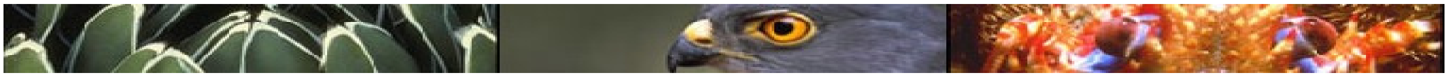

BioInspired!

Volume 6, Issue 4
November 28, 2008

THE BIOMIMICRY INSTITUTE

The Biomimicry Institute in 2008 *(Bryony Schwan)*

After a great deal of hard work by our amazing portal development team, we are very excited to announce that Ask Nature, our biomimicry design web portal, has been launched. It is the world's first digital library of Nature's solutions, organized by function, that can serve as an educational and cross-pollinating tool as well as a collaboration forum among biologists, engineers, designers and other innovators. Its 'Wiki' design allows people to contribute information about their work, helping us to expand the database rapidly. Its availability on-line, for beta testing, was announced by Janine at the annual Green Build Conference November 19-21 in Boston where she was one of the two closing keynote speakers along with E.O. Wilson, the pre-eminent Harvard University biologist dedicated to the conservation of biological diversity. The Green Build conference provided us with the opportunity to reach nearly 25,000 architects, engineers and designers from around the world. The Ask Nature website will be linked to E.O. Wilson's data base on the natural history of the world's known species, called The Encyclopedia of Life (EOL), as well as many others. Associated with the portal is the introduction of, and link to, the Innovation for Conservation program. This is a conservation program managed by TBI through which companies that have benefitted from biologically inspired designs can thank their sources of inspiration by contributing to programs that conserve those organisms or ecosystems.

On October 20th in Marin, California, the Biomimicry Institute co-sponsored with Bioneers the first conference on Biomimicry Solutions to Climate Change. Some of the world's leading innovators, scientists and companies presented their work in this field to an audience of investors, scientists, government officials and the public. Janine Benyus was the opening keynote speaker, and panels followed with discussions of bio-inspired energy, green building, biofuels and carbon fixation. It has been widely acclaimed as an inspiring introduction to the potential for biomimicry to help us find solutions to this global problem.

This year The Biomimicry Institute launched our two-year interdisciplinary Certification Program in Biomimicry. After receiving an overwhelming number of applications to the program, the first cohort of 16 students (mostly professionals in the fields of engineering, architecture, biology and business) began the program in May. They are working with on-line instructional materials, taking some course work locally, and they have already participated in two of five week-long in-person intensive sessions at sites in Montana and Vermont.

We held our second annual Education Summit this August at the University of Montana's Biological Station at Yellow Bay, MT. Seventeen people comprised of K-12 teachers and instructors from engineering, design, architecture, education and business programs attended the three day conference. They hailed from Canada, Mexico, China and the states of Vermont, Oregon, California, Arizona, Georgia, Colorado, and Minnesota. Participants shared information about the opportunities and challenges they experience when teaching biomimicry in a variety of contexts. Ideas were developed and new collaborations were forged during the three days of presentations and discussions that deepened the collective understanding of how to teach biomimicry and how students learn to use biomimicry tools. Afterwards a Biomimicry Educator's Google Group was established by the Institute to support further dialogue and interactions between summit attendees. All educators involved in biomimicry are welcome to join by contacting Cindy Gilbert.

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TBI provided a workshop on integrating biomimicry into the science curriculum for K-12 teachers at the Montana Education Association conference in Missoula on October 16-18. Participants responded very favorably to the session. "This made my appreciation for biomimicry even greater. I think biomimicry can greatly increase student interest in biology." "Very inspiring - mind boggling." "I would definitely use this in my classroom in biology to point out form and function connections and examples of innovation in science and technology."

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The Biomimicry Institute in 2008 *(continued)*

Under the heading of non-formal education there have been lots of fun developments. We have begun an extensive collaboration with the Zoological Society of San Diego and we are also now working with Tree Media in Los Angeles to develop an on-line biomimicry television channel. Beyond that we have provided content for documentaries to five other production companies. One of the most creative and exciting projects this year has been a children's CD of biomimicry songs called *Ask the Planet*, to be released the first of the year. Singer/songwriter Amy Martin composed all 17 songs and has developed accompanying curriculum for each song for use in elementary schools and informal educational settings. Several celebrity vocalists donated their time and talent to sing along with the Missoula Coyote Choir – a choir comprised of 17 children ranging in ages from 7-12. The music and accompanying curricula are designed to reconnect children with nature, create a sense of awe for the environment and teach them about the concept of biomimicry. The CD will be available for purchase through the TBI website as well as through museum, national park and zoo stores at the beginning of 2009.

The fourth *BioInspired! Newsletter* of 2008 starts with an update on the growing success and expansion of the PAX companies. PAX Scientific has been a regular contributor to the *BioInspired! Newsletter*, from an brief introduction in September 2004, an overview of the science behind the PAX Streamlining Principle in December 2004, notes on a talk by Jay Harman and Onno Koelman in March 2006, and an article by Peter Fiske on evolving design models in June 2008.

The success of biomimicry depends on a wide range of activities, from lectures, workshops and courses to applications that demonstrate the practical value of biomimicry. It is also essential that the field of biomimicry continues to grow and develop through research in theory, methods and processes. Three newsletter articles describe an organizational tool for biomimetic design inquiry (Tom McKeag), research in the cognitive aspects of biologically-inspired design (Ashok K. Goel) and implications of a comparison between biological and technological systems (Julian Vincent).

A key goal of biomimicry is to bring together a wide range of disciplines in helping to create a more sustainable future. The newsletter closes with a pointer to the 10th International Digital Print Exhibition that approached the same goal from the perspective of artist/scientists. If you are in the New York area before January 25/2009, you can see the exhibit 'in the flesh'.

Bryony Schwan

PAX Scientific: the Business of Biomimicry (*Kasey Arnold-Ince)*

Kasey Arnold-Ince is Director of Communications for the PAX companies.

With rising energy prices driving a need for increased efficiencies in both power utilization as well as in system-wide productivity, industry is finally appreciating the business case for cleantech. Encouraged by this shift, biomimetic engineering company PAX Scientific is increasing its efforts to bring natural streamlining to the world of fluid-handling equipment. To that end, we are quite the busy biomimics here in California:

- PAX Scientific continues its air handling and fan development research, and its work with master licensee PaxFan to commercialize these designs. PAX Scientific has spawned three related companies (see below) to address specific market areas, adding specialists in a variety of engineering and scientific disciplines. We have grown so much that we are now spread across four separate locations!
- PAX Water Technologies continues to expand its reach into the municipal water market. The company's mixing technology, the PAX Water Mixer, is designed to apply nature's flow strategies to the challenge of maintaining the quality and safety of drinking water stored in reservoir tanks. Mixing the water prevents microbial growth and reduces the need for chemical disinfectants. PAX's energy efficient in-tank mixer blends up to 7 million gallons of water by employing approximately 300 watts—the power used to light three 100-watt bulbs. We now have PAX Water representatives in 24 states and in Ontario, Canada. Our newest offering: a solar-powered option for off-the-grid operation.
- PAX Mixer continues to spearhead research into optimized mixing applications in a variety of industries. This research is supported by a three-year $1.9M Advanced Technology Program grant from the US Department of Commerce that was awarded to parent company PAX Scientific. Because these studies have the

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PAX Scientific *(continued)*

potential to benefit both companies, Mixer's scientists are working closely with engineers from the Water subsidiary to achieve the project's goal: leveraging nature's mixing methodologies into a new class of industrial mixers. We believe these mixers will offer better productivity and lower operating costs (including energy and maintenance).

- PAX's newest company, PAX Streamline, is in development mode with teams of engineers focused on identifying and producing solutions in the areas of power generation (optimizing wind turbines) and cooling (improving both the effectiveness and the energy efficiency of heating, ventilation and air conditioning systems, as well as refrigeration units). Streamline is also conducting continuing research into other areas where the Streamlining Principle may provide efficiency benefits that reduce the carbon footprint of industrial equipment. In addition to employing CAD and CFD tools, Streamline continues PAX's hands-on design approach. At our Novato location, we operate our own prototyping lab, thermal test rig, machining shop, and carbon fiber fabrication lab.

At PAX, we are learning a lesson from the slender blade of grass that breaks through the concrete: patience and perseverance pay off.

Kasey Arnold-Ince

THE BIO-NINE CUBE: An Organizational Tool for Biomimetic Design Inquiry *(Tom McKeag)*

Tom McKeag teaches the Applied Biology for Designers and Artists course at the California College of the Arts, San Francisco, California, and a biomimicry course for gifted elementary students in the Dixie School District, Marin County, California.

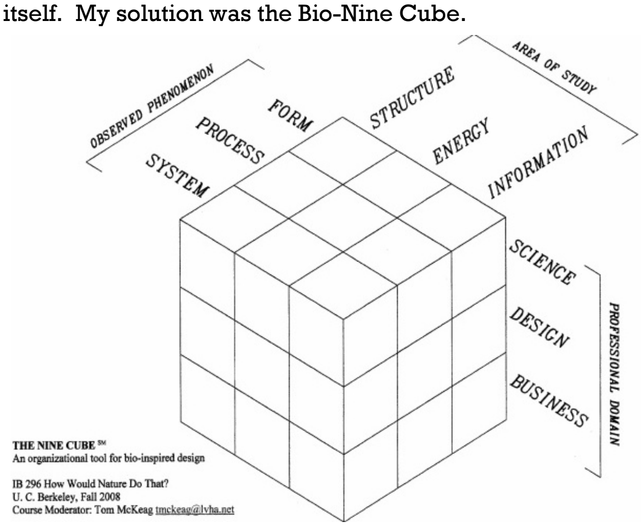
I teach a graduate course in bio-inspired design at U.C. Berkeley, "How Would Nature Do That?" I have had the great privilege of being sponsored by three distinguished faculty from the departments of Integrative Biology, Plant and Molecular Biology and Business: professors Robert Full, Lewis Feldman and Andrew Isaacs, and have been assisted by PhD student Margot Higgins. The goals of the course are to teach innovation using the study of nature as a lens, introduce a methodology for interdisciplinary collaboration, and sharpen awareness of the promise and pitfalls of working with biologically inspired products and solutions. Our students come from the worlds of architecture, biology, engineering, art and information.

My approach to the material is to encourage experiential, project-based learning in interdisciplinary teams working to short deadlines. I rely heavily on guest speakers, field trips and case studies to prepare students for their work.

Teaching bio-inspired design in this way can be daunting but very rewarding. You must present a wide range of general and technical information to students with varied backgrounds and capabilities. You must promote active, inter-disciplinary cooperation among them. You must inculcate methods of inquiry, analysis and creativity that will serve as a foundation for the ultimate goal of innovation. In return, you are likely to be blessed with an array of astonishing and fresh approaches to just about any problem you present.

One danger to this approach is for the students (and teachers) to get lost in the weeds of anecdotal information and thematic dead ends. The field of bio-inspired design can be characterized by emerging and fast-changing progress, scattered practitioners, and seemingly limitless scope. This is not reassuring to a generalist looking for an easy protocol for inquiry into the subject.

In developing this course, I realized that I needed a framework to guide me and help my students. This framework had to be complete, useful, instructive and provocative. In other words, it would have to map out a reasonable universe of possibilities to investigate, be directly helpful in a starting a search, inform study, and provoke thought about the study itself. My solution was the Bio-Nine Cube.



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THE BIO-NINE CUBE *(continued)*

The Bio-Nine Cube is a cross-reference system of twenty-seven cells based on the intersection of three axes:

1. Observable phenomena, represented by form, process and system.
2. Area of study, represented by structure, energy and information.
3. Professional domain, represented by science, design and business.

This cube could be viewed as framing the possibilities in the acts of observation, inquiry, and social endeavor. My intention is that this cube be used as a tool for educators to organize their classes, for students to plan their research, and for problem-solvers to analyze their approach. I should note that the cube could be made more universal by substituting the professional domain categories of research, design and management for the more specific science, design and business.

Let me give you an example of how I have found this framework to be useful. In industrial design, for instance, a practitioner might be interested in choosing an adhesive and want to know "how does nature stick to things?" She might discover some thematic leads in the literature or at a naturalist database like the Encyclopedia of Life or at a function-based web portal like the Biomimicry Institute's. She may be content with what she has found and proceed to seamlessly incorporate it into her proposed design.

However, she may not be so fortunate. I have found that one of my students' greatest challenges has been to appropriately apply biological information to practical designs. This difficult step in the iterative design process demands a lot of focused effort: testing, revising, rejecting and honestly analyzing everything from methods and materials to motivation. Without such effort, no design solution will succeed. A methodology for inquiry and analysis based on the Bio-Nine Cube can encourage examination of all possibilities.

If our student organized her research with the cube, she might start with observable phenomena and assemble an array of solutions such as the form of the gecko foot, the metabolic process of mussel byssel production, and the system of filamentous threads on a fungus. This wider selection immediately invites comparison, the start to analysis.

These phenomena might then be reviewed in the areas of study. How does the form of the gecko's foot, for instance, inform what we know or believe about structure, energy or information? Conversely, how do these areas inform us about the gecko?

Finally, all of this inquiry can be either informed or applied to the professional domains of science, design or business. Intention, of course, is always important and problem-solvers should know where they are headed and where they are coming from. Our student's approach to adhesion would certainly be different were it intended for a business marketing strategy rather than a building design.

Naturally, many occurrences in our world do not fit neatly or exclusively into these cells. It may be also evident to the reader that there are multi-directional flows of information possible within the cube. There is a two-way flow of information influence implied for each cell, much like a natural membrane. Choosing one cell or axis as a starting point will determine a unique pathway. The relationships between the cells (and the relative emphasis given to each) become as important as the substantive content discovered in their space. In short, this is a systemic tool, and I hope that educators, researchers and problem-solvers will find it useful.

Tom McKeag

Findings from Cognitive Studies of Biologically Inspired Design *(Ashok K. Goel)*

Ashok K. Goel is an Associate Professor of Computer and Cognitive Science at Georgia Institute of Technology, and a Co-Director of Georgia Tech's Center for Biologically Inspired Design.

By now there are many, many case studies of successful biologically inspired design: we know that for many design problems in engineering, architecture and computing, biological systems provide an excellent source of productive analogies. However, there are few detailed cognitive studies of biologically inspired design; a cognitive study systematically examines design behaviors and analyzes the behaviors in terms of information representations and processing. If we can understand the cognitive information processing in biologically inspired design, then we can develop pedagogical techniques and computational tools for fostering effective design practices.

At Georgia Tech's Center for Biologically Inspired Design, Michael Helms, Swaroop Vattam and I, working in collaboration with Jeannette Yen and Marc Weissburg, have conducted a series of *in situ* cognitive studies of biologically inspired design. These studies were conducted in the context of an interdisciplinary course on biologically inspired

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Findings from Cognitive Studies *(continued)*

engineering design. The instructors of the interdisciplinary course led by Yen taught biologically inspired design using a problem-based learning approach. Design projects in the course grouped interdisciplinary teams of four to five students, where each team had at least one student from biology with the rest coming from different engineering disciplines. Each team was responsible for identifying a problem, exploring solution alternatives, and developing a final design based on designs of biological systems. As observers, we attended the classroom sessions, collected course materials, documented lecture content, and observed teacher-student and student-student interactions in the classroom. We also did *in situ* observations of a few of the teams engaged in their design projects. Here, I briefly describe two findings from our studies; details of these and other findings can be found in our papers listed below.

Multiple Representations (or Allergen Trapping): We have found that in making analogies to biological systems, designers use multiple kinds of information (e.g., structure, function, causality and teleology) represented in multiple modalities (e.g., verbal, visual, and mathematical). These multiple, and multi-modal, representations enable analogical mappings between biological and engineering designs at multiple levels of abstraction such as structure, function and behavior.

Figure 1 is a reproduction of a drawing made by a design team with the left column in the figure representing information about biological systems and the right column the final engineering design solution. The goal of the project was to design a portable, stand-alone, home air filtration unit to trap allergens and other harmful particles. The designers considered several biological systems as sources of analogy to address this problem, including the human respiratory system, the human lung, the human kidney, hemoglobin, zebra mussels, oysters and clams, baleen whales, cyclosalpas and larvaceans, diatoms, and spider silk. Based on these different analogical sources, the designers generated and critiqued several designs during the course of the project. The first design, for example, was based on an analogy to the design of human respiratory system. The final design solution used a multi-stage filtration process. The first stage filter was inspired by spider silk, and was similar to current fiber-based filter designs. The second and third stage filters in the design solution were sheets of diatom frustules, with pore diameters of 0.2 and 0.02 microns respectively.

Figure 1 is noteworthy for several reasons. It represents information of many different kinds such as shapes, structure, behavior and function, and represents them in different modalities, such as verbal and visual. Further, the different kinds of information are interlinked, as indicated by the arrows within a column. Analogical mappings between the designs of biological systems and the engineering design solutions occur at multiple levels of abstraction, as indicated by the arrows between the left and the right columns. Finally, analogical mapping at one level of abstraction appears to support mappings at the other abstraction levels.

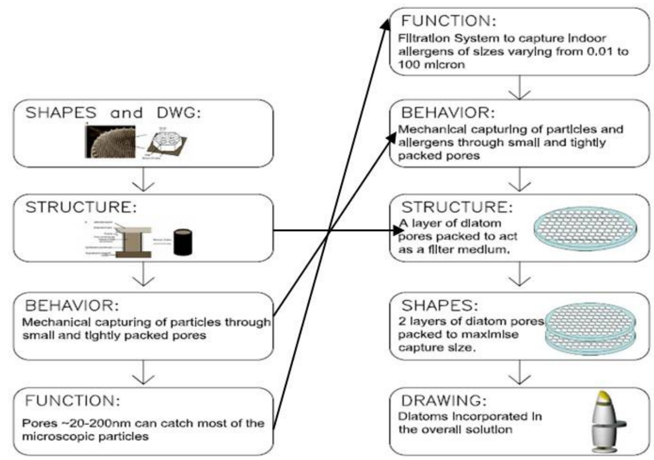

Figure 1. Multiple Representations (graphic from a student project)

Multiple Processes (or the Eye in the Sea): Although the literature describing case studies of biologically inspired design typically reports the use of single biological system as the source of analogy for a design problem, note that the design for trapping allergens used analogies to two different biological systems: spider silk and diatoms. In fact, we found that about half of all design projects used such *compound analogies*. Further, we found that the use of compound analogies entails an intricate interplay between the processes of problem decomposition and analogical reasoning. On one hand, the decomposition of a problem into sub-problems results in retrieval of biological analogues. On the other, analogical mapping between a problem and a biological solution leads to additional problem decomposition.

The Eye in the Sea design project illustrates the use of compound analogies in biologically inspired design. The goal of the project was to design a small underwater robot with locomotion modality that would ensure stealth. The initial research for the underwater robot focused on the copepod (a small crustacean, 1-2 mm in length) as a source for understanding stealthy locomotion. In exploring this concept, designers became aware that the copepod used two distinct rhythms of appendage movement for achieving motion underwater. A slow and stealthy rhythm was used when foraging for food and a quick but non-stealthy rhythm was used when escaping from predators. This understanding led the designers to decompose their original problem into two separate functions, one for slow movement and one for rapid movement, both of which required stealth. This new problem decomposition was based on the understanding of the design problem gleaned from the copepod analogy. The knowledge of the slow, stealthy mechanism used by the copepod, known as a "metachronal beating pattern" was also transferred from the copepod source.

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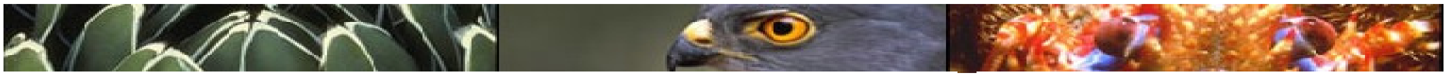

Findings from Cognitive Studies *(continued)*

Next, the designers had to address the second sub-function: fast, stealthy motion. They identified squid locomotion as an inspiration for achieving this function. The squid mechanism, jet propulsion, is both much faster and stealthy, matching its wake with external disturbances that naturally occur in the surrounding water. Notice the stealth achieved here (wake matching) is different from the stealth achieved by the copepod (wake minimizing). **Figure 2** develops an information-processing model of the generation of this solution using the framework of the compound analogical design. Step 1 depicts the nature of the problem space early in the design. The main function is to move underwater stealthily, and the copepod is identified as a solution analogue. In step 2, based on knowledge from the copepod analogy, the function of moving underwater is decomposed into sub-functions. The solution to the function of moving slowly by minimizing wake is adapted from the copepod to generate a partial solution. But the function of moving fast, yet stealthily, remains unresolved in step 2. In step 3, the squid analogue is retrieved to address this function. Its solution of using jet propulsion for movement is transferred to the current problem to generate the remaining solution. These two partial solutions are aggregated to achieve the final design.

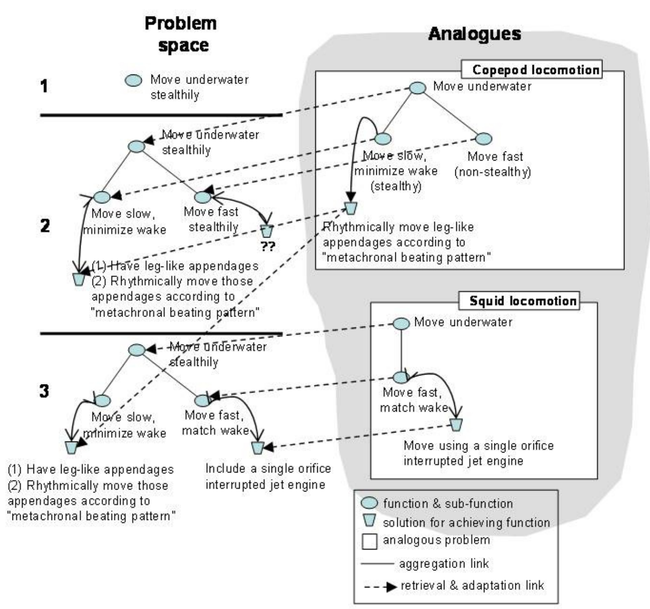

Figure 2: Design Trajectory of the Eye in the Sea

Supporting Biologically Inspired Design Using DANTE: The cognitive studies that I have briefly described above have led us to a deeper, though still quite incomplete, understanding of the information processing requirements of biologically inspired design. Vattam, Helms and I are now developing an interactive computational environment for supporting biologically inspired design in practice. The computational foundation, called DANTE (for "the Design by Analogy to Natural Teleologies Engine") provides tools for expressing and accessing multiple representations of complex biological systems, including text, diagrams, and structured knowledge representations that explicitly capture a system's structure, behaviors and functions. The structured knowledge representations also provide a vocabulary for expressing design problems. Given a design problem, DANTE will support the retrieval of information about multiple biological systems relevant to the problem, enabling the designer to browse through the information. We expect the authoring, retrieval and browsing tools of DANTE to be ready for beta-testing by the end of this calendar year, and intend to put it on a web server so that it can be used as widely as possible.

Prof. Ashok K Goel
http://home.cc.gatech.edu/dil/3

Acknowledgements:
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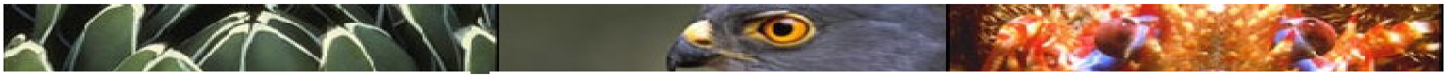

A Comparison of Biological and Technological Systems *(Julian Vincent)*

Professor Julian Vincent is Director of the Centre for Biomimetic and Natural Technologies at the University of Bath (UK), Associate Chief Editor of the Journal of Bionic Engineering, and one of the founders of BioTRIZ Ltd.

What can Nature teach us? In addition to providing a rich library of specific forms and processes that have been honed by millions of years of natural selection, the underlying structure of Nature's systems can help us understand how some ecosystems and species have survived for impressive periods of time in spite of numerous stresses. These underlying patterns may also help explain current human behaviour and suggest pathways for our cultural evolution.

Energy vs. Information

TRIZ (Theory of Inventive Problem Solving) formalised the idea that problems arise from conflicts between our desires and the impediments standing in our way. Altshuller, the founder of TRIZ, developed a comprehensive matrix of results and conflicts (or contradictions). He identified inventive solutions that resolved these conflicts, rather than merely settling for a compromise.

The paper "Biomimetics: its practice and theory" (J. Vincent, O Bogatyreva, N. Bogatyrev, A. Bowyer, A-K. Pahl) transformed the TRIZ contradiction matrix into six fields of operation:

- Substance (the material from which something is made)
- Structure (the way the materials are arranged)
- Energy (the source of energy, or the amount of energy, whether more or less)
- Space (space occupied by the system, or space available for it to work)
- Time (the order in which things might happen, or the time required for something to be done)
- Information (the control mechanism and things which influence it).

The resulting matrix allowed a comparison of the operations used in technology and biology to solve problems from nanometre to kilometre scales.

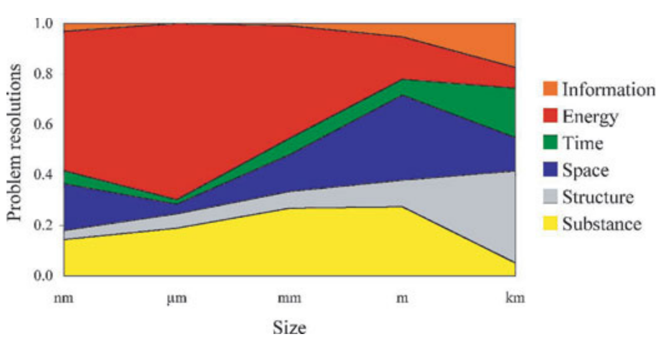

Figure 1. Engineering TRIZ solutions arranged according to size/hierarchy

Although the problems solved by biology and technology are largely the same, the methods are only comparable in about 12% of the cases. As shown in **figure 1**, we use energy as our primary `lever' up to the metre scale, with 'substance' in next place. When faced with an engineering problem, we largely rely on energy-intensive chemistry and metallurgy to provide an ever-expanding supply of new substances as new requirements arise.

In contrast, biological systems tend to use information, structure and space as shown in **figure 2**. Energy is the least used, at about 5% of the cases. In comparison, energy is used in about 60% of engineering solutions, a 10-fold difference. Whereas we have developed over 350 polymers, biology largely works with two types: proteins and polysaccharides. These materials are imbued with information, starting from the DNA molecule that controls amino acid assembly. Often, their structure and orientation in space allows these common polymers to deliver a wide range of functional capabilities while maintaining a low level of embedded energy.

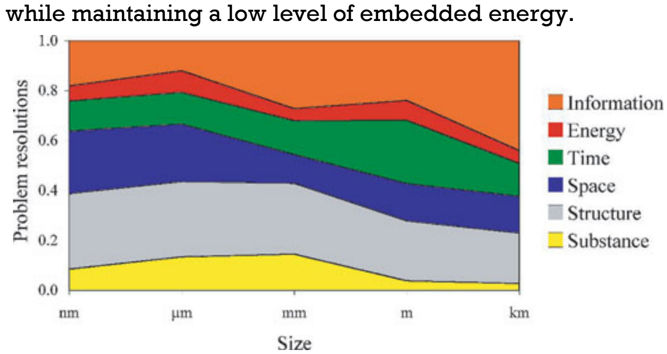

Figure 2. Biological effects arranged according to size/hierarchy

The low usage of energy by biological systems is likely due to the relative scarcity of energy. Except for cosmic dust and gases lost to space, matter on earth has been recycled continuously for billions of years. In contrast, energy 'flows'. Although energy *quantity* is conserved, its *quality* (the ability to do useful work) continually degrades until it is lost to space as low-grade heat. The primary source of energy on Earth is solar radiation which both heats the Earth and drives numerous chemical, biological and physical cycles. Although solar energy can be stored, this only shifts usage and does not increase the total amount of energy available.

Humans have been able to release large amounts of energy by tapping fossil fuel stores as well as nuclear energy at a rate far exceeding the rate at which these stores are replenished. The benefits are clear: energy is the driving engine of human progress, allowing us to do more things at a much faster rate than other species. Yet this progress is based on eating into the Earth's energy capital, rather than living off the income. As Georgescu-Roegen pointed out, "Perhaps, the destiny of man is to have a short, but fiery, exciting and extravagant life..." (Southern Economic Journal 41:347-381, 1975)

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Biological and Technological Systems *(continued)*

'Making' vs. 'Being'

Our technology is largely based on "heat, beat and treat". We use copious amounts of energy to homogenise materials through processes such as smelting, destroying embedded information. We then use more energy to impose a new structure (moulding, casting, forging) to produce the desired product. This is 'making', where we are largely outside the system and use its resources in their 'low information' form.

In contrast, biological systems do not have the luxury of vast energy reserves but instead use information embedded in materials to create shapes and function. Self-assembly is common in nature, water is often the solvent and processes tend to occur at ambient temperatures. Due to the short range over which most forces act, biological systems utilise hierarchy to increase scale. Hierarchies allow adaptation and combination of building blocks in efficient ways, both from a material and energy perspective. This is 'being', where the agents are working within the system, leveraging the full capabilities of its resources.

An intriguing question is whether 'being' and working within a system reduces the complexity of interactions. An organism that is embedded in a larger system tends to only concern itself with those parts of the system that directly affect it. Its impact tends to be circumscribed. Change tends to be evolutionary, incrementally building on what has come before. In comparison, an organism that is outside of the system needs to understand how the system works. That organism can have a much larger impact but this power can encourage taking a more revolutionary approach, which can increase risk, take longer to integrate and is more likely to destabilise the system in unexpected ways.

In the case of architecture, we typically design buildings based on insitutionalised principles and build them to last decades (if not longer). In effect, we are making a prediction of the future. In contrast, animals tend to continually adjust their homes in response to local environmental pressures. Birds build nests that over time are better insulated on the windward side. Compass termites build nests oriented such that the internal temperature remains constant regardless of the position of the sun in the sky. These examples likely involve relatively simple rules that provide insulation where required and reduce the section profile in the hottest direction. Architects such as Ralph Knowles have experimented with exploring how natural forces (sun, gravity, wind) and rhythms can be creative elements in architectural design. Designing a building based on the ambient site conditions can result in a remarkably efficient and pleasant building.

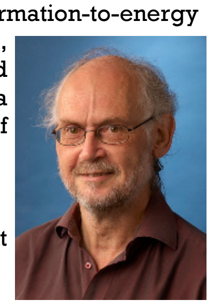
Implications for the Human Species

Human behaviour is often considered to be separate or different from that of other species. This belief is held both by those who consider humans as "above" nature as well as those who claim our behaviour is somehow "unnatural". Yet many characteristics of human actions have analogies in nature. This should not be taken as justification for our behaviour nor does it discount the value of human culture. However, understanding the potential consequences of our actions may help guide our steps.

Disturbed or disrupted ecosystems are typically colonised by pioneer or Type I species. These species are often competitive, opportunistic, short-lived and fast breeders. The abundance of freely available resources supports relatively inefficient and linear (non-cyclical) usage. In many ways, the Industrial Revolution was a key turning point in our relationship with nature. Our ability to tap (if only temporarily) abundant and cheap energy allowed us to act like a pioneer species that did not need to conserve but could focus on spreading fast. This phenomenon is relatively new in human history. For example, industrial agriculture with its focus on short-term yield is quite different from earlier agriculture where farmers worried about passing a legacy to their children and their children's children.

Type I species compete for resources but use those resources inefficiently. They breed profusely but only occupy the stage for a short time, surviving by spreading seeds that can remain dormant for long periods of time. They are well-adapted to their niche, but by converting solar energy to abundant biomass set the stage for ecological succession that eventually will displace the Type I species. Over time, Type II species begin to take over and in turn are replaced by Type III species. Throughout this process of ecological succession, energy usage becomes increasingly efficient, matter is cycled within the system, cycles begin to slow, and symbiosis becomes more prevalent. As energy flow decreases, information becomes increasingly important.

The human species prides itself on adaptability. Will our history be that of a Type I species, or worse, an invasive species that is more of a disruptive influence, consuming rather than building living capital? Or will we adopt the attributes of Type II and Type III species: effective and efficient use of resources, an increasing information-to-energy ratio, balanced and reciprocal relationships, and integration into the encompassing and supporting systems? Will we become a footnote or will we truly become part of Earth's vibrant and diverse 'web of life'?



Prof. Julian Vincent

Acknowledgements

- Material Beliefs: Interview with Julian Vincent
- Is traditional engineering the right system with which to manipulate our world?
- R. Knowles; papers on architecture, nature and context
- D. Korten; Natural Succession and the Step to Maturity

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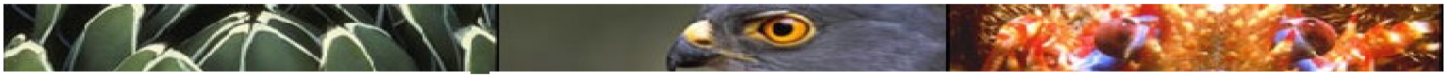
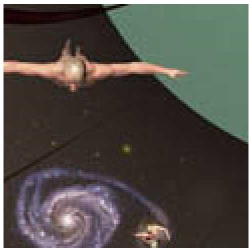
The Biomimicry Institute, 2003-2008



Digital'08: Imagination on Behalf of Our Planet



Roger Ferragallo

Art & Science Collaborations, Inc. (ASCI) challenged entrants to the 10th International Digital Print Exhibition to "boldly envision on behalf of our planet" around a series of questions on the current environmental challenges, new and positive approaches to sustaining life, and ways of inspiring us to "confront the consequences of our current way of living".

ASCI, a 20-year-old nonprofit based in New York City, is dedicated to building connections between the arts, science and technology, while raising public awareness about artists and scientists.

According to Cynthia Pannucci, ASCI Founder/Director:

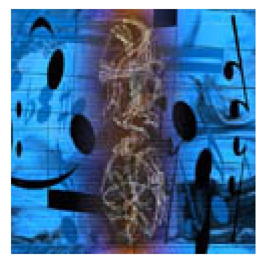
> "Foremost, to me, the power of art is to make people question their own assumptions, … to joyfully create connections to their own experiences/knowledge, and to dream. To me, this is the first part of the process of truly innovative and creative science as well."

The display can be seen at The New York Hall of Science between October 4, 2008 and January 25, 2009. All images and statements by the artists/scientists can also be viewed at the online exhibition at http://www.asci.org/artikel994.html.

Nathaniel Freeman

Katherine Kollins

Edward Ramsay-Morin



Hugh O'Donnell

Calendar of Public Events

Date	Location	Event
Dec. 5, 2008	San Juan, Puerto Rico	Caribbean Green Expo Closing Plenary : *Biomimicry and the Built Environment: Creating Conditions Conducive to Life*
Dec. 9-12, 2008	Sanya, China	International Workshop on Mechanics and Biomimetics of Biomaterials & Animal Locomotion
Dec. 14-17, 2008	Bangkok, Thailand	2008 IEEE International Conference on Robotics and Biomimetics
Feb. 5, 2009	The Netherlands	Materia's 2009 Congress Presentation: *Biomimicry: Innovation Inspired by Nature*
Feb. 10, 2009	Arizona State University, Tempe	Innovation Space Presentation: *What would nature do? Biomimicry as a Path to Sustainability*

Date	Location	Event
Feb. 24, 2009	Fort Worth, TX	Frost Foundation Lectureship on Global Issues Presentation: What would nature do? Biomimicry as a Path to Sustainability
March 3, 2009	Syracuse University, New York	Lecture: Biomimicry: Innovation Inspired by Nature
Mar. 31-Apr. 2, 2009	Loughborough University, UK	Fifth International Conference on Bio-Acoustics.
July 27-31, 2009	Edinburg, UK	17th International Conference on Composite Materials

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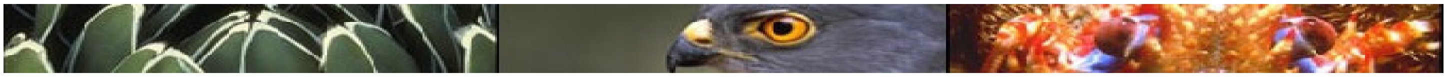
The Biomimicry Institute, 2003-2008



"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

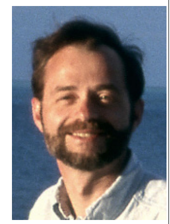
BioInspired! is published quarterly and is posted on a public-access Weblog hosted by TypePad. For those of you familiar with RSS Readers, TypePad supports various feed formats (look for the *Subscribe to this blog's feed* link in the right navigator).

Comments can be posted on the newsletter Weblog. At this time, the TypePad RSS feed does not deliver comments.

If you wish to subscribe to this newsletter, please complete the E-newsletter sign-up form.

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 Spammed.

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!

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The Biomimicry Institute, 2003-2008