.
June 24-26, 2008	The Algarve, Portugal	Design and Nature 2008
June 26-July 14, 2008	Universidad Ibero-americana	Biomimicry Workshop
July 26-28, 2008	Yellowstone National Park	Exploring Nature's Best Ideas
August 4-6, 2008	Yorktown Heights, New York	Using Nature's Design to Bring Relevancy To and Revitalize Your Science Curriculum

Date	Location	Event
Oct. 10-12, 2008	Changchun, China	The 2nd International Conference of Bionic Engineering
Oct. 14-18, 2008	Nanjing, China	International Symposium on Nature-Inspired Technology
Oct. 16-17, 2008	Missoula, Montana	2008 MEA-MFT Educators' Conference (K-12 workshop on Oct. 16)
Oct. 16-19, 2008	Minneapolis, Minnesota	ACADIA 2008: Silicon + Skin, Biological Processes and Computation
Oct. 17-19, 2008	San Rafael, California	Bioneers 2008
Oct. 20, 2008	San Rafael, California	Biomimicry's Climate-Change Solutions: How Would Nature Do It?

"Biomimicry (from *bios*, meaning life, and *mimesis*, meaning to imitate) is a new science that studies nature's best ideas and then imitates these designs and processes to solve human problems. Studying a leaf to invent a better solar cell is an example. I think of it as "innovation inspired by nature."

The core idea is that nature, imaginative by necessity, has already solved many of the problems we are grappling with. Animals, plants, and microbes are the consummate engineers. They have found what works, what is appropriate, and most important, what lasts here on Earth. This is the real news of biomimicry: After 3.8 billion years of research and development, failures are fossils, and what surrounds us is the secret to survival.

Like the viceroy butterfly imitating the monarch, we humans are imitating the best and brightest organisms in our habitat. We are learning, for instance, how to harness energy like a leaf, grow food like a prairie, build ceramics like an abalone, self-medicate like a chimp, compute like a cell, and run a business like a hickory forest.

The conscious emulation of life's genius is a survival strategy for the human race, a path to a sustainable future. The more our world looks and functions like the natural world, the more likely we are to endure on this home that is ours, but not ours alone."

A Conversation with Janine Benyus

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Last, but not least, please send any feedback or comments to:

Norbert Hoeller

Clippings, Resources and Events

Four public-access Weblogs hosted on TypePad are now available to share information of interest to the Biomimicry Community.

- Clippings: short articles relating to Biomimicry.
- Resources: pointers to more extensive information.
- Events: workshops and relevant conferences.
- BioInspire: *NEW* Twenty-six issues of John Mlade's monthly magazine published between January 2003 and July 2005

These Weblogs can be monitored with your favorite RSS Reader. Anyone can post comments. Please be aware that TypePad requires an e-mail address and will display this address to people viewing the comment. Each Weblog has a 'sticky' post at the top with suggestions on how to reduce the impact of getting SPAMed.

Contributions of clippings, resources and events are greatly appreciated! Please see the note at the top of each Weblog for instructions.

Thanks, Norbert Hoeller

A CALL TO TEACHERS AND STUDENTS OF BIOMIMCRY ~
If you are integrating biomimicry into your teaching or learning, we want to hear about it! Just fill out the on-page form you'll find on the web at http://sinet.ca/tinc?key=zkJeYXyN&formname=BioEducation. When you're done filling out the information, you simply click on "ok" (lower right) and you're done. Thanks in advance!