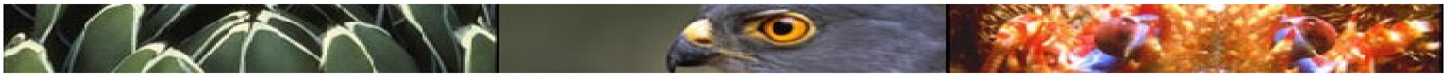
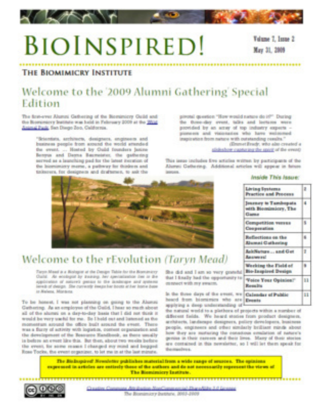


BioInspired!

Volume 7, Issue 3
September 8, 2010

CENTER FOR BIOLOGICALLY INSPIRED DESIGN

Welcome Back to *BioInspired!*


BIOINSPIRED!

Volume 7, Issue 2
May 21, 2009

The Biomimicry Institute

Welcome to the 2009 Alumni Gathering Special Edition

Welcome to the rEvolution (Taryn Mead)

After a year's absence, *BioInspired!* has been re-launched with a new sponsor, Georgia Tech's Center for Biologically Inspired Design (CBID). Whereas the previous newsletter was intended for a broad audience, this newsletter will focus on promoting the *practice* of bio-inspired design. It will ask provocative questions that explore fundamental issues, helping to strengthen the discipline.


Biomimicry Guild Newsletter

Greetings From Montana

The first *Biomimicry Newsletter* was published in October 2003 as a quarterly communications vehicle for the core biomimicry community, with a distribution in the low hundreds. In 2006, Janine Benyus and Dayna Baumeister wanted a newsletter suitable for a wider audience. The first *BioInspired!* issue was sent to nearly 1,300 subscribers in July 2006 under the sponsorship of the newly formed Biomimicry Institute. Through the support of the Biomimicry Guild, The Biomimicry Institute and dozens of contributors, the last issue in May 2009 reached 4,762 subscribers.

With this issue, the newsletter is going back to its roots. The target audience is the growing number of individuals and organizations committed to practical applications of bio-inspired design (BID), attracted by the potential for encouraging sustainable technology and innovation. CBID is a particularly good sponsor because it represents a "group of interdisciplinary biologists, engineers and physical scientists who seek to facilitate research and education for innovative products and techniques based on biologically-inspired design solutions". Some of the key elements of CBID were developed at the 2005 Biomimicry & Design Workshop in Costa Rica.

BioInspired! will continue to be published quarterly in both PDF and web-based formats. Issues will contain an average of 10 pages or about 5000 words. Content will be technical but not academic, avoiding jargon or discipline-specific concepts. The scope will range from the strategic to the practical, but always striving to be insightful, relevant, useful and evidence-based. Scientific integrity and credibility will be emphasized.

Articles will:

- disseminate information on new developments in the field
- promote activities at CBID and other leaders in bio-inspired design
- provide readers with opportunities to get involved, create networks and contribute to sustainable human behavior, product development and practices

Topic areas will include:

- case studies on successful applications
- discussion of useful biological principles
- biological or engineering analysis of specific biological systems that are useful in solving certain classes of problems
- information search strategies and design techniques
- issues relating to bio-inspired design education

The newsletter is part of the larger Bio-Inspired Design Community initiative and will be funded through the community membership fee.

Inside This Issue:

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 Center for Biologically Inspired Design.

The Bio-Inspired Design Community

The Bio-Inspired Design (BID) Community will promote the practical application of bio-inspired design, emphasizing the 'challenge to biology' approach. The objective is to foster more effective and efficient methods for developing solutions based on natural principles. The goal is to encourage the conscious application of principles that support and promote solutions facilitating sustainable human behavior and leading to successful products, services and systems initiatives.

Motivation

Individuals and organizations have a thriving interest in doing pragmatic and relevant design based on principles and solutions learned from nature. At the same time, the number of active BID practitioners is growing, providing a source of inspiration, moral support and practical guidance to the 'next wave'.

A community serving the needs of individuals and organizations using BID as a key problem-solving method will help build bridges between different experience levels and disciplines. It will be a hub for collecting and broadcasting BID information, knowledge and expertise. Such a community can explore initiatives in three areas:

- motivation to apply BID by demonstrating its value in various contexts
- development of tools, methods and approaches supporting the effective and efficient use of BID
- expanded opportunities to apply BID through sharing successes, identifying trends and encouraging collaboration

Membership

Current practitioners in the field of bio-inspired design are the cornerstones of the BID community. They actively share their real-world experiences and insights, coach 'up and coming' members of the community, and lead discussions on fundamental issues relating to BID. In turn, they gain fresh perspectives on advances in BID, access to a more diverse personal network, personal satisfaction at helping others become successful at practicing BID, and community recognition for making a tangible contribution to expanding the field of BID.

Up and coming members (the 'next wave') have a responsibility to apply what they have learned through the community and report their experiences. As their experience grows, they coach others. They benefit from an accelerated learning curve through feedback and ideas from the larger community and participating in BID opportunities. They will also gain greater confidence to try new approaches and take on new challenges.

The BID community needs facilitators who translate between disciplines (science, biology, engineering), organize and synthesize knowledge, develop tools and methods, and ensure community members can effectively use these BID aids. Facilitators can help identify ways of incorporating the richness, immediacy and credibility of face-to-face meetings into the virtual community. The community participates in piloting tools and methods that demonstrate tangible improvements and provide widespread value. Facilitators are recognized for improving the efficiency and effectiveness of the community.

Lastly, the BID community needs people knowledgeable in human history, psychology and cognition, helping facilitate the intersection of design and human behavior. The interdisciplinary nature of BID is a creative act, and understanding how to encourage these efforts may yield techniques to enhance creativity generally as well as promote BID as a way of thinking. If BID is to succeed as an agent of change, our community must include individuals who are versed in the art of identifying resistance to change and pathways by which change may be effected. We need think about our relationship with the nature and how our values affect the organization of technology and institutions if humans are to become "honoured as part of the biosphere". The community offers opportunities to discuss new ideas and approaches that could lead to expanded efforts in education, research and practical training.

The community will start with roughly 100 'charter members' based on personal recommendations and early newsletter distribution lists. We will seek to attract participants from diverse backgrounds to expand the areas in which BID is relevant. Members will be recognized for active participation and helping to grow the community. We will operate as an informal cooperative with members influencing in how the community will be organized.

Services

A $15 quarterly membership fee for individuals will support the quarterly newsletter and a dynamic, collaborative website. In the future, a membership structure for academic institutions, businesses and other organizations will be developed.

Services provided by the website will include comprehensive user profiles, forums, blogs, event calendars and information libraries. Members will have the greatest content access and website privileges, as well as access to future services such as customized reports, tools for matching opportunities with capabilities or support for collaborating on specific projects. The website will also support limited access by visitors and registered users who are not yet paid-up members. This allows the BID community to reach a wider audience and attract new members.

The Bio-Inspired Design Landscape

Interest in bio-inspired design is accelerating. Biomimicry is regularly on the agenda of high profiles events such as Bioneers, Green Build and UN conferences ranging from climate change to biodiversity. BIONIS (the Biomimetics Network for Industrial Sustainability) has been actively "promot[ing] the application of Biomimetics (Design Inspired by Nature) in products and services and its use in education and training' since 2002. The journals Bioinspiration & Biomimetics and the Journal of Bionic Engineering are dedicated to the field. A steadily growing number of courses are available from The Biomimicry Institute and universities, including the Biomimicry Professional Certification Program.

Biologically-inspired patents in the US and China are showing exponential growth (Patented Biologically-inspired Technological Innovations: A Twenty Year View, Bonser). The Third International Conference of Bionic Engineering is being held on September 14-16/2010, in Zhuhai, China. More important, significant biologically-inspired innovations are now available in the marketplace, including the PAX Streamlining Principle, Lotusan® self-cleaning paint, PureBond® water-resistant adhesives, Mirasol® structural color displays and Regen Energy's EnvironGrid swarm-logic power controllers.

BID Landscape - Architecture

Architecture has come to the field of modern biomimetics relatively recently compared with engineering and medicine, but the profession's adoption appears to be accelerating rapidly. Computational capacity, development of sophisticated sensors and building information systems, and new materials and methods are changing this tradition-based profession.

Technological advances in form-making tools now available to nearly any practitioner also explain this rapid adoption. Powerful parametric software programs like Rhino and Grasshopper have enabled designers to form organic shapes within the constraints of digital building plans and to test stresses on these shapes. Laser sintering and contour crafting devices now allow rapid prototyping. These tools have enabled an evolving paradigm shift in the way that designers approach the problems of building design. Many designs now proceed from the complex formulation of constraints and the custom optimization of structural elements rather than the more traditional aggregation of standard manufactured parts.

A good example of this is the Great Court roof of the British Museum by Sir Norman Foster and Partners. A torroid shaped glass roof was constructed over the court and links the central cylinder of the old library with the rectangular perimeter of the court. The roof design was a collaboration of engineers, architects and a mathematician, and its final form is the result of the forces acting on the existing historical buildings and the roof, rather than a concept of the individual designer retroactively engineered to work.

More architects are also discovering the rich treasure trove of inspiration nature offers. In the best cases of such adoption, the translations go beyond mere form and metaphor to include functional advantages. The so-called Water Cube or Aquatics Center at the Beijing Olympics is an innovative use of both form and materials. Its famous "water bubble" frame is based on a least surface formulation called the Weir Phelan model, and the ETFE (Ethylene tetrafluoroethylene) stretched over this frame is lightweight, relatively durable and efficient.

The drive to save energy within buildings is also prompting designers to capitalize on thermodynamic forces, something natural organisms have been doing for billions of years. The pioneering work of Mick Pearce is a case in point. His Eastgate Building in Harare, Zimbabwe, and Council House Two building in Melbourne, Australia, are examples of nature-inspired strategies for passive climate control in buildings. The Eastgate's cooling mechanisms were inspired by the structure of an African termite mound (http://www.greenbiz.com/blog/2009/09/02/how-termites-inspired-mick-pearces-green-buildings).

Historical examples of bio-inspired architecture include the Eiffel Tower, 1889, and the Crystal Palace, 1851 (http://www.greenbiz.com/blog/2010/03/03/it-worth-looking-nature-profit) and the work of Frei Otto and the engineer Heinz Isler (http://www.greenbiz.com/blog/2009/07/22/structure-old-shell-game). Although Isler's intent was not to mimic nature but to push the bounds of structural performance, he realized he could quickly source solutions by earnest observation of natural phenomena.

BID Landscape - Architecture *(continued)*

Future trends in the profession are likely to include many that are bio-inspired: increasingly sophisticated feedback loops for environmental controls, information-embedded materials that obviate the need for active energy use, and systems design are all examples (http://www.greenbiz.com/blog/2010/06/16/will-synthetic-biology-lead-truly-living-buildings). Finally, the wider cross-disciplinary approach beginning in other fields has also come tentatively to architecture. This offers exciting possibilities for collaboration and innovation.

Tom McKeag
California College of the Arts and UC Berkeley
Founder and President of BioDreamMachine

BID Landscape - Industrial Design

Over-simplifying it, we could say that design as a human activity is mainly our conscious action to modify our environment. If we consider our environment as our context, then design affects our context at different levels and in different scales. From small to big (micro to macro) we can define a local, regional, national and global context. Within this same logic from small to big, our man made world is enriched by diverse design disciplines which are closely interrelated but operate on different levels of complexity and scale, such as Industrial Design, Interior Design, Architecture, and Urban Planning. In the smaller hand-scale or human scale, we have Product Design or Product Design Engineering.

Industrial Design has been greatly influenced by nature. Examples include diverse movements that range from the "*Aerodinamism*", "*Styling*" and "*Organic Design*" styles of the mid-twentieth century, to today's "*Blobjects*" (Holt, 2005) as popularized by contemporary design icons such as Phillip Starck, Mark Newson, Ross Lovegrove or Karim Rashid, among many others. It is not surprising, then, that Industrial Design education, "*the teaching of a horizontal and cross-discipline profession*" (Papanek, 1984) has also incorporated bio-inspired studies for more than thirty years.

The "industrial" aspect of Industrial Design has a strong link with engineering design and technology. In this area, diverse bio-inspired approaches have generated some of the most important inventions in the last three centuries of human history. Fields of research such as "*biomechanics*", "*bio-engineering*", "*bionics*", "*robotics*", and "*biomimetics*" had their origin mainly during the mid twentieth century and are today widely explored fields.

More recent bio-design is what some researchers have defined as "biophilic design" (Kellert, Heerwagen & Maador, 2008) to describe an "*innovative approach that emphasizes the necessity of maintaining, enhancing and restoring the beneficial experience of nature in the built environment.*" Biophilic design has its origin in the term "biophilia" coined by scientist E.O. Wilson in 1984, which is the "inherent human inclination to affiliate with natural systems and processes, especially life and life-like features of the non-human environment". This approach is based on scientific evidence that contact with nature has strong positive effects in human beings, in terms of healing from diseases, productivity at work, etc. As such, it tries to bring nature and natural elements back into the built environment. This in turn promotes the use of bio-inspired design within the manmade dwellings, to enhance human well-being by connecting us to nature, or to elements which remind us of nature.

A visual summary of some of the different examples of bio-inspired design mentioned above is found in the following figure. The examples are classified in terms of form, function and process or system from nature, based on the levels of "biomimicry" as proposed by Janine Benyus (1997).

In the upper area we see several examples of "Biomorphism", or forms inspired in nature. They range from pieces from the arts and crafts and art nouveau period in the early 1900's to the organic furniture and spaces of the 1950's, and finally to some contemporary "blobjects".

The middle band shows function inspired by nature, which usually has a strong technological focus. Many early inventions, such as barbed wire or cat eyes are bio-inspired. More recently, the invention on "Velcro" and even the famous "lotus effect" are also bio-inspired. Currently in the market we can find many bio-inspired products such as the bionic car concept inspired by the boxfish, the swimming suits inspired in shark skin, protective devices inspired in armadillos and pillbugs, and many others.

Finally, the lower band illustrates bio-inspired design at the level of processes or systems, probably one of the most difficult yet important aspect. Because of the scale of bio-inspired systems thinking, some theories of urbanism, architecture and landscape design have also been included in the graph, such as the metabolic and symbiotic architecture, eco-cities and others.

BID Landscape - Industrial Design *(continued)*

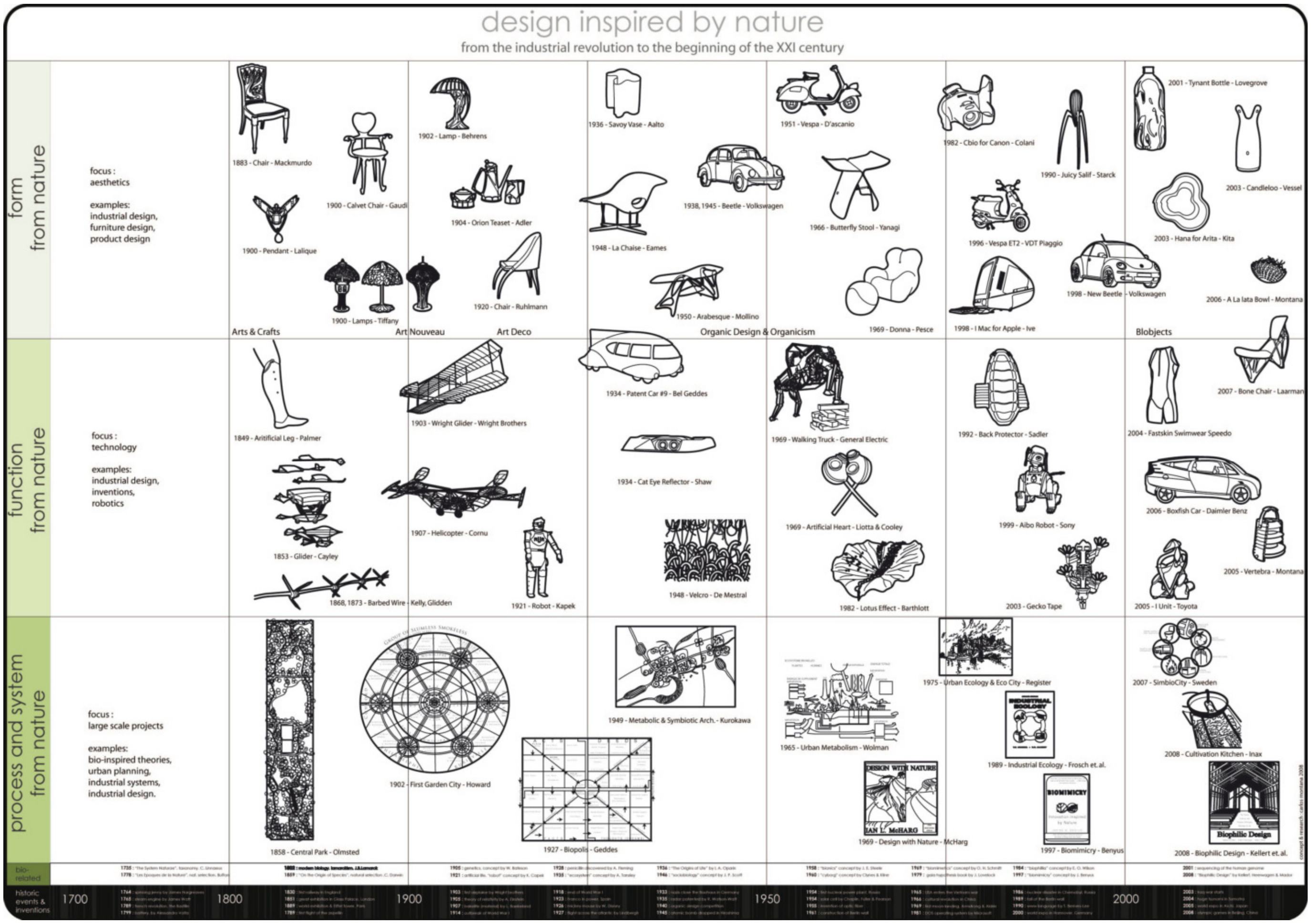
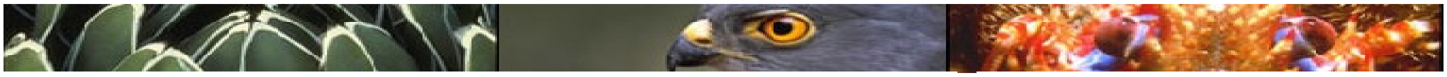


Figure 1: Visual summary of Bio-Inspired Design Examples: 1) form 2) function 3) process and system from nature, since the Industrial Revolution.

Two of the most relevant examples of contemporary imitation of nature which are strongly linked to Industrial Design and operate at a systems level are 'Industrial Ecology' and 'Cradle to Cradle'. The term Industrial Ecology was coined in 1989 (Frosch, R & Gallopoulos, N) and widely divulged by Graedel & Allenby (1995). This new systems-based multidisciplinary relationship between industry and ecology that proposes analogies between natural systems (ecosystems) and human-made systems related to industrial production. Two of the most important analogies of Industrial Ecology with nature are in terms of 'metabolisms' and 'symbiosis'. Industrial metabolisms are related to the study of flows and cycles of materials and energy in industry, while industrial symbiosis describes the way in which different 'industrial organisms' can co-exist in an 'industrial ecosystem'. The best known example of Industrial Ecology is the Kalundborg Eco-Industrial Park, located in Denmark, where diverse industries conveniently located nearby share their energy and materials such that wastes from one industry become resources for the other.

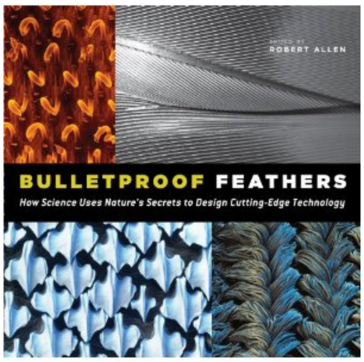
The 'Cradle to Cradle' theory developed by McDonough and Braungart (2002) proposes closed-loop life-cycles inspired by nature for architectural and industrial production, as opposed to the traditional linear life-cycle previously known as 'Cradle to Grave'. Our current efforts for 'recycling' diverse mixed wastes of industrial products and urban construction is better described as a 'down-cycling' process and 'end-of-the-pipe solution' in which the materials lose their properties. Cradle to Cradle proposes design strategies from the 'beginning-of-the-pipe' in which products are intentionally designed to be 'up-cycled' in closed-loop systems. In nature nothing becomes waste and everything becomes part of the food chain. Thus, Cradle to Cradle can be understood as a type of bio-inspired design at the systems level, in which designers, architects and urban planners imitate how ecosystems work in nature.

Dr. Carlos Alberto MONTANA HOYOS
Associate Professor - Industrial Design
University of Canberra, Australia



BID Landscape - Materials

The list of materials inspired by biology is long and diverse, ranging from the ubiquitous Velcro to Lotusan paint, the Fastskin swimsuit, dry adhesive 'gecko' tape and waterproof adhesives inspired by mussels. A search on Google for '*biomimetic material*' results in over a million hits, including a pointer to [The Biomimetic Materials Laboratory] at the McGill University Faculty of Engineering.



The recently published **Bulletproof Feathers: How Science Uses Nature's Secrets to Design Cutting-Edge Technology** includes a chapter by Prof. Julian Vincent on *New Materials and Natural Design*. Although biological and engineered materials overlap in their functional characteristics, they differ greatly in their constituents, manufacture, structure, usage characteristics and disposal. For example, water is usually avoided in most engineered materials since it causes degradation. In biological materials, water is a key reaction medium and often a critical component. Although water may have a small molecular size, it 'lifts above its weight class' as a plasticizer, lubricant and structural component. It is also a crucial component in 'assembly zones' that organize the way biological polymers interact, making sure that hydrophobic areas can identify and stick to each other.

Vincent describes how proteins constructed from a pool of 20 different amino acids can have a wide range of properties, from the relatively flexible collagen and elastin to dragline silk that is stronger than steel yet produced at ambient temperatures and pressures. Polysaccharides, the other major biological polymer, are found in gels and space fillers as well as stiff fibers such as cellulose, the raw material for some of our first plastics. He goes on to describe the key principles of other materials such as soft and stiff composites, ceramics and biomimetic skins.

Vincent repeatedly emphasizes the importance of structure and hierarchy in biological materials. Whereas engineered tends to focus on a narrow range of scale, hierarchy "is the only way in which biological organisms can make large structures, and is therefore intrinsic." In biology, hierarchy influences all aspects of materials from their construction to recycling and strongly determines characteristics such as stiffness and strength. Understanding hierarchy and scale can point us to new ways of using existing manufacturing technologies that are less resource intensive.

Vincent's chapter closes with a discussion of technology transfer and a comparison of biological vs. technological 'solution pathways'. His BioTRIZ team estimates that we manipulate energy and substance to solve 85 percent of our materials processing problems, with energy making up the largest component at 70 percent. In biological systems, structure at 20 percent and information at 15 percent appear to be used most frequently, with energy the least used at five percent (see Biomimetics: its practice and theory for more details as well as *A Comparison of Biological and Technological Systems* in the November 2008 *BioInspired!* Newsletter).

In contrast to materials that can theoretically be recycled indefinitely, the quality of energy degrades continuously. Similarly, alternatives can be found for most materials, but we still rely largely on solar radiation for our energy. Understanding the principles underlying biological materials can help us develop technologies that, like nature, minimize energy consumption.

Norbert Hoeller
Editor, BioInspired! Newsletter

BID Landscape - Systems and Processes

Much of our modern technology involves complex systems, which are characterized by a large number of interacting parts. In many cases, these interactions are so difficult to model that designers have only a dim idea what will happen when the parts are put together. The escalating cost of building new generations of aircraft is a manifestation of this problem. In other cases, the system is so complex that central management may be difficult (if not impossible) or incredibly inefficient. Someone accessing this site from, say China, is connecting through a series of internet nodes embedded in a fantastically large and fluid network. How does one manage this traffic easily given the size, scale and variation of traffic in the global net?

Our ability to build increasingly complex systems that may defy our design and management skill has led engineers and scientists to examine how complex natural systems are organized. In many cases, these systems perform highly elaborate and coordinated behaviors without an apparent central governing authority. Embryos develop into organisms, loosely aggregated collections of semi-autonomous cells efficiently distribute materials, and colonies of insects have a highly ordered and efficient system for maintaining their living conditions.

BID Landscape - Systems and Processes *(continued)*

Across a range of systems, the key principles of complex system organization and management are that local agents (cells, organisms, species) transmit information about both the state of the system and their individual actions, by modifying the local environment. This produces a one-to-many communication system that has two important consequences:

1. Agents can act on this local information using very simple rules (a second principle) in an appropriate way without the need for central coordination.
2. Local actions with a desirable outcome are reinforcing by changing the state of the system in a way that is communicated to local agents (a third principle), which can then act on this information.

Slime molds utilize these principles to construct highly elaborate and efficient transport networks. The organisms are actually aggregates: a multinucleated mass of tissue that is not differentiated into discrete cells except in certain circumstances. They have no nervous system, much less a brain. Nonetheless, these primitive organisms can produce highly efficient transportation networks. When the slime mold *Physarium* is placed in an environment with resources mimicking the location of transit stations in and around Tokyo, the resulting pattern of connections was more efficient than the current subway design. The network produced the same minimal distances between any two points but with a smaller overall network. The investigators were able to model this by positing that connections between two points respond to the flux through them, so they grow when material moves through them efficiently, but are pruned otherwise. Obviously, one would not want to construct a network in this way, but it provides a design template that is potentially better than other methods. Since information can also be said to "flow" it may help design better ways to connect sensor networks as well.

Groups of organisms also self-organize in ways to produce impressively efficient performance, and scientists have adapted those rules in a variety of ways. AntNet directs internet traffic based on the behavior of ant colonies, which find the best routes to resources so that the colony enjoys the greatest rate of provisioning. Real ants communicate by chemical trails that let other ants know a possible route. If more ants take the trail (because say, it is the fastest), then the pheromone concentration increases and attracts more ants until such time as it becomes too highly trafficked, in which case ants will end up switching to another trail. AntNet uses virtual ants in an equivalent manner - these virtual ants produce signals that modify the state of the network to recruit more traffic on given route, so quick routes become noticed and preferred.

Similarly, new algorithms that direct queries to server networks hosting multiple internet sites (such as Amazon or other commerce or banking services) use a virtual equivalent of bee communication during foraging. A query coming in to the server bank from a given application is "advertised", just as a bee advertises the location of its flower patch to its hive mates. The goal of a server is to minimize its idle time (much like the goal of the bees) so servers switch their attention to applications with many queries and small wait times. In both these cases, the biologically inspired approach is better than existing methods, particularly for rapidly changing conditions - adaptability and robustness are a hall mark of organic self-organization.

The critical distinction is that traditional ways to solve these problems are backwards looking: the appropriate solution is derived using prior information. Biological strategies develop rules that respond to changes in the state of the environment but also change its state. Variations of these principles have been used to route delivery trucks or direct factory manufacturing.

Despite some successes, biologically inspired solutions to problems in complex systems seem less numerous than examples from materials or biomechanics, for reasons that are not clear. It may be that there are fewer instances of the necessary parallelisms between natural and human. Perhaps it is no accident that the most successful applications concern transport or distribution, both of which have some obvious physical correlates. It may be that the constraints in natural systems do not permit easy transference. Ant or bee colonies consist of numerous individuals strongly united by a single goal, whereas collections of humans do not always display this level of allegiance.

Perhaps we are limited by a failure to abstract principles creatively. A number of large companies are trying to circumvent organizational hierarchies by emphasizing one-to-many communication, local task recruitment and changes in environmental state based on the resulting decisions. Hopefully, increasing our ability to understand and teach the cognitive processes that underlie our ability to transfer principles from one field to another will accelerate our ability to learn from biological systems. Given the complexity and success of self-organization in biology, it is likely we will find additional solutions if we are clever.

Marc Weissburg
Center for Biologically Inspired Design
Georgia Institute of Technology

BID Landscape - Cognition

The Biomimicry Guild has developed a number of methods to help designers, including the original biomimicry methodology and Design Spiral and the new Biomimicry Approach (Draft: 2009). A complementary approach is to study *how* designers design. How do designers behave, think, perceive, act, communicate and learn when designing? What knowledge, experience, styles, biases and values do they bring to a situation? What kinds of internal and external representations and models do they use and construct? How is designers' work situated in the physical, social, cultural and information worlds around them? How does designing interact with other processes of an artifact's development such as prototyping, realization, use and evolution? How do designers collaborate in teams and organizations, across space and time?

For four years, Georgia Tech's Design & Intelligence Laboratory (http://www.dilab.gatech.edu/) and Center for Biologically Inspired Design (http://www.cbid.gatech.edu/) have been exploring these questions. Our methodology has been to conduct *in situ* observations of interdisciplinary teams of designers, develop cognitively consistent information-processing models of biologically inspired design, compare the models with design case studies, build computational tools for supporting education, and evaluate the effectiveness of these tools.

Preliminary findings about some of the processes involved in biologically inspired design can be organized into six categories:

1. Co-evolution of problems and solutions, particularly where the problem space is poorly defined.
2. Compound analogies that incorporate the different levels and aspects of problem decomposition.
3. Problem-driven and solution-based design processes, similar to the 'challenge to biology' and 'biology to design' methods.
4. Functions and causal mechanisms as a basis of understanding and constructing models of biological systems.
5. Multimodal external representations, helping designers and biologists develop shared mental models.
6. Locating and understanding research in biology relevant to the current design problem.

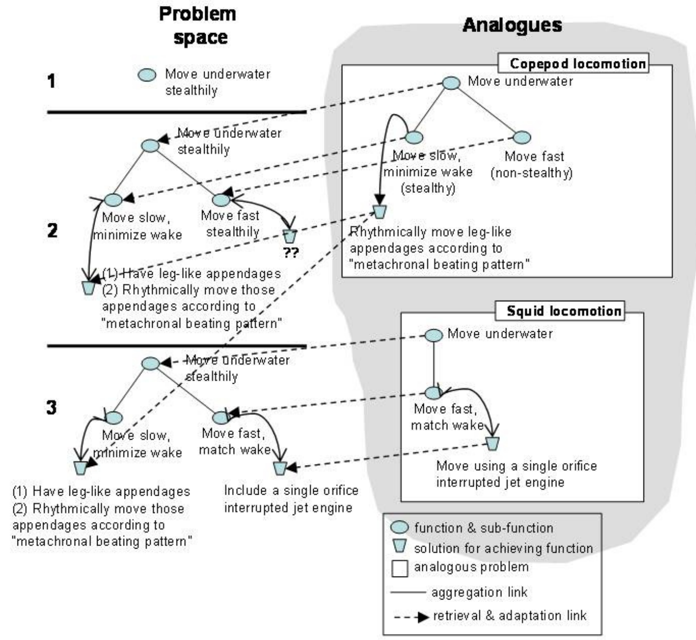


Figure 2: Design Trajectory of the Eye in the Sea (from the November 2008 issue of the *BioInspired!* newsletter)

Although based largely on studies of the concept phase of engineering design, we expect that at least some of these findings are generalizable to other domains such as architecture and computing. More research is required to test the robustness and reliability of our findings and to verify their applicability to other design domains. Lastly, we need to relate our work on biologically inspired design cognition to the vast literature on general design cognition. Further detail on this research and the findings will be published in the November 2010 issue of the *BioInspired!* newsletter.

Ashok K. Goel
Design & Intelligence Laboratory
Georgia Institute of Technology

Bio-Inspired Design Q&A

Although our designs have been inspired by nature for millennia, the *discipline* of bio-inspired design itself is relatively new. We do not have sufficient examples to develop reliable, efficient and effective processes, nor do we have a general theory that links the domains of biology with those of technology (Vincent, Biomimetics: its practice and theory). Although we currently have a surplus of questions, the combined knowledge and expertise of the BID Community can help explore the issues and find answers. Please 'pitch in' using the forums linked to each question!

Where does BID deliver the greatest value?

Bio-inspired design case studies range from materials (Velcro, gecko tape, Lotusan, Mirasol display) to biomechanics-morphology (tidal power, whale power, PAX Streamlining Principle, insect-like locomotion) and processes/systems (Todd's Living Machines, industrial ecology, swarm-based decision making). Recent developments where bio-inspired design shows potential for significant benefits include:

- non-centralized methods to attain a central goal based on self-organized animal systems (recent Social Biomimicry: Insect Societies and Human Design conference)
- complex system designs based on network interactions in ecological systems and other regulatory systems (such as Rules for Biologically Inspired Adaptive Network Design or popular write-up Slime mould simulates Tokyo rail network)

Biological systems typically need to deal with greater variability due to fluctuations in biochemical parameters and reduced control over the environment (compared to engineered systems). A greater understanding of resilience and adaptability in biological systems may help us improve the robustness of our systems.

Some questions for discussion in the Application Areas forum:

- In what areas does bio-inspired design show significant benefits over other methods?
- What are the characteristics of problems that are particularly suited to bio-inspired design?
- In what ways does bio-inspired design add value?
- What developments are in the pipeline that might open up additional application areas?

Are there fundamental differences between emulating at the form, process and system levels?

Forms in nature can often be directly emulated, although even in this case strict emulation is rarely desirable. Emulating process can be more challenging: although we can learn much from communication and decision making in social insects like honeybees, it does not make sense to emulate the exact details of their dance. The same issues arise when emulating systems: it would not be practical to develop an industrial ecology based on how animals metabolize food or eliminate waste. In addition, it is rarely possible to emulate all aspects of a system, even if we have a good understanding of all the components and their interaction.

Some questions for discussion in the Emulation Levels forum:

- Are different methods/processes required for each level of emulation?
- What aspects of nature should we be trying to emulate at each level?
- Do the different levels of emulation require different thinking process to understand and apply the appropriate principles?

How can we bridge differences in culture and language?

The benefits of inter-disciplinary collaboration are clear, but the mechanics can be challenging. Different disciplines have different ways of making sense of the world. Even the terminology can stand in the way. Some questions for discussion in the Bridging Differences forum:

- How can we facilitate communication and collaboration across disciplines?
- How can we facilitate the transfer of knowledge between academics and practitioners?
- What common thought processes might be useful as a way to build bridges?

What are the inhibitors to success?

Some questions for discussion in the Inhibitors to Success forum:

- How can we overcome the lack of 'hard' data? This appears to be a particular problem in ecological networks.
- How can we deal with differences in constraints or problem-solving mapping? Ant navigation tactics may not work for the travelling salesman problem because the goals are different. Self-organizing systems often involve organisms that are highly related, a characteristics not usually found in human societies.
- How do we achieve a consensus on underlying principles, such as those relating to ecological systems?
- How do we bridge differences in the metrics used to analyze biological systems compared to the human analogy? Linkage characters are a key metric for analyzing ecological networks, while industrial networks minimize energy/waste or maximize profits.

Bio-Inspired Design Q&A *(continued)*

Is there a theory underlying bio-inspired design?

Julian Vincent's Royal Society paper **Biomimetics: its practice and theory** argues that biomimetics lacks a theory which allows for a well-defined, repeated process for transferring knowledge between biological and technology in the sense of determining which subject areas or principles may be successfully applied. On the other hand, bio-inspired design involves analogical reasoning and the construction of cross domain analogies. There is a considerable amount of cognitive science research on how people do this and some hypotheses about the thinking process.

Some questions for discussion in the Theory of BID forum:

- What might a theory of bio-inspired design look like? Although much attention has been directed to process issues, a 'content theory' as described in The Ontology of Functions: Biology, Engineering and Beyond may also be important.
- What parts of such a theory exist, and where are the significant gaps?
- What groups are contributing to a greater understanding of the fundamental issues?

'Deep Patterns' and Design

Janine Benyus has often talked about 'deep patterns' in nature, typically in the context of the Life's Principles as described in **Biomimicry - Innovation Inspired by Nature** and the revised 2008 'butterfly' version. The Life's Principles appear to be most often used as a qualitative evaluation tool at the end of the design cycle, although the Biomimicry Guild is extending their application to other parts of the design cycle. David Oakey applied the 'diversity' principle in his work on the Entropy carpet tile as described in *Biomimicry Case Study - the Story of Entropy* (page 7 of the December 2005 *Biomimicry Newsletter*). The Ecological Performance Standards could be another 'up front' application.

Some questions for discussion in the 'Deep Patterns' and Design forum:

- How do we search for 'deep patterns' that reveal underlying generalities without imposing our own biases on nature?
- What 'deep patterns' are particularly useful in the various phases of the design process?
- What additional information do designers need to effectively utilize 'deep patterns'?
- Some of the Life's Principles reflect underlying natural limits. Can limits be turned into an enabling force that encourages creativity?

What is the relationship between BID and sustainability?

Many argue that nature and sustainability are inseparable, and therefore solutions emulating nature must also be sustainable. The implication is that sustainability is a fitness factor that can be selected for at the organism level. On the other hand, sustainability may be a systems property that cannot be directly predicted based on the attributes of components. Emulating a form process or system in a different context may not carry with it the desired sustainability characteristics, and could even result in undesirable behavior. Controversy over biofuels, particularly (but not limited to) corn-based ethanol, demonstrates the difficulty of predicting results when a process or device is 'translated' from one complex system to another.

Some questions for discussion in the BID and Sustainability forum:

- Should we limit ourselves to bio-inspired designs where sustainability is a clear outcome?
- Should sustainability and environmental responsibility be goals that are outside of any specific design process?
- Are there principles underlying sustainability in nature that can be applied in design?

Calendar of Public Events

Date	Location	Event
Sept. 14-16, 2010	Zhuhai, China	Third International Conference of Bionic Engineering (ICBE'10)
Sept. 15-21, 2010	Leeuwpoort, South Africa	Biomimicry & Design Workshop - South Africa
Sept. 18, 2010	Calgary, Alberta	Artcity Festival - presentation by Carl Hastrich "On Biomimicry and Design"
Sept, 20, 2010	Phoenix, AZ	CoreNet Global Summit, *Space Matters* presentation by Taryn Mead
Sept. 22, 2010	Leoben, Austria	Prospects of BIONICS for Functional Material Science and Engineering
Sept. 22-23, 2010	Chicago, IL	Cusp Conference - Whitney Hopkins, Guild Speakers Bureau, will give a biomimicry presentation.
Sept. 23-28, 2010	Leeuwpoort, South Africa	Biomimicry Educators' Training Workshop - South Africa
Oct. 6-7, 2010	Eindhoven, the Netherlands	Biomimicry Workshop - workshop will be led by Dayna Baumeister together with BiomimicryNL founders Saskia van den Muijssenberg, Bas Sanders and Annette Schumer.
Oct. 8-13, 2010	Eden, The Netherlands	Biologist at the Design Table (BaDT) training
Oct. 14-16, 2010	Deauville, France	Women's Forum - presentation by Dayna Baumeister on Oct, 15
Oct. 15-17, 2010	Rhinebeck, NY	Design by Nature: Creative Solutions with Biomimicry, Permaculture & Sustainable Design - with Dayna Baumeister, John Todd, and others
Oct. 25-26, 2010	Singapore	Annual International Conference on Green Information Technology
Nov. 18-20, 2010	Boston, MA	Systems Thinking in Action: Fueling new cycles of success - presentation by Dayna Baumeister on Nov. 8
Nov. 21-27, 2010	Gaviotas, Colombia	An Invitation to Visit Gaviotas in November 2010
Dec. 14-18, 2010	Tianjin, China	ROBIO 2010 - IEEE International Conference on Robotics and Biomimetics

An online events calendar readable by anyone is available at http://bioinspired.sinet.ca/Events. Users who have registered on the site can post new events.

Call to Action

The Advisory Group needs your input! The BID Community will only be successful if it serves the needs of its members. This is your opportunity to tell us what you want the BID Community to become.

If you have not done so already, please take a few minutes and register on the site. Registration provides access to additional website content and also allows you to post comments. If you register by **October 15th**, you will be given full member privileges at no charge for three months.

The registration process is relatively painless. Click on the Create new account link in the left sidebar and:

- select a user name,
- enter your e-mail address
- enter your first and last name
- answer four survey questions

The website will e-mail you a password as well as a 'one-time link' that you can use to login and set a password of your choice.

Once you are logged in, explore the site and let us know what you think. We need your input on potential BID Community services that you would find valuable. Please review any existing comments to the BID Community Services forum and rate your interest using the Fivestar rating system at the bottom of the comment. You can also create a new comment describing services not yet posted.

Lastly, the community needs a catchy name! As with the BID Community Services, please review the 'Name the Community' Contest forum, rate the proposed names and add your ideas.

Come back regularly to check for new comments or click on the appropriate **Subscribe** link at the bottom of the initial forum post for e-mail notification of new updates. You can subscribe to the specific post or to all posts of type Forum.

Thank you, on behalf of the BID Community Advisory Group:

Ashok Goel, Petra Gruber, Norbert Hoeller, Janice McDougall, Tom McKeag, Eileen Stephens, Karen Verbeek, Marc Weissburg, Jeannette Yen

Updating Your Registration Survey Information

You can update your survey answers at any time by clicking on:

- the **My account** in the left sidebar
- the **Edit** tab to update your information
- the **BID Survey** tab below it

When done, click on the **Save** button at the bottom of the page.

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