Biomimicry: nature's design process versus the designer's process

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Abstract

This research recognizes that today the design industry is on the ground floor of a paradigm shift ushered in by the demand for sustainable, renewable green products, technologies and industry standards similar to Leadership in Energy and Environmental Design (LEED) and The Living Building Challenge. This shift needs to include biomimicry as a best practice for earth stewardship with the goal of improving the overall health and well being of the end-user and his environment. This research paper will compare The Design Process that nature uses to that which interior designers use to solve problems. In order to guide the designer through the nature's design process, Carl Hastrich designed a new method for the Biomimicry Institute, *Challenge to Biology Design Spiral*. However, the industry at large has not recognized the science of biomimicry or employed Hastrich's *Design Spiral* in its problem-solving process. This paper argues that, although designers utilize time-tested tools and methodologies i.e. programming, schematic and design development, they now should include a biomimetic approach to explore nature's database for sustainable solutions and innovations. According to this study, as we shall see, the one thing nature does differently from designers to solve a problem is to "biologize" the question by asking, "What do you want your design to do?" unlike designers who ask, "What do you want to design?" This paper will review key points, case studies of applications of biomimicry in product design and manufacturing and an architectural project that lay the foundation of this important movement.

Keywords: interior design, nature, biomimicry, biologize, design process, Carl Hastrich, challenge to biology design spiral, sustainability.

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1 Introduction

This study asserts that the practice of interior design should add a biomimicry phase to its design process and should "biologize" its design problems by using nature's time-tested principles and methods. The Biomimicry Institute defines "biologize" as a biomimetic approach used to evaluate design criteria [1]. This approach asks nature to "model, mentor and measure" and then "mimic form, process and ecosystem at all levels of design" [1, 2]. Since nature has already solved many problems with which designers are grappling, "Doing it nature's way" [3] could influence the outcome of design problems with sustainable solutions.

The focus of this research paper is to compare The Design Process which Nature and interior designers use to solve problems. In this study nature's method is defined by the Biomimicry Institute's, The Challenge to Biology Design Spiral designed by Carl Hastrich, along with a key tool to assist the designer with this process: Life's Principles [1, 4]. The Challenge to Biology Design Spiral is a practical tool to guide the professional through nature's evaluative, reiterative design process so that the final product or solution "mimics nature at all levels of design [1]. Life's Principle*s* are nine laws of nature essential to the process, *i.e.* "nature runs on sunlight...uses only the energy it needs, fits form to function" [2].

The interior design method is from Kilmer and Kilmer's textbook, Designing Interiors, a philosophy which echoes the premise of this study that an "improved design process will lead to improved design" [5]. There are two reasons that this particular model was selected: its similarity to Hastrich's model in that it has well defined "relationships between the design process and phases of the project" [5] and feedback from an educators' questionnaire supporting it as a viable method. To further support the argument that designers need to add the new phase "biologize" [1] to their design process, this research has prepared a comparative analysis, in chart form, of Kilmer's design process versus Hastrich's Challenge to Biology Design Spiral. Nature provides a vast biological toolbox of solutions for the interior designer to use in resolving problems of sustainability [6].

This research will examine two case studies of biomimicry translated into products: fabrics colored by structural design inspired by the protein layers of butterfly wing scales and surface technologies inspired by anti-microbial properties of shark skin [7, 8]. The field of architecture has successfully blended architectural principles and biomimicry to create remarkable environments. This research examines one case study: HOK's Lavasa, Hill Project near Pune, India.

In the past the interior design profession has not formally incorporated the biomimicry process into its standard practice. The biomimetic approach has been offered as an optional method by only a few in the industry. Biological discoveries are multiplying exponentially, and designers should take advantage of these cutting edge solutions. We are surrounded by nature, and when designers take the time to "biologize" [1] and ask nature how these ecosystems

work, they will be inspired and informed as to how to create interior environments that function like nature.

2 Nature versus design

This study argues that designers should include biomimicry in their design process and compares two models nature and interior designers use to problem solve: The Biomimicry Institute's, Challenge to Biology Design Spiral [1, 4] and Kilmer's design process [5].

Through a series of graphic comparative analyses it was deduced that interior designers should graft a biomimicry phase into the programming stage of the design process. This would allow practitioners to *biologize* their design challenges by asking nature "what do you want your design to do?" not "what do you want to design?" [1].

2.1 The challenge to biology design spiral

Industrial designer, Carl Hastrich, created the *Challenge to Biology Design Spiral* [1, 4] for the Biomimicry Institute as a common sense approach to guide designers and other innovators through nature's reiterative design process, fig. 1.

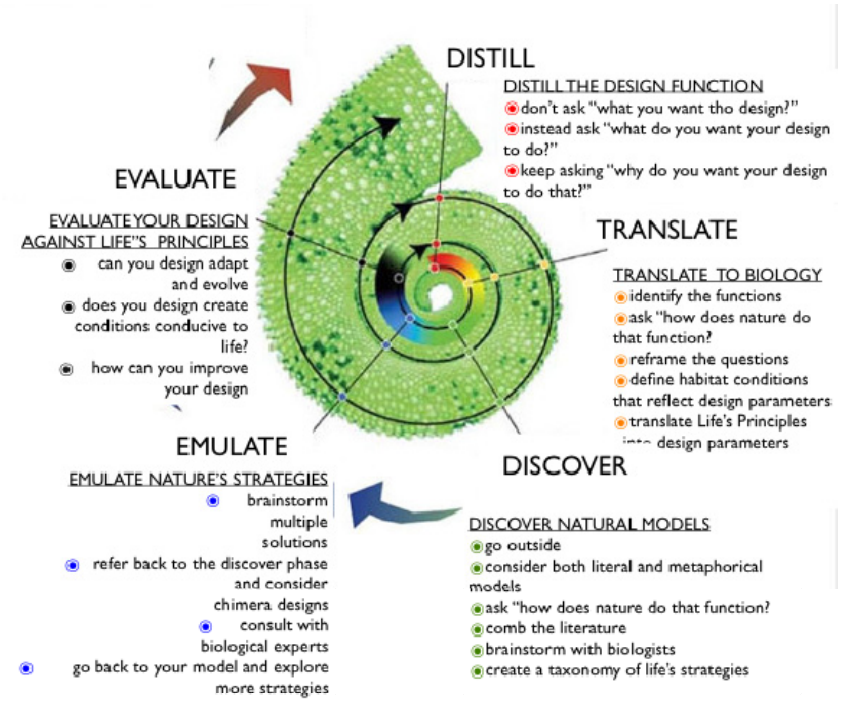

Figure 1: The challenge to biology design spiral. Source: www.biomimicryinstitute.org/about-us/biomimicry-a-tool-for-innovation.html.

Each of these phases is comprehensive, "non-product specific" and is arranged around an "outward spiral" [4]. Each time one makes a complete revolution around the spiral it solves some aspect of the problem. Subsequent revolutions refine the results to resolve deeper aspects of the challenge.

Utilizing the biomimetic method with its "small feedback loops" and applying *Life's Principles* to the results can help the designer discover truly sustainable solutions to design challenges in a unique manner that is unimpeded by linear classic methodologies [4] Because this is a reiterative process, after it resolves one challenge and evaluates how it compares to Life's Principles, most likely another problem appears, and the process begins again [1].

2.2 Life's Principles

When biomimetic principles are applied during the design process, the solutions will emulate nature's attributes. Life's Principles are the filter through which the designer tests solutions against nature's attributes and are an essential step in the "biologize" phase of programming [1]. The biomimicry approach is a practical framework that allows the designer to evaluate problems by asking nature to "model, measure and mentor, and then mimics form, process and ecosystems at all levels of design" [1] to find solutions to complex problems.

Life's Principles are the nine laws of nature and are "water based, dynamic non-equilibrium, subject to limits and boundaries" [1]. Benyus considers these traits an essential tool for measuring sustainability: "Nature runs on sunlight, uses only the energy it needs, fits form to function, recycles everything, rewards cooperation, banks on diversity, demands local expertise, curbs excess from within and taps the power of limits" [1].

2.3 Kilmer and Kilmer's design process

The interior design model is from Kilmer and Kilmer's *Designing Interiors* textbook and was selected based on the following criteria; a comprehensive, eight step design process with a supporting chapter on programming; its similarity to the Biomimicry Institute's, *Challenge to Biology Design Spiral* and feed-back from an educational questionnaire [5].

Regardless of complexity, in order to solve a problem the designer must identify and understand the problem's dimensions. Initially the process is broken into two phases: "Analysis: to separate the problem into separate parts: identify, dissect and analyze the problem and Synthesis: to form by combining parts to implement a solution" [5].

These two stages are then broken down further to create eight phases: commit, state, collect, analyze, ideate, choose, implement and evaluate [5]. Kilmer's model is similar to Hastrich's design spiral in that it also uses a spiral but uses a top-down approach that narrows funnel-like as it moves down through the stages to "focus on the problem" [5]. This is a reiterative process, as the central axis completes a feed-back loop, fig. 2.

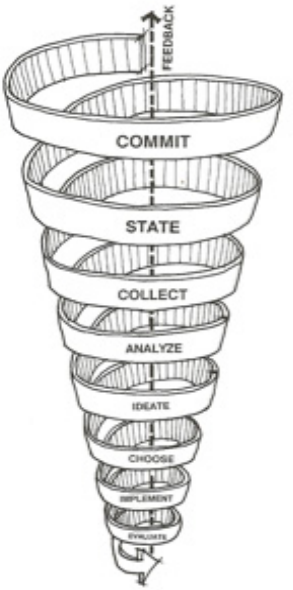

Figure 2: Kilmer's design spiral. Source: Kilmer, Designing Interiors.

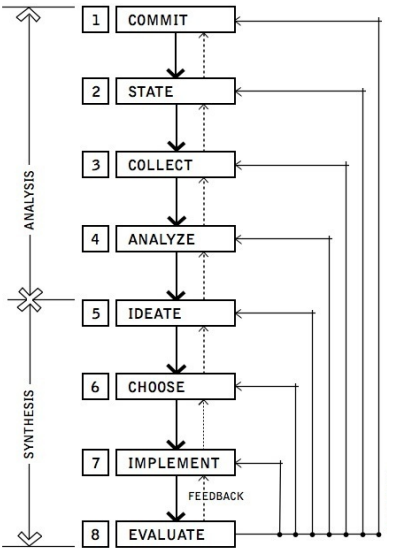

Figure 3: Kilmer's design process. Source: Kilmer, Designing Interiors.

2.4 A biomimetic phase

A side-by-side analysis of the biology design spiral and Kilmer's design process was created in order to evaluate their differences and similarities, table 1. To support this examination a table was prepared to graphically portray the two processes. As a result of the comparative analysis between Hastrich's model and Kilmer's model it was discovered that the main difference is the approach. Designers ask, "What do you want to design?" The biomimicry approach biologizes the question by asking nature "what do you want your design to do?" [1, 4]. This essential difference between these two methods is central to this study's argument that interior designers should include a biomimetic approach in their problem solving process. By grafting biomimicry into the (collect) phase of the design process, designers will be enabled, like nature, to solve problems that are genuinely sustainable.

3 Biomimicry inside

This study examines two case studies that biomimicry has translated into products with practical interior applications.

Table 1: Design process chart analysis.

Kilmer's Design Process		Hastrich's Design Spiral
1. **Commit** – start		
2. **State** – define problem establish objectives define the issues		1. **Distill** – identify real challenges develop a design brief of the problem "what do you want your design to do" not "what do you want to design?"
3. **Collect** – gather facts, data research, programming "what do you want to design?" *add biologize phase here		2. **Translate** – into biological terms **biologize** ask questions from nature's perspective. How does nature do or not do this? How does nature achieve this function?
4. **Analyze** - examine carefully in detail to identify key factors		3. **Discover** – biological models and look for champions who answer/resolve your challenges. Abstract to find repeating patterns and process within nature that achieve success. Create a taxonomy of life's strategies
5. **Ideate** – establish overall design schematic drawings and concept statement written or graphic 6. **Choose & Refine** – select the best option, preliminary design, design development, final design, find out best way to proceed & state in clear manner		4. **Emulate** – nature's strategies, develop concepts and ideas that apply the lessons from you Natural teachers and apply as deep as possible in your designs; mimic form, process and ecosystem morphology, scale, biological process…
7. **Implement & Construct** – take action on selected ideas and giving it physical form. Detail & specify the specifics Set performance criteria, Synthesize. Translate into reality		5. **Evaluate** – review solutions against life's principles "…is it built to shape? what role does water play?, is it locally attuned?, use life-friendly materials?, enhance the bio-sphere? …create conditions conducive to life?"
8. **Evaluate** –measurement of what has been done, post-occupancy, future applications, self-improvement phase		**Identify** - develop & refine design brief based on lessons learned from Life's Principles. Identify ways to improve your design.

Case study one: How does nature create color?

Manufacturer: Tjin Fibers Unlimited, Morphotex
Biomimetic attributes: Structurally colored fibers and fabrics
Inspiration: Morpho butterfly wing scales refract and scatter light
Practical applications: Dye free fabrics
Design Problem: industrial toxins and energy consumption resulting from the fabric dyeing and manufacturing, color fading and skin sensitivity to dyes.
Biomimetic Solution: Mimicking the protein layers on wing scales to create color by refracting light. The interaction between the layers and light refraction create the presence of pigments. The illusion of color is fade resistant.

The Morpho butterfly is brown. Structural engineering in the wing scales protein architecture creates the intense blue color. The color is created by light refraction not the presence of pigments [7]. If fabrics can be structurally colored then designers should *biologize* and ask nature how to apply this kind of technology to walls, surfaces, furnishings and accessories. This product meets sustainability goals by eliminating pigments and the dyeing process; thus reduces energy consumption; avoids replacement costs due to color fading and is non-toxic.

Case study two: How does nature resist and control bacteria?

Manufacturer: Sharklet Technologies, Inc., Sharklet AF™
Inspiration: Galapagos shark skin
Biomimetic attributes: Anti-microbial surface
Design Problem: bacteria and microorganism growth
Biomimetic Solution: Mimicking the profile of the shark scale denticles to naturally resist bacteria and microorganisms from resting on surfaces.

This technology was discovered through electro-scan microscopy. The unique surface of sharkskin naturally resists microorganisms from settling on the surface by up to 85% over "conventional surfaces" [8]. This surface pattern discourages the bacteria from forming colonies or "bio-films" causing them to die or move to another surface [8]. This product has wide spread applications in the healthcare, commercial and residential fields. This product meets the goals of sustainability in that it reduces costly, toxic, chemical applications. Designers should ask nature how to apply this surface innovation in their interior solutions.

4 Architectural case studies

From my designer's perspective, I ask: Why can't I design a building like a tree? A building that makes oxygen, fixes nitrogen, sequesters carbon, distills water, builds soil, accrues solar energy as fuel, makes complex sugars and food, creates

microclimates, changes colors with the seasons and self replicates. This is using nature as a model and a mentor, not as an inconvenience. It's a delightful prospect… [9]

This study examines one architectural case study in which nature was used as a design consultant in applying the principles of biomimicry in the design process: HOK's master plan for Lavasa's, Hill Station in India. This analysis includes a brief history, the design problem, biomimetic inspirations and solutions. With regard to its relevance to interior design and the design process, the thesis posits that the fields of architecture and interior design should adopt a "whole-building approach" and work together to develop a "single well-integrated system" [11]. Although designers primarily work within a structure's walls, these remarkable projects set a precedence for the built environment that testifies how vital the biomimicry approach is for the industry at large and mankind as a whole. According to Benyus, "The built environment is the most fertile ground for the application of Biomimicry" [12].

Janine Benyus and fellow biologist Danya Baumeister co-founded The Biomimicry Guild, a bio-consultant design firm, which takes a company or client through the biomimicry process: to educate, to access nature's database and "bring a biologist to the design table". Their in-house "referral service" puts clients in touch with engineers and scientists to develop new strategies, or to consult over the phone using "Dial-a-biologist" [6]. The Guild's client roster is off to a good start with HOK, NASA, and General Electric (GE), to name a few on board [13].

In 2004, world renowned architectural firm HOK, looking for a new approach to sustainability, consulted with The Biomimicry Guild for guidance on how to "*biologize"* the problems at the Lavasa site and asked, "What do you want your design to do?" [1, 11]. Four years later HOK and the Biomimicry Guild formed a professional alliance, the first of its kind, where nature and the built environment have teamed up to solve design problems sustainably [12].

Case Study One

The Lavasa, Hill Station Project
Location: Maharashtra, India
Developer: Ajit Gulabchand, Hindustan Construction Company
Architect: HOK
HOK Team Leader: Dhaval Barbhaya
Biological Consultant: Biomimicry Guild
Time Frame: 2001-2008

HOK received three international awards for the master plan of the Lavasa Hill City Project: "Best Master Plan from the Congress of the New Urbanism, USA, Award of Excellence for the Dasve master plan and an Honor Award for the Mugaon Master Plan from the American Society of Landscape Architects" [14].

The Lavasa Project is located in the Sahayadri Mountains between Mumbai and Pune. HOK won an international competition to plan Lavasa, the first hill station since British rule ended in 1947 [12]. What began as a strand of small villages along the water's edge turned into a project lasting more than 7 years. During this time HOK developed an 8,000-acre master plan for a population base of 200,000, which it is hoped will attract 2 million visitors annually [14]. This project included the planting of a million new trees [15].

Design problem: Lavasa is a unique mountainside site that was deforested as a result of slash and burn practices. For three months each year monsoon driven rains cause severe soil erosion. Most of the year this area is arid, as the next nine months bring on drought-like conditions that rapidly evaporate huge volumes of water. Consequently, the water levels in the valley lake basin fluctuate wildly by as much as 9 meters per season [12].

Biomimetic solution: The original ecosystem at Lavasa was a moist, deciduous forest prior to deforestation [16]. HOK used the deciduous forest system as a building model, because intact forest environments retain soil, store water and minimize erosion and evaporation with leafy canopies and complex root systems. Engineers, for later use during the dry season, designed buildings to collect rainwater in underground reservoirs that mimic a tree's taproot and circulation system.

To solve rooftop water run-off problems, HOK used the unique shaped leaf of the indigenous banyan fig tree as a model to create the roof tiles. These tiles mimic the long narrow "drip-tip" leaf shape, which increases water flow and creates friction that self-cleans the surface [16].

To control water over-flow from run-off during the rainy season, HOK mimicked native harvester ant nests. The ants construct radiating grooved earth dams around the central nest hole to redirect water away in multiple directions. This successful ant engineering was mimicked in the design Lavasa's drainage system for the master site plan.

Figure 4: Harvester ant nest. Source: http://www.flickr.com/photos/38854234@N08/4239404731/.

Figure 5: Banyan fig leaf. Source: http://www.flickr.com/photos/47437292@N00/219066994.

Figure 6: Lavasa, Hill Station, Davse Source: http://en.wikipedia.org/wiki/Lavasa.

Biological Inspiration and Models: Deciduous Forest, Banyan fig leaf and Harvester ants.

In June 2009, The Biomimicry Guild team recognized the potential value of biomimetic principles in creating living buildings and living communities. In response they developed a new biomimicry tool "Ecological Performance Standards" to measure the environment of a building or community in comparison with the surrounding ecosystem [17]. The driving principle is that the built environment with all its components, should maintain a life-sustaining ecosystem similar to that of an intact ecosystem. HOK, designers, in the Lavasa project, used these standards to measure how their solutions were performing i.e. rainfall and ground water retention, tree regeneration and soil loss/gain. The results will provide valuable feedback and guidance for future projects. HOK utilized these performance standards to help the designer/architect look at nature as mentor to create buildings that are living machines that conserve, filter and recycle water, run on sunlight and are modeled after the prairie ecosystem [17].

5 Biomimicry now

The global issue of sustainability is at the top of many industries' agendas and has renewed the interest of designers and others in the industry in pioneering new methods and technologies. The answer is running along beside us: Nature offers diverse, solar powered, inexpensive, water-based sustainable solutions to intricate design challenges.

Bringing nature aboard to help solve human problems sustainably by employing biomimicry is now recognized as a viable approach. In 2008, the architectural firm HOK and The Biomimicry Guild formed a partnership, the first of its kind, to include biomimicry in its problem-solving process. This

alliance is noteworthy because of HOK designers' well-known reputation as green pioneers who helped establish the U.S. Green Building Council's, Leadership in Energy and Environmental Design (LEED) certification system [12]. HOK's embrace of biomimicry into its practice is revolutionary and this alone has the capability of launching the concept worldwide.

HOK is *biologizing* in the field of architecture. This supports the argument put forth in this study that the interior design practice should also form an alliance with the Biomimicry Institute and "bring a biologist to the design table" by adding a biologize phase to their design process [6]. This paper concludes that the application of biomimicry principles during the design process will move the designer into a new era of sustainable applications, technologies and approaches.

However, Benyus warns that one or two interesting technologies thrown into a project, although a good start, does not solve the sustainability issue. Only when we consider how everything works together like an ecosystem and is interconnected and operates like nature's communities can we begin to make a difference [17].

Ultimately, the practice of creating sustainable environments should use as few resources as possible to create and operate a beautiful, health orientated, habitat that operates in a closed-loop system that recycles all waste, generates all its energy needs and is designed with the long term goal of preserving mankind's survival [18].

References

[1] Biomimicry Institute, "Biomimicry: A Tool for Innovation," 2007-2010. http://www.biomimicryinstitute.org/about-us/biomimicry-a-tool-for-innovation.html

[2] Benyus, Janine M., *Biomimicry: Innovation Inspired by Design*, New York: Harper Perennial, pp. 2-7, 2002.

[3] Implications. "Learning from Nature." *InformeDesign*, University of Michigan, Vol. 4.1. pp.1-5, 2010. http://www.informedesign.umn.edu

[4] Hastrich, Carl, "The Biomimicry Spiral," *Biomimicry Newsletter,* The Biomimicry Guild, Vol. 4.1. 2006. http://biomimicry.typepad.com. newsletter/files/biomimicry_newsletter_v4.pdf

[5] Kilmer, Rosemary & W. Otie Kilmer, *Designing Interiors,* Florida: Holt Rinehart and Winston, Inc., pp. 154-176, 1992.

[6] The Biomimicry Guild. "Biomimicry Guild Method of Consulting," 2009-2010. http://www.biomimicryguild.com/guild_services.html

[7] Ask Nature. "Wing scales Scatter and Diffract Light: Morpho Butterflies," http://www.asknature.org

[8] Sharklet Technologies, Inc., "*From evolution to Medical Solution*." http;//www.sharklet.com/

[9] McDonough, William & Michael Braungart, "The Next Industrial Revolution." *Atlantic Magazine*, 1998. http://theatlantic.com/past98oct/issues/industry.htm

[10] National Resources Defense Council, "Adopt a Whole-Building Approach." *NRDC, The Earth's Best Defense*, www.nrdc.org/ buildinggreen/ approach/
[11] HOK News Articles. "HOK and the Biomimicry Guild Form Alliance to Integrate Nature's Innovations in the Design of Buildings Communities and Cities Worldwide," 2008. www.hok.com/cfm/NewsArchive.cfm?CurYear= 2008&PressRelease=0&Category
[12] Vella, Matt, "Using Nature as a Design Guide: Janine Benyus, dean of the burgeoning "biomimicry" design movement," *Business Week Online*, 2008. www.businessweek.com/innovate/content/feb2008
[13] HCC Group, "Lavasa Corporation," 2010. http://www.hccindia.com/. lavasa_corporation.php
[14] Jacobs, Carrie, "India's New Eco-Friendly City," *Travel & Leisure*, 2010. http:www.travelandleisure.com/articles/indias-new-eco-friendly-city/1
[15] Gendall, John, "Biomimicry: Architecture That Imitates Life," *Harvard Magazine,* 2009. http://harvardmagazine.com/2009/09/architecture-imitates -life
[16] Benyus, Janine, Tim Mcgee and Sherry Ritter, "Biomimicry in Community Planning," *Biomimicry Institute*, 2009. http://www.biomimicryinstitute.org/
[17] Berkebile, Bob, Jason McLennan. "The Living Building: Biomimicry in Architecture, Integrating Technology with Nature," http://elements.bnim. com/resources/livingbuildingright.html