Biomimicry Newsletter

Greetings from Snow-Covered Montana!

Snow! Quite the surreal experience for Janine and I, returning from a fabulous seven days teaching our fourth annual Biomimicry and Design workshop, the second time in Costa Rica. The contrast between the verdant, raucous tropics and the serene, hibernating northern forest is dramatic. Interestingly, these two habitats are similar to those in which our work at the Guild delves. One week we might be traveling and engaging with curious engineers, creative designers, and impassioned managers; conversations full of vibrant ideas and new frontiers. The next week we move into a quieting; walking through the winter landscape searching for clues on better insulation strategies, or digging into the biological literature, literally disappearing for hours into the amazing secrets biologists have uncovered about hundreds of thousands of creatures on this planet (including those sleeping in their dens in Montana and those scrambling up the tropical canopy).

Inside

The biomimicry community continues to grow. In February we met with over 40 individuals interested in helping us discover how to bring the prototype Biomimicry Portal to its next developmental stage. Look for a summary of this meeting and an update in our next newsletter. Just a few weeks ago, our design course brought 24 designers, engineers, architects, and business folks together with eight "frogs" (our code name for the biologists). We have already developed continuing relationships (internships, sub-contracts, and collaborations) with several folks from the course. We will include a report on this course in our next newsletter, as well.

In the coming months, Janine and I, as well as others working with the Guild, will be visiting and working with companies like General Electric, General Mills, Kohler, Herman Miller, Interface, and Dial. We will also be speaking at several schools, including Aquinas and the University of North Carolina. Janine will be in Australia for several weeks in May and will also be speaking at several different conferences. We also hope to be announcing the birth of our new website and logo, due sometime this spring, thanks to the hard-working efforts of Carl Hastrich, who decided to give up his design career in Melbourne, Australia to immerse himself in biomimicry. Gratefully, the website will have much more information about our efforts at both the Guild and the Institute to naturalize biomimicry in our

Volume No: 4
Issue No: 1
March 27, 2006

culture, as well as information on how you can get involved. As part of the closer community, we hope to ask for your feedback on the site before we have a public birth (launch, a term from rocket science, just doesn't seem appropriate for a site dedicated to "what would nature do?").

Both Janine and I hope that all is well with you and your family and friends. We wish we had the time to interact with each of you more often. Hopefully, this newsletter remains an important part of connecting.

Life is good.

Dayna and Janine

The Biomimicry Education Team

A key initiative of the Biomimicry Institute is to "Establish Biomimicry programs in K-12 schools, colleges, and universities." A number of universities are offering courses to students in architecture, art, biology, engineering, industrial and environmental design. The process of developing a curriculum and teaching these courses includes finding effective teaching methods and materials to make biology accessible to the students.

Until recently, each institution developed its courses independently, with the guidance of the Biomimicry Guild. In late 2005, we had sufficient depth and diversity of experience to allow formation of a Biomimicry Education Team that shares ideas and strategies through monthly conference calls, e-mail and Weblogs. The current distribution list includes:

Biomimicry Guild	Dayna Baumeister, Janine Benyus, Rose Tocke
California College of Art	Jeremy Eddy, Lynne Sopchak, Suzanne Redding
California State Northridge	Janet Kübler
Centennial College	Ted Rosen
Georgia Tech (CBID)	Marc Weissburg, Jeannette Yen, Craig Tovey
Ontario College of Art & Design	Bruce Hinds, Ian Clarke, Norbert Hoeller
Simon Fraser University	Nima Motamedi
University of Strathclyde	Dennis Dollens
University of Illinois	Elva Rubio

University of Maryland	Brent Spranklin, Hugh Bruck , Satyandra Gupta
University of Minnesota	John Carmody, Marc Swackhamer
University of Montana	Carol Brewer
University of Toronto	Li Shu

Our objectives are:

- Sharing methods/tools to help students gain an appreciation of nature.
- Creating a resource list, including a library of teaching methods and a repository of projects and assignments.
- Encouraging student-to-student collaboration.
- Developing a tested, modular curriculum that can be adapted to the specific needs of each institution.

To date, the team has had five calls, each starting with a roundtable that often leads to a spirited discussion. Other topics discussed included:

- What type and level of biological knowledge does a Biomimicry practitioner need to be successful?
- How do we empower the students - to question assumptions, to critically observe nature and our place in nature, to teach themselves?
- How do we hone their skills at abstraction?
- How do we encourage multidisciplinary collaboration?
- How can we integrate Biomimicry and a respect for nature's wisdom in all the courses the students are taking?
- What are the top things students need to leave with so that they can successfully apply Biomimicry in the workplace?
- How does Biomimicry fit with the other disciplines?
- What kinds of Biomimicry applications can designers realistically deliver?
- How can we find real problems relevant to senior design students?

We have discussed at length what kind and how much biology should we be teaching to non-biology majors in Biomimicry/Biomimetics classes. Although the various classes have different goals, they generally share the following objectives:

1. Help students appreciate the wisdom of nature and its lessons.
2. Expand the designer's 'solution set' to include examples from nature.
3. Help designers develop more sustainable solutions.
4. Help designers appreciate the complexity of real-life systems, so that they can more effectively influence these systems.

5. Encourage biologists and engineers to develop a common framework in which biologically inspirations can be applied to problems in human design and manufacturing.

Teaching biology helps to further each of these goals. However, non-biology students seem to have significant difficulties absorbing biology in sufficient depth to be effective. The struggle to make sense of the biology may actually inhibit their ability to develop innovative biomimetic solutions. An alternative approach proposed by some would involve attacking each objective through distinct teaching approaches and content tailored to the learning styles of the students. For example, we might teach students how to work effectively in multidisciplinary teams to achieve the second objective. Instead of 'learning biology', learn how to 'better communicate effectively with biologists'. Building such a collaborative framework will also help biologists understand the engineering and design perspective, so that they can see where their knowledge and skills fit in.

The conference calls have given us the opportunity to get to know each other and provide a forum for sharing information. We have created a Weblog to store minutes and recordings of calls along with other information such as Sue Redding's IDSA presentation and article, the Okala sustainability curriculum and Carl Hastrich's 'spiral' methodology. A Biomimicry Resources Weblog storing information of more general interest is also under construction. In the future, this material will be integrated into the Biomimicry Database and Portal.

For 2006, the team plans to focus on:

- Structured harvesting of material and methods from Biomimicry courses.
- Improved collaboration between institutions (students and faculty).
- Linkages with cross-disciplinary initiatives such as the Georgia Tech Solar Decathlon 2007 (Georgia Tech Selected for Solar Decathlon 2007) and Ontario College of Art and Design 'frog pond' project.
- A series of specific projects, such as creating innovative ways of making biological concepts available to students and designers.
- Funding for a face-to-face workshop on Biomimicry education.

Norbert Hoeller: nhoeller@primus.ca

The Biomimicry Design Spiral

I had been working recently as a Product Designer for Moose, a toy company in Australia (www.mooseworld.com.au), focusing on the Design Methodology and how our design team would work with the other areas within the company. My own personal mission is to incorporate sustainability into my designs. I had the pleasure of attending the Costa Rica Biomimicry workshop in 2005 and learning the practical aspects of applying Biomimicry. When I returned to my job in Melbourne, I worked with the creative team to see where Biomimicry could fit in. The team members were overwhelmed by the evolving Biomimicry methodology – they had difficulty applying the methodology in a classical design situation.

My personal approach to design involves breaking down a large project into individual task-oriented activities, each with a specific goal (for example, brainstorm a concept and develop ten ideas, decide how a hinge works that it could be efficiently produced). My first attempt took the classical linear design process (develop, refine, and test) and mapped it to the Biomimicry process in six areas:

- Design Brief
- Production Design Specification
- Concept Design
- Detail Design
- Manufacturing + Testing
- Sales – Market

The result was an 11x17" table that proved too bulky and linear to promote creativity.

I then worked from the existing methodology and broke it down into five broader phases described on page 16: Identify, Translate, Discover, Emulate and Evaluate. These terms were chosen to reflect the tasks involved in developing ideas in general, rather than being product or problem specific. Each phase has both a broad vision/goal as well as clearly defined tasks, to focus efforts and develop momentum - see pages 17-18 for details.

To give the sense of a continually evolving design process, I arranged these phases on an outward spiral as shown on page 16. Each 'turn' of the spiral is an implementation of the Biomimicry methodology. By following the spiral through a series of turns you get closer to a truly biomimetic, innovative and sustainable end

result. The first turn might be a concept solution, with subsequent turns refining that solution and developing multiple product versions. Later turns of the spiral might reflect the impact of embracing sustainability and Biomimicry at an organizational level. The spiral adds flexibility to the design process and encourages further exploration within the design that is often hindered by linear processes.

The spiral suggests two apparently contradictory thoughts:

1. It can help slow us down, avoiding the expediency that can occur if we try to achieve the end point too quickly, or get stuck at a 'shallow' solution. The spiral encourages us to repeatedly refine our problem statement, discover new approaches, and evaluate the 'fitness' of our solutions.
2. The spiral process can encourage us to speed up the process through faster but linked turns, rather than trying to achieve a 'Cadillac' solution in one step. In the real world of constraints on time and resources, each turn delivers value and at the same time allows us to integrate new information into the process.

Although the spiral is incomplete, insofar as it does not portray the feedback loops between phases within a turn, it mirrors aspects of how nature innovates – multiple small steps, continuous feedback, repeated fine-tuning, and increased 'fit' with the Life's Principles.

Carl Hastrich: carlhastrich@carlhastrich.com

Biomimicry Case Study - The PAX Streamlining Principle

A conversation about natural flow with PAX Scientific's Jay Harman and Onno Koelman.

"Those who are inspired by a model other than Nature,
a mistress above all masters, are laboring in vain."
Leonardo da Vinci

Leonardo da Vinci spent the last 10 years of his life trying to understand turbulence. His work on blood flow within the heart and its valves has only been fully appreciated by medical science in the last ten years. The human heart uses only 25% of the energy used by the best human-designed pump - not by suppressing turbulence, but by using turbulence to improve efficiency.

Jay Harman, CEO

As a child, I spent a lot of time in the water in Australia, where I noticed that seaweed, which is quite fragile and easy to pull from the rocks, is nonetheless able to survive storms and surges without difficulty. No one I asked could explain this contradiction to me. After hours of careful observation, I realized that the fronds of the seaweed were changing their shape to present the least resistance to the movement of the water. The same shapes occur when the wind moves across leaves or flags, although the speed of the movement makes this harder to observe.

In spite of our observation that straight lines are the shortest distance between two points, a spiraling flow is much more efficient. In nature, everything is always moving, but moving in spirals rather than in straight lines. Even forms in nature that seem static are also based on the spiral, from the nautilus shell to the rose to the patterns of particle decay. The fact that similar structures occur across multiple phenomenon and in a variety of scales is striking: tornados, seashells, whirlpools, lilies, DNA, eddies, and the lily flower are all based on this underlying design. These shapes are not only functional, but extraordinarily beautiful.

Nautilus

At PAX, we study the flow geometry underlying all these forms and create devices that replicate these geometries. One of these devices is a PAX impeller that can be used in pumps, as a propeller for boats, or a mixer for tanks. The design can be many times more efficient than the best designs currently on the market. The magnitude of this improvement is surprising. Traditional impeller design has become increasingly sophisticated but is also narrow and specialized, so that any efficiency improvements are

incremental at best. In the Richard Foster S-curve model of innovation, the PAX impeller is clearly a discontinuous switch in technology.

Aside from reduced energy requirements, PAX technology also delivers low noise, directional thrust, increased throughput, even pressure distribution, reduced material requirements, and low shear. The impellers move fluids smoothly without cavitation or damage to substances carried in the fluid. For example, a critical challenge for artificial hearts is eliminating damage to blood cells. The human heart does this by following the geometry of natural flow, the same flow principles which led to the PAX impeller.

Onno Koelman, Design Engineer

Despite the many benefits to our designs, commercializing our work has proven to be challenging. Often people feel threatened by new ideas, and the "Not Invented Here" syndrome is a major problem. Many companies find innovation both exciting and threatening. For us at PAX, it is critical to understand the customers' exact needs. Few companies are interested in energy efficiency, and even fewer are interested in discussion of the principles of Biomimicry; what is important is how Biomimicry can affect their bottom line and provide them a competitive advantage in the market. Clients are more attracted to benefits such as reducing size and therefore the materials needed, or reducing costs by making an application that provides the same productivity while using a smaller-sized motor. There is such a heavy emphasis on cost reduction throughout industry that there always needs to be a clear measure of how an innovation can affect the bottom line.

When the company was founded, we expected commercialization of PAX products to take 12-18 months; in fact, due to the challenges I just mentioned, it has taken nearly 8 years. Recently, we decided to focus on creating a product for mixing large volumes of water. An initial test in a 1-acre lake showed that a PAX impeller could efficiently mix a million gallons of water while only drawing 1/15th horsepower. This was an astounding number, particularly since the industry standard suggested a one horsepower motor would be required for this volume of water.

The PAX Mixing Impeller

Many municipal water systems use large reservoirs. Stratification due to solar heating causes a stagnant layer of water to form at the top of the reservoir, allowing the growth of bacteria. Also, chloramine levels in this layer can drop, again allowing the growth of bacteria, which can expose consumers to health risks. This market looked ideal to us - clear benefits, low barriers to entry, large growth potential. We were also fortunate to have an industry partner interested in putting innovative ideas into practice. Right now, there is a competitive product on the market that weighs 600 pounds and is 20 feet tall. Our solution is 6 feet tall and supports a 6-inch PAX impeller. We recently completed a six-week study in the hottest months of the summer, collecting significant amounts of data. The PAX solution not only reduced the weight and bulk of the product, allowing an easier installation, it also mixed the water more effectively for an equivalent amount of energy consumed.

Jay Harman (again)

X-Ray of Calla Lily

The success of this project has been a turning point for PAX Scientific - companies from around the world are now showing an interest. The long-term potential is immense, due to the large number and types of devices that move fluids. We estimate that, over the next 20 years, PAX technology has the potential of reducing total world-wide energy usage by one-third.

Designers ultimately are trying to deliver a function - something that serves a need for humanity. Economics and aesthetics have always been a driving factor, although the latter seems to have lost out to cost in the post-war era. Reducing our impact on the environment by improving energy and resource efficiency has become increasingly important. Nature is a superior designer - I have yet to find a single instance where humans have designed something that improves on nature's strength to weight ratios, streamlining, and energy efficiency. Many of industry's designs are "first order" or rough approximations. The Archimedes' water screw of 250BCE is the forebear to industry's pumps, propellers and numerous other devices. However, the limitations of Archimedes' understanding, as well as the manufacturing capabilities of his era, prevented him from developing a better solution. Unfortunately, these limitations have remained with us until now, when we have a chance to take a second look at natural flow geometries.

At PAX, we found and researched something that nature clearly does better than the best human designs. Nature has many other solutions yet to be discovered. The solutions are always very simple and elegant, although they may initially be difficult to understand and apply. Anyone has the potential for making a groundbreaking discovery through close observation of nature, continually asking questions, and refusing to accept the standard answers. The opportunities for creativity and innovation are boundless - nature expresses the flow geometry of the PAX Streamlining Principle in a breathtaking variety of ways.

Jay Harman: jharman@paxscientific.com

Onno Koelman: okoelman@paxscientific.com

Credits:

Nautilus	Norbert Hoeller
X-Ray of Calla Lily	With permission from Richards' Radiographs
PAX Mixing Impeller	Copyright 2006, PAX Scientific, Inc - All Rights Reserved

Members Corner

Mary Hansel - Biomimicry in a Consulting Engineering Company: Or, How the Heck Do We Apply Biomimicry Anyway?

You all know the power of biomimicry and the WOW! Janine inspires when she speaks about it. Well, she sparked me up when I heard her at an Industrial Ecology conference at UC Berkeley in August 2000. Actually, the spark came the following morning while standing in sunlight at my kitchen counter making a cup of tea: "Janine Benyus needs to come to the Galapagos Islands with leaders in my firm to teach us about biomimicry."

I had recently begun working as sustainability coordinator for Carollo Engineers, a firm of about 650 employees that designs municipal water and wastewater treatment systems. Engineers tend to be a conservative, risk averse breed to begin with, and I am convinced that environmental engineers dealing with drinking water and wastewater treatment are at the far right end of the innovative/conservative continuum. I had been racking my brain for a way to open up the engineers' design mentality so they would consider effective new ways of meeting our client's needs that eliminate the harmful consequences of current processes. We must have the courage and willingness to innovate. And what is biomimicry, but a tool for innovation… so imagine my delight upon hearing Janine's introduction to the fascinating world of biomimicry. Plus, I had lived and worked as a volunteer in the Galapagos for 7 months and also wanted to share the wonder of that place with others, so…

The Galapagos Experience

Five Carollo employees traveled for a week in the Galapagos Islands with Janine in May 2001. We were surrounded by organisms that have already solved many of the challenges we face in our industry. For instance, both mangroves and marine iguanas desalinate fluids… WITHOUT the immense energy inputs we use to desalinate water.

"This does not end when we climb on a plane tomorrow … we need to bring Biomimicry into our tribe as a leading, perhaps ***the*** *leading methodology to redefine our design services."* - John Heckler, Partner

"Biomimicry is useful in situations where we wish to solve a problem by developing a new model, for considering process modifications, or for R&D. …it would have led us to phased digestion years earlier. There are many enhancements available we can use in the way we design things that don't involve developing a new membrane or a new pump…we don't need to be manufacturers to use this methodology." - Allen Todd, Partner

Ah, the headiness we came home with was, alas, trumped by the urgency of meeting the immediate needs of client projects, physical separation (the trip participants all live in different places), failure to demonstrate results that would spread this exciting meme to a critical mass, and our old friend inertia. Four and a half years after our trip we still have not yet brought a biomimic to the design table to participate in one of our projects.

I recently asked one of the partners who went on the Galapagos trip whether Biomimicry had made a lasting impact on him. He reported that learning about the cyclic principle that improvement follows feedback inspired him to develop a cyclical concept to improve our services. After a new or upgraded facility goes online, we return or "cycle back" to evaluate our designs' performance and how we can improve. Our clients appreciate this innovative approach.

When we were in the Galapagos, Janine described Jay Harman's work with impeller design, likening it to the spiral in the seashells we were finding on the beach. On Janine's recommendation, we contacted PAX Scientific to explore whether their biomimicry-inspired impeller technology had application in our industry. Carollo has since evaluated a potable water mixing device developed by PAX in several large (1-4 million gallon) drinking water storage tanks (described more fully in The PAX Streamlining Principle case study above). Tests show the PAX-designed impeller provided reliable mixing that surpassed the effectiveness of conventional mixing technology, while using less energy. Moreover, it is simple to install. PAX Scientific is now preparing to beta test the product with a large municipal utility in anticipation of commercial release in late 2006. Our engineers are WOWed by this technology, knowing that it will allow utilities to improve water quality while reducing energy use and the amount of chlorine used for disinfection.

Beyond Galapagos

Carollo's Research & Development group and others in the firm are keeping an eye out for further opportunities to pursue a biomimetic approach to improve processes in our industry. In January 2005, Carollo and the Biomimicry Guild submitted a research proposal to the Office of Naval Research to explore more resource efficient and cost effective desalination technologies using a biomimetic approach. We have also identified a list of biomimicry-inspired products, such as Lotusan paint and products for corrosion/scaling and biofouling for application in our industry, with the intent to pilot test when appropriate.

We have devoted a fair amount of resources to raising awareness of biomimicry, both inside the company and out. Efforts include:

- Several in-house presentations.
- Presentation to the National Decentralized Wastewater Treatment Capacity Development Project Workshop in Washington, D.C. (Nov.

2005). Interest was expressed on using biomimicry as a source for innovation in urban stormwater planning. Let's talk if you have ideas!

- Presentation to the Sarasota, FL County Commissioners (May 2004). This presentation led them to invite Janine as keynote speaker for their 2005 annual economic development fundraiser. They have since sponsored a workshop on biomimicry led by Dayna and formed a group that has earmarked funding to pilot biomimicry as an economic development engine in the County. WOW!
- Published an article in the December 2002 American Water Works professional journal, WE&T titled, "Biomimicry: What Can Water Professionals Learn from Mother Nature?" We just submitted an abstract with PAX Scientific for a second article.
- Purchased several copies of Janine's book for our libraries and clients. Several partners and employees have read it.

Challenges

Despite Allen's quote that "we don't need to be manufacturers to use this approach", most engineers in our firm believe exactly the opposite... that biomimicry is a fascinating concept, useful for fundamental research done in universities, but without a lot to offer in applied consulting. Further, the vast majority of our clients has never even heard of biomimicry, and find it difficult to see how it fits into their world of operating facilities that consistently meet regulations. And, quite frankly, we and our clients who are intrigued with the concept when we introduce it to them are finding it difficult to justify using the approach on projects; it is an investment of ratepayer monies for unknown return. We are, however, continuing to look for opportunities to bring a biomimic to the design table to improve current design practice, and believe our efforts are more likely to succeed with the industry research foundations than individual clients.

Rewards

Biomimicry has benefited Carollo in at least three ways:

- Ability to participate in PAX Scientific product testing, which will provide an efficient mixing device we can bring to our clients that will improve performance and save money, energy and chemicals. The engineers working on the project have really enjoyed the process of helping bring this great technology closer to market and it has created a biomimicry buzz in our company.

- Our work with biomimicry reinforces our image as an innovative firm with our clients and the public. Our own efforts reach a fairly limited number of our clients, but Janine has garnered the public's attention by mentioning us in the New York Times, Esquire Magazine, and at the Bioneers Conference.
- The WOW! Factor of biomimicry has ignited the imaginations and interest of many people, both within our firm and in our industry.

The WOW! Factor of biomimicry, coupled with the demonstrated PAX technology, has helped open up the design mentality of several of our engineers, paving the way for future innovation aimed at developing and implementing more sustainable solutions. Wow!

Mary Hansel: MHansel@Carollo.com

Biologists at the Design Table Workshop

The third BaDT Workshop is planned for July 22 through July 27, 2006 at the Theodore Roosevelt Memorial Ranch in Dupuyer, Montana. Led by Janine Benyus, author of *Biomimicry: Innovation Inspired by Nature*, and Dayna Baumeister, PhD biologist and Education Director of the Biomimicry Guild, this five-day intensive course trains biologists interested in applying biomimicry to design.

Students will have an opportunity to learn the key concepts of Biomimicry through hands-on exercises with other biologists, engineers, designers and managers. They will take home:

- "A sense of possibility, because sustainable models already exist ... right outside!
- A proven method for bringing nature's ideas to the design table
- Tools and expert contacts for further explorations
- A whole new way of viewing and valuing the genius that surrounds us"

For more information, please see http://www.biomimicry.net/BaDT.html.

Clippings, Events and Resources

Three public-access Weblogs are now available to share information of interest to the Biomimicry community.

Clippings	http://biomimicry.typepad.com/clippings/
Events	http://biomimicry.typepad.com/events/
Resources	http://biomimicry.typepad.com/resources/

The Biomimicry Newsletter has moved from ThinkCycle to a public-access Weblog on Typepad. If you have any problems downloading or reading past issues, please let me know.

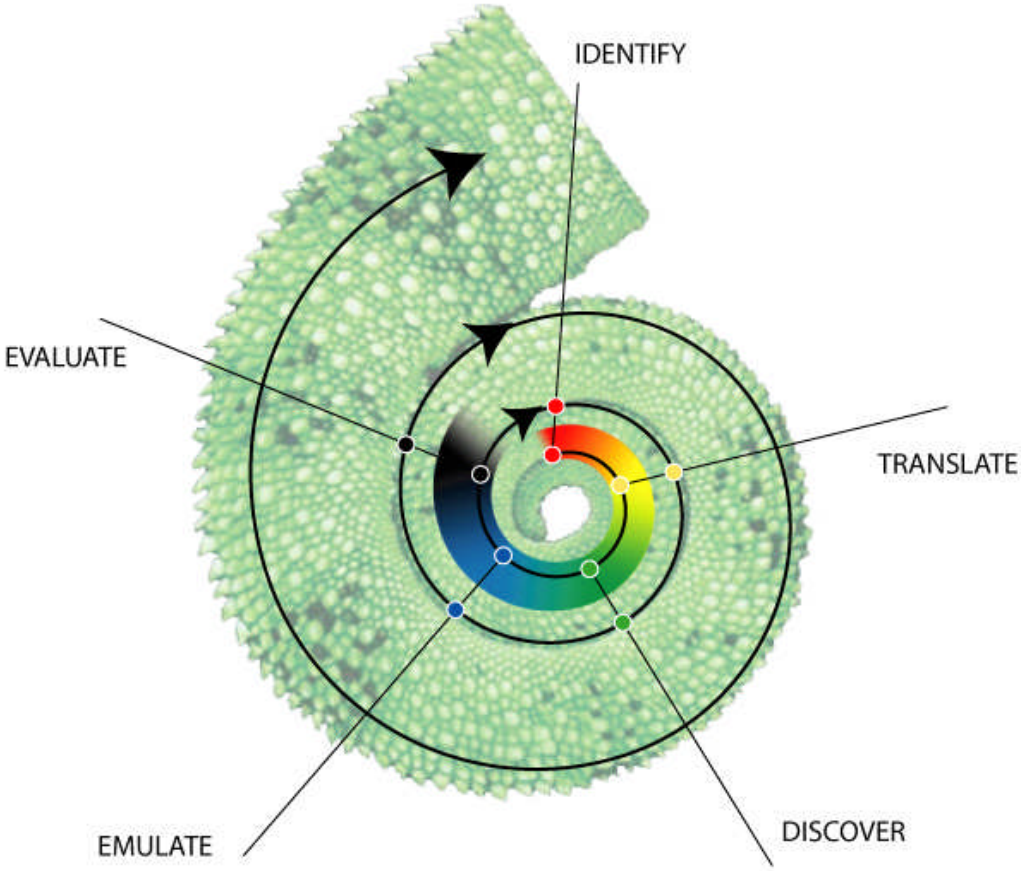
Newsletter	http://biomimicry.typepad.com/newsletter/.

You can comment on any entry through the **Comments** field in the entry trailer. TypePad asks for an e-mail address which will be publicly visible - I set up an e-mail account on Yahoo (Hotmail is also popular) specifically for this purpose, in case the e-mail gets SPAMed.

Contributions to the Weblogs are greatly appreciated!

Norbert Hoeller: nhoeller@primus.ca

The Biomimicry Design Spiral



	IDENTIFY:
Develop a Design Brief of the human need.	
	TRANSLATE:
Translate the Design Brief into Biological Terms.	
	DISCOVER:
Discover Biological Models that meet the design brief.	
	EMULATE:
Develop solutions based on the Biological Models.	
	EVALUATE:
Review solutions against Life's Principles:	
	IDENTIFY:
Develop a new Design Brief from questions highlighted by Life's Principles.	

Step by Step Process

1. IDENTIFY:

Develop a Design Brief of the human need.

Deconstruct the Problem:
Develop a Design Brief with specifics about the problem to be resolved.
Break down the Design Brief to the core of the problems and the design specifications
- What do you want your Design to do? (not "what do you want to design?")
- Continue to ask why until you get to the bottom of the problem.

Define the specifics of the problem:
- Target Market; who is involved with the problem and who will be involved with th solution?
- Location: where is the problem, where will the solution be applied?

2. TRANSLATE:

Translate the Design Brief into Biological Terms.

Biologize the question; Ask Questions from the Design Brief from Nature's perspective.

Identify Functions:	Define the Habitat/Location
How does Nature do this?	Climate conditions
How does Nature NOT do this?	Nutrient conditions
Reframe Questions with additional key words.	Social conditions
	Temporal conditions

Collate the questions so that they can be asked as:
How does Nature achieve this function in this environment?

3. DISCOVER:

Discover Biological Models that meet the design brief.

Find the best Natural Models to answer your questions:
- Consider Literal and Metaphorical

Find champion adapters by asking "whose survival depends on this?"
Find organisms that are most challenged by the problem you are trying to solve, but are unfazed by it.
Look to the extremes of the habitat:
Turn the problem inside out and on its head:
- Open discussions with Biologists and specialists in the field

Create a taxonomy of life's strategies:
From this list, choose the most promising strategies for emulation given the habitat and design parameters.

4. EMULATE:

Develop solutions based on the Biological Models.

Develop concepts and ideas that apply the lessons from your Natural teachers.
Look into applying these lessons as deep as possible in your designs:

Mimicking Form:	Mimicking Function:	Mimicking Ecosystem:
o Find out details of the morphology o Understand scale effects o Consider influencing factors on the effectiveness of the form for the organism o Consider ways in which you might deepen the conversation to also mimic process and/or ecosystem	o Find out details of the biological process o Understand scale effects o Consider influencing factors on the effectiveness of the process for the organism o Consider ways in which you might deepen the conversation to also mimic the ecosystem	o Find out details of the biological process o Understand scale effects o Consider influencing factors on the effectiveness of the process for the organism

5. EVALUATE:

Review solutions against Life's Principles:

- Is the design modular/segmented?
- Is it built to shape?
- Does it use self-assembly?
- Is shape designed to minimize material?
- Is it optimized rather than maximized?
- What role does water play?
- Is the design cyclic does it adapt to cycles?
- Does it use recycled materials? Is it recyclable?
- Is the design locally attuned?
- Does its manufacture and use free energy? Abundant materials?
- Can the design detect feedback? Can it adapt? Evolve?
- Does the design promote appropriate behaviors by users?
- Is there cross-pollination?
- Does the design embrace diversity and redundancy?
- Does it use life-friendly materials?
- Is the manufacturing benign?
- Does the design enhance the bio-sphere?
- How does the design coexist?
- Does the design "create conditions conducive to life"??

Take appropriate questions from above and continue to question your solution.
Identify further ways to improve your design and develop new questions to explore

Questions may now be about the refinement of the concept:

Packaging, Manufacture, Marketing, Transport
New Products - additions, refinements
Etc...

1. IDENTIFY:

Develop a new Design Brief from questions highlighted by Life's Principles.