GRAPHIC DESIGN + BIOMIMICRY

Integrating Nature into Modern Design Practices

Margaret McKosky
ACKNOWLEDGEMENTS

This book would not have been possible nor nearly as good without the talent, contribution and support of the following people who graciously committed their time to help guide me through. Also, a special thanks to the organizations that inspire me everyday.

Nancy Ciolek, Lorrie Frear, Bruce Ian Meader, Josh Owen
my wonderful and brilliant Committee Members

Jessica Jones and Andrea Leggitt
for taking the time to speak with me and allowing me to use their knowledge and research

Biomimicry 3.8
for inspiring me to do this book

The Designers Accord
for encouraging me to share this project

Rochester Institute of Technology
for supplying me with knowledge and opportunities

My Family & Friends
whose patience, love and support sustain all efforts, but were especially tested on this one
Bi·o·mim·ic·ry
(noun)
the design and production of materials, structures, and systems that are modeled after biological entities and processes

from the Greek bios, life, mimesis, imitation

1 New Oxford American Dictionary 3rd ed © 2010
BEGINNING

Situation Analysis
Biomimicry is a relatively new discipline that studies nature’s finest ideas and then attempts to imitate these designs and processes to solve human problems. It is simply innovation inspired by nature, or as Janine Benyus, one of the leading researchers of biomimicry today would say it is the conscious emulation of life’s genius on the path to a sustainable future.

The core concept is that nature over 3.8 billion years has already used its imaginative prowess to solve many of the problems that society is currently grappling with today. Nature has found what works, what is appropriate, and most importantly what lasts here on Earth.

With that being said, life found within nature is the secret to survival and the area to which we should be seeking the answers to our problems. However, in order to emulate nature’s genius and reflect it onto our existing world, we must view nature in an entirely different manner. As the Biomimicry Guild and Institute believes, we need to look at nature as model, measure, and mentor. The Guild and its collaborators have developed a specific practical design tool called the Biomimicry Design Spiral based off of the Golden Ratio for using nature as model which helps to further explain this notion.

Sustainability is also an important contributing factor and reoccurring theme throughout the process of biomimicry. Essentially, it is the goal when using biomimicry within the realm of design to create hybrids of timeless, sustainable pieces. This is where nature as measure is introduced. In learning from the principle factors that work within nature, we can then embed them into our own sustainable design solutions.

Lastly, in viewing nature as mentor, it is a summation of how one should view nature with a modern outlook. It is vital to note that biomimicry introduces an era based not on what we can extract from nature and all that it encompasses but on what we can potentially take away and learn from nature. When the world of biomimicry and graphic design mesh, it has the power to create a beautiful landscape of opportunities.

The challenge at hand is to now take these time-tested ideals nature has produced over the years and echo them to produce effective design solutions. By constructing nature as model, measure and as mentor, a new way of evaluating and creating effective design solutions will emerge out of the abyss of the already creative design process to an entirely new, innovative process full of potential. Biomimicry can be used as a tool to create more sustainable design solutions due to it being a design methodology itself, occurring in the ideation phase of the graphic design process rather than the execution phase. For instance, a designer would start with a human design problem, identifying the root of challenge and then review how nature would go about solving this problem. What would nature do? It is crucial to look at the natural form, process, and system already found within nature so one can mimic its process within the ideation stage.

There will be a cross fertilization of ideas along the way, but in the end the juggernaut of biomimicry will shed a new light onto the field of graphic design. Thus creating an avant-garde mode of thinking which in turn will lead to an alternate, innovative and revolutionary graphic design process.
OBJECTIVE

Scope of Project
The idea for this thesis project came to me after many scrutinizing hours of brainstorming and asking myself: What is it that I want to say after the culmination of my six years of design study and education? I knew I wanted to create something that had the ability to change designers perceptions, ultimately challenging the current paradigms. I also knew I wanted to demonstrate how design cannot only be good, but do good. I am always amazed and inspired by how elegantly ecosystems thrive, foster cooperative relationships, and adapt to ever changing conditions and wonder, how can graphic design find it's niche within the current thriving ecosystem today?

So, I chose to integrate two very distinct disciplines, Graphic Design and Biomimicry, not only because I am passionate about both areas, but I feel that in order to design for the greater good, it is necessary to look to nature in order to do so. This is essentially what biomimicry strives to do. It looks to organisms and their natural ecosystems to draw inspiration and emulate their designs in the best way possible. Nature’s design principles have developed over 3.8 billion years and have produced the most ecological, timeless, and constructive design solutions so not only is it logical to look to nature to solve our problems, it is crucial for our survival if we wish to generate any changes for our future.

As with any creative process, it requires practice for it to become second nature. This new Graphic Design + Biomimicry process I am proposing is meant to challenge the current paradigms and create the potential for change. In doing this, I am aware that not all designers will agree with this new process or the ideas presented in this book and may think that some of them are a little too metaphorical per say.

Yet, this is the beauty of biomimicry: it allows designers to echo actual strategies and principles found within nature, creating an entirely new design that they may never have thought of before. Naturally, as designers we are problem solvers. We apply our creative talents to finding new and appropriately innovative solutions to common questions. These questions may include how to best articulate a brand, how to connect to consumers. There are fundamental needs such as equality, education, food, water, community, and sustainability. As graphic designers we should be creating work that has a purpose. There's a lot of beautiful graphic design work being done everyday, but what is it for? This book is also about trying to find work that has meaning and that will ultimately make a positive impact. Although I understand there is very necessary work designers must do every day that may not have the most meaning to them or influenced by nature’s designs. I'm not saying that biomimetic graphic design and good design should be held above that of design which seeks to do anything less than help save the world. Any inference that the work in this book is more noble or worthy is not my intention. The purpose of this book is to raise awareness, propose a new mind-set and celebrate this newfound biomimetic graphic design process. Whether for the greater good or greater profit, it is all still design helping to visually communicate a message for others to appreciate, which is ultimately why we do what we do.

¹ Christopher C.H. Simmons, Just Design
With that being said, it is very easy for graphic designers to get caught up in only pleasing their client, focusing on articulating their message in order to communicate with their audience. Sometimes the message gets lost and they forget about how their piece will fit in with the rest of the ‘ecosystem’ and the other functions their piece should serve. Since we work in a cultural business, we have the potential to change our client’s perceptions of their consumption patterns, as well as our own, helping to reduce our overall carbon footprint. This perhaps is the greatest leverage point for biomimetic-graphic design. We must learn to be a part of a multi-disciplinary brainstorming team in order to identify the best leverage points for the most change.

After engaging in this book, designers will know how to do this, using the biomimetic principles to help guide them along the way. I am hoping designers will try to incorporate this new design process and take away a new mode of thinking, applying this process not just into their work, but into all aspects of their lives allowing them to be more creative overall.

In this book I have tried embracing what others have done before me, exhibiting what they have found and proposing my own ideas and solutions. This is the accumulation of all my research and should act as a catalog of my ideas and findings. Hopefully after looking and reading through this reference guide book, designers will be encouraged by this different way of thinking, forcing themselves to innovate, experiment, push and adapt their designs further than ever before. The objective at hand is to create good design that also has the potential to do good, for the world and everything that encompasses it. We are on the cusp of great change: will designers curl up at the thought of this or embrace this new mode of thinking to help shape a positive future for design, people, and most importantly our planet?

Life’s design brief is simple. Learn how to create and make things while creating conditions conducive to life on earth.

JANINE BENYUS
AWARENESS

Innovators at the Institute
Janine Benyus is also the visionary co-founder of Biomimicry 3.8, formed by integrating The Biomimicry Institute and The Biomimicry Guild in 2011. Biomimicry 3.8 brings together scientists, engineers, architects, designers and other innovators to create sustainable technologies and business practices. The organization achieves this through a global network of experts providing education, professional training, research, analysis and consultation to individuals, institutions and corporations. It is vital to note that the Institute is a not-for-profit organization that promotes the study and imitation of nature’s remarkably efficient designs to use those models to create sustainable technologies.

Biomimicry 3.8 also offers short-term workshops and two-year certificate in biomimicry for professionals.

Today, Biomimicry 3.8 focuses on three areas:

1. Developing educational programs for students, professionals and the general public
2. Working to create public policies that use biomimicry as a solution to sustainability challenges
3. Encouraging companies that are profiting from biomimicry to provide financial support for biodiversity

Thanks to the efforts and work of the biologists, designers and innovators at Biomimicry 3.8, more and more designers are realizing a simple truth when trying to find responsible, ecological solutions: if we’re trying to do it, chances are, nature already did it better.²
INDUSTRY STANDARDS

Modern Design Practices
Biomimicry is quickly becoming a cornerstone for sustainable design practices and the Institute & Guild have worked hard alongside companies to help them achieve ground-breaking designs, products, and materials all inspired by nature. Designers from all over the globe, designing everything from toothbrushes to trains and airplanes, are working to integrate the principles of biomimicry and sustainability into all aspects of design. This includes education, to practice and production, and ultimately consumption. What is happening here within the creative industry is that new standards are being set, ultimately challenging the current paradigms that exist in modern design. Creative and designers alike are starting to catalyze this new system and way of thinking by collectively building their intelligence around important issues such as climate change and social justice, and tackling those issues and challenges with optimism and creativity. This is the satisfaction a designer is able to attain when modeling their work using the biomimetic + graphic design principles. They come up with ideas that they may have never thought of before that nature brilliantly thought of and designed millions of years ago. These ideas can suddenly turn into the most brilliant, yet simplest idea. In taking these older ideals devised by nature and applying them within a new process, it creates designs that are timeless, innovative, and revolutionary.

However, it is not as simple as it may seem at first. Many designers who want to incorporate biomimicry into their work and design process may not know where to start. Some famous biomimetic solutions have gotten passed around the mainstream press— including examples like self-cleaning surfaces modeled on lotus flowers, or the sticky repositionable tape inspired by gecko feet or wind turbines inspired by whale fins—but biomimicry isn’t as easy as using nature as a crib sheet. “One of the big realizations that designers have when they play with biomimicry is that it’s not a tool, it’s a mind-set shift,” says Dayna Baumeister, who co-founded the Biomimicry Guild with Benyus in 1998. “Because of that— because of the fundamentally different way of thinking— it’s hard.” Even for biologists, it requires a shift in thinking, says Baumeister, from learning about nature to learning from nature, including how each of those processes fit within a larger ecosystem. In a way, it’s examining nature’s solutions for survival, but through a design lens, says Chris Allen, project manager for AskNature.org. “You can look at brilliant engineering and strategies for living over thousands of years.”

Because biomimicry experts believe that designers play an integral role in making sustainable, nature-inspired decisions in a project, they believe that is where their influence is best appropriated. A biologist working in biomimetic design is known as a Biologist at the Design Table, or, in a biomimetic-appropriate acronym: a BaDT. BaDTs create a bridge to biological understanding. Biomimetic work is deeply rooted in solid science, but it’s BaDT’s job to translate that science so designers can immediately make the link to the design challenge. This way biologists are able to be part of the design team from brainstorm to prototype, continually adding biological insight to the process. There are currently very few BaDTs— only about 75 worldwide— since they have to undergo extensive training. But eventually, the goal is to have a BaDT in every design firm who can help guide the designers towards smarter, more nature-influenced solutions.
It is crucial that designers embrace this new set of biomimetic standards and understand that the cross-disciplinary dialogue is a vital and necessary component within the design process in order to emulate designs found within nature. Designers need to collaborate with other professionals. Not strictly biologists, however, but also scientists, engineers, architects… The more areas of expertise in the room, the greater the range of possibilities in coming up with timeless, sustainable design solutions. This new process also gives designers and professionals the competitive edge within the industry. People are extremely invested and interested in the field of biomimicry because it has produced some of the most successful and innovative designs seen today. When products are designed with the biomimetic industry standards, not only are they aesthetically pleasing, they are also modern, functional, sustainable, cost-effective and life-friendly designs.

As previously mentioned, the Guild has worked alongside world-class companies to help them achieve this shift in thinking, from a long-standing relationship with flooring and finishes company Interface, to a team currently on-site at an architectural project in India, where they’re creating buildings that not only are made from natural materials, they actually behave like natural organisms. Using biomimetic principles, we’ve also been able to learn more about our own species. The Guild is starting conversations with global companies that manufacture goods like cosmetics— in which case their own in-house scientists have been studying hair and skin for decades. Currently there’s a great deal of excitement bridging algorithms found in nature and information technology or ‘generative design,’ where we’re able to extrapolate data from the way that nature goes through its iterative design process in evolution.

It is important to note that to adopt this biomimetic, you are also agreeing to adopt responsible design practices. Practicing responsible design is more than just using life-friendly materials and sustainable technologies. It is about raising awareness, getting involved and staying active. We need to let others know about the exciting field of biomimicry and the current biomimetic standards. The easiest way to do this is to adopt these new standards within your own process by applying them within your designs. It is also about being active within your local community and getting involved with any programs or organizations that are striving to create a positive environmental impact. This is the only way we are going to challenge the current paradigms and spread the word about biomimetic design.

Another way you can practice responsible design is to always be conscious of your surroundings within your local community and the larger eco-system we reside in. Use materials that are found locally rather than ‘outsourcing’ to the internet. Always ask yourself: What Would Nature Do? How would nature solve this design problem? If you look hard enough, you will find that nature is where all of the answers to our design problems lie. Good, responsible design practice involves multiple viewpoints and is adaptive to new information.
RESOURCES

You've read, defined and now know the basis of what it means to integrate biomimicry + design, and hopefully you are inspired and want to learn more! The following resources will provide a good starting point.

BIOMIMICRY 3.8

http://biomimicry.net/

The Biomimicry 3.8 website provides the basics about biomimicry + design and gives you information on various learning opportunities and workshops, as well as biomimicry-related activities going on at academic institutions around the world. Exploring the Case Studies will give you a feel for how biomimicry plays out by emulating nature’s forms, processes, and systems. Make sure you sign up for the Biomimicry Newsletter so you can stay up-to-date with all of the exciting biomimicry inspired designs happening today!

TED

http://www.ted.com/

TED is a nonprofit organization devoted to Ideas Worth Spreading. It began in 1984, starting out as a conference bringing together people from three worlds: Design, Entertainment, and Technology. Since then its scope has become ever broader.

Janine Benyus has been appearing on TED since 2005 as a speaker in their TED Talks. She shares her brilliant insight and developments on biomimicry, providing heartening examples of ways in which nature can influencing our current designs and technologies.

There are other inspirational videos to see as well on various biomimicry topics and design.

CHECK OUT

Benyus: Biomimicry in Action
Benyus Shares Nature’s Designs
This blog was created by one of the designers and visual communicators at Biomimicry 3.8, Jessica Jones. Its purpose is to promote the biomimetic way of thinking. She has carefully organized her thoughts and research over the years into several sections revolving around the word ‘momentum.’ DesignMomentum is meant to help build and create momentum within the small niche of graphic design and biomimicry. This is all in hopes of raising awareness of life’s principles and to foster and bring forth a new, alternative design process and promote positive change within the design community.

It provides excellent case studies to best illustrate her points, helping others to understand how designing from nature and using life’s principles can create some of the best design solutions.

**BOOK LIST**

- **Biomimicry: Innovation Inspired by Nature**
  - Janine Benyus
- **Biologic: Designing with Nature to Protect the Environment**
  - David Wann
- **Cats’ Paws and Catapults: Mechanical World of Nature and People**
  - Steven Vogel
- **Cradle to Cradle: Remaking the Way We Make Things**
  - William McDonough & Michael Braungart
- **Deep Design: Pathways to a Livable Future**
  - David Wann
- **Design Lessons from Nature**
  - Benjamin De Brie Taylor
- **Nature’s Operating Instructions: The True Biotechnologies**
  - Kenny Ausubel
- **On Growth and Form**
  - D’Arcy Wentworth Thompson
- **Sustainable Graphic Design**
  - Wendy Jedlicka
- **Structural Biomaterials**
  - Julian Vincent
- **The Way Nature Works**
  - Robin Rees
Biomimicry focuses on finding structures, processes, strategies and mechanisms that nature has been using for a billion years, that we can emulate and use in modern design.

TERRY TEMPEST WILLIAMS

How Would Nature Begin?

In asking this question, it is integral to first consider how does nature communicate? How would nature begin it’s design process, delegating specific tasks to each organism to confirm the design gets completed? Not just completed, but completed in the right way and in the most sustainable way conducive to life. These are fairly simple questions with many elegant insights and all the answers lie within nature and the organisms that keep our ecosystem revolving. This second step in the process after defining the problem or issue is analyzing. Nature has been innovating for 3.8 billions years and has already solved many of the design challenges we are having today. So in order to understand nature’s process, we must perform a comprehensive analysis.
METHODOLOGY

Biomimicry + Graphic Design
To better fit in with the rest of nature, humans (graphic designers) can more correctly identify the problem, filter through nature’s solutions, think in a systems perspective, and design for human user experience.¹ Exploring how to integrate Biomimicry + Graphic Design is one of the many avenues to a more sustainable world and is arguably one of the most powerful leverage points to creating conditions conducive to life. Before exploring how biomimicry can help graphic designers create more sustainable solutions, it’s essential to revisit the methodologies of both disciplines so you can understand how both can work together.

**Methodology of Biomimicry**

Biomimicry is the conscious emulation of nature’s genius—innovation inspired by nature.² In a society accustomed to dominating or ‘improving’ nature, this respectful imitation is a radically new approach; a revolution really. Unlike the Industrial Revolution, the Biomimicry Revolution introduces an ear based not on what we can extract from nature, but on what we can learn from her.³ Biomimicry’s methodology is analyzing nature and mimicking it’s functions and deep patterns to create life-friendly solutions. It is not the aesthetic mimicry of something without the function, a point especially important for aspiring biomimetic graphic designers.⁴ For example, biomimicry is not re-sizing your canvas size to be the same proportion as the golden ratio because this ratio in nature serves as a streamlining function for growth and water flow. Biomimicry is not die-cutting your piece into the shape of a nautilus shell or simply using color palettes found in nature. This is a common mis-conception among designers who are just learning and being introduced to biomimetic graphic design. The golden ratio or color palettes found within in nature are good place to start and use for inspiration, but then you must take these and adapt them in a way that nature would within it’s eco-system, providing not only form but function as well. This is where the methodologies of both graphic design and biomimicry intersect, using some of the basic elements and principles found within design and nature.

However, mimicking form, function or shape is just the first step of becoming better adapted. Really learning from nature means remembering nature’s processes and ecosystem strategies, that everything is created and done in context for a particular reason in conditions that are conducive to life.⁵ Until we understand this and create designs and products that mimic living systems and processes rather than a machine, we haven’t reached the full extent of biomimicry. Biomimicry also recognizes the many simple rules and principles obeyed by nature for survival over the long-haul. It’s important to understand that biomimicry is iterative and is not immune to the many challenges and time-constraints of working in old systems and paradigms.⁶ Therefore, a design that just mimics a few Life’s Principles or one deep pattern in nature is okay. The design can become more sustainable the second time around. This is a very important take away that designers should take careful note of. Biomimicry is an ever-evolving process, always adapting to the current environmental and social conditions. Since design is iterative, having to start somewhere and always continuing, there is always an opportunity to go back to a project and make it better.
Designers are visual communicators. In order to create, we have to go through a process. It requires being innovative, meticulous and resourceful, taking each project from initial concepts to a final design solution. In order to fully create our client’s vision, we must understand all of the details about the project and part of that is to first define the design problem. Once the design problem is defined, we begin the necessary research in order to begin the ideation phase of brainstorming. This is where graphic designers have to focus on generating multiple variations of ideas to present to the client. Finally, the implementation phase can begin, narrowing down the ideas and choosing ones that will be the most successful. In the simplest of terms, we take a design problem, generate ideas through sketching and brainstorming and implement the best idea to produce a successful design solution.

However, design is not entirely about juxtaposing images and text to produce content in relation to the context of the problem. It has the power to do more. There is a common misconception among the general public (non-designers) who may not be aware of the methodology of Graphic Design or what graphic designers do and think that all we do is make and print stuff that will only end up in landfills as waste. This is such a negative outlook to have because then every designer would ask themselves, “Why am I designing this if it is just going to end up in the trash?” Today we have the power to change that negative outlook and turn it into something positive. Take that piece of ‘trash’ and see how it can better fit within the larger ecosystem, creating conditions conducive to life and benefiting us rather than hindering us from reducing our carbon footprint.

In order to explore graphic design as a strategic process to assist societal problems, we need to think very differently in terms of multidisciplinary design teams and working directly within our local communities and cultural organizations. This all relates back to the act of responsible design within modern practices.

While this new process affects the graphic design methodology by instituting the use of natural processes, principles and influences to promote change within critical social issues; the role of good communication design is just as relevant than ever. Herein lays an incredible opportunity for graphic designers to illustrate its social relevance, influence, and creativity by using biomimicry within their process.

METHODOLOGY OF GRAPHIC DESIGN

Designers are visual communicators. In order to create, we have to go through a process. It requires being innovative, meticulous and resourceful, taking each project from initial concepts to a final design solution. In order to fully create our client’s vision, we must understand all of the details about the project and part of that is to first define the design problem. Once the design problem is defined, we begin the necessary research in order to begin the ideation phase of brainstorming. This is where graphic designers have to focus on generating multiple variations of ideas to present to the client. Finally, the implementation phase can begin, narrowing down the ideas and choosing ones that will be the most successful. In the simplest of terms, we take a design problem, generate ideas through sketching and brainstorming and implement the best idea to produce a successful design solution.

However, design is not entirely about juxtaposing images and text to produce content in relation to the context of the problem. It has the power to do more. There is a common misconception among the general public (non-designers) who may not be aware of the methodology of Graphic Design or what graphic designers do and think that all we do is make and print stuff that will only end up in landfills as waste. This is such a negative outlook to have because then every designer would ask themselves, “Why am I designing this if it is just going to end up in the trash?” Today we have the power to change that negative outlook and turn it into something positive. Take that piece of ‘trash’ and see how it can better fit within the larger ecosystem, creating conditions conducive to life and benefiting us rather than hindering us from reducing our carbon footprint.
Designers create something that does not exist
Human technology springs from what is variously called invention, discovery, development or planning
Graphic Designers can borrow devices from other designers and history
Humans have a great affinity for flatness
Designers love the mechanical and geometrical shapes, using right corners in abundance
Designers, and people, like to create by taking something and manipulating it into something else, taking away and adding, then disposing what was not used
Overly productive, using brute force resulting in excess, waste and pollution

What can our technologies provide?

Biologists study something that exists: nature, in all its splendor
Nature’s process is that mechanism, Darwin uncovered, evolution by natural selection
Nature makes very few flat surfaces
Nature, on the other hand, uses very few right angles, if any, using curves and gradual gradients
Nature, however, would cut something into pieces and reassemble them from the ground up, building by lacing them together; optimizing the material with little to no waste to dispose of
Highly protective, using finesse resulting in conserving and nurturing

What do we need? How can nature provide?

GRAPHIC DESIGN
( Technologic, Humans )
Designers create something that does not exist
Human technology springs from what is variously called invention, discovery, development or planning
Graphic Designers can borrow devices from other designers and history
Humans have a great affinity for flatness
Designers love the mechanical and geometrical shapes, using right corners in abundance
Designers, and people, like to create by taking something and manipulating it into something else, taking away and adding, then disposing what was not used
Overly productive, using brute force resulting in excess, waste and pollution
What can our technologies provide?

BIOMIMICRY
( Biologic, Nature )
Biologists study something that exists: nature, in all its splendor
Nature’s process is that mechanism, Darwin uncovered, evolution by natural selection
Nature makes very few flat surfaces
Nature, on the other hand, uses very few right angles, if any, using curves and gradual gradients
Nature, however, would cut something into pieces and reassemble them from the ground up, building by lacing them together; optimizing the material with little to no waste to dispose of
Highly protective, using finesse resulting in conserving and nurturing

What do we need? How can nature provide?

Inspired by—thoughts of Steven Vogel, Cats’ Paws and Catapults: The Mechanical World of Nature and People
MEmE

Nature’s Design Principles,
Indirect Method
Meme, by definition, means an element of a culture or system of behavior that may be considered to be passed from one individual to another by non-genetic means, esp. imitation. Biomimetic graphic design in itself is somewhat of a ‘meme.’ It is a design process and style that has been spread and passed along throughout today’s culture and society via various channels and networks of communication. To be active within this biomimetic graphic design unit, designers must transmit their ideas through the form of cultural analogues that can respond and adapt to the ever-changing times and conditions. To better understand this, it is critical that designers learn, memorize and apply the following design lessons and life principles nature has so graciously given us.

This is the indirect method of beginning to apply the two methodologies; biomimicry + graphic design, using abstracted principles of how nature designs. These principles of nature are present in all organisms at multiple scales and levels that fuel and inspire deep sustainability. They are the criteria for thriving and surviving on earth, while creating conditions conducive to life and can be applied to all stages of the graphic design or visual communication process. Each principle challenges humans to think systemically within a broader context than just thinking of a single organism. The following principles are a distilled combination of those life’s principles enumerated by the Biomimicry Institute and Janine Benyus, Michael Braungart and William McDonough (Cradle to Cradle), Steven Vogel (Cats’ Paws and Catapults), D’Arcy Thompson (On Growth and Form), Julian Vincent (Structural Biomaterials), Jeremy Faludi (sustainable design strategist and researcher, articles for Worldchanging.com) and my own limited experience of knowledge and research on the subject of biomimetic design.

**Design Principles of Nature**

1. Self-Assembly from the Ground Up
2. Waste = Food
3. Evolve Solutions, Don’t Plan Them
4. Adapt to Changing Conditions, Adjust to the Here & Now
5. Respect Diversity, Diversify to Fill Every Niche
6. Self Appropriate Technologies
7. Be Resourceful
8. Optimize Rather than Maximize
9. Use Life-Friendly Chemistry
10. Organize Fractally
11. The Entire System is Greater than the Sum of Its Parts
12. Leveraging Interdependence, Feedback Loops
13. Foster Cooperative Relationships
14. Don’t Foul your Nest
1. Self-Assembly from the Ground Up

The most important things happen at the smallest scales. This is adaptable to
many levels. For instance, on the material level, instead of taking a block of
something that you cut away, take small parts that combine to form the whole.
This reduces waste and increases design flexibility.

Jessica Jones, the graphic designer and visual communicator at the Institute
put it very eloquently when I spoke with her via phone conference...

If you gave nature a piece of construction paper and asked it to make a leaf,
it would cut it into pieces and then reassemble the pieces from the bottom
up... but humans would take it, take scissors and cut the shape out of it.
(Story original told by Janine Benyus)

On the system level, design networks, not pyramids. The nodes should create
the overall structure by their interrelations, because this method is more robust,
scaleable, and flexible than a system with an over-arching plan that must have
certain nodes in certain places.

The second aspect of this, ‘the most important things happen at the smallest
scales’, refers to the fact that the most complex, detail-filled aspects of
biological designs are done at the smallest scales: at first, a bone looks like a
stick; look closer, and you see its porous structure; look closer, and you see
the material is a composite; look closer, and you find that composite has three
or four deeper levels of substructure; look closely enough and you get to the
DNA, which is complex enough to contain the blueprints for the whole bone
and the rest of the animal. Sometimes designing for the most minute detail
can cause the whole over-arching design to be determined.

2. Waste = Food

This perhaps is one of the most important principles, using waste as a resource
rather than disposing of it off in a landfill somewhere. Michael Braungart and
William McDonough, authors of *Cradle to Cradle: Remaking the Way We Make
Things*, have the best developed model for this, with their concept of biological
nutrients and technical nutrients. Strictly speaking, as Janine Benyus points out,
modern industry does act like ecosystems in nature— a ‘type 1’ system, the
weeds that colonize an area after a disturbance. However, type 1 ecosystems
aren’t sustainable, they eventually give way to type 2 and type 3 ecosystems,
which have increasingly greater interdependencies, with increasingly closed-
loop resource flows, such as rainforests. Creating type 3 industrial ecosystems
has historically been tricky to implement because the pace at which products
change, and markets change, are often rapid—industry has so far always been
in a ‘disturbed’ state as new technologies change the rules of the game;
natural ecosystems, by contrast, transform from type 1 to type 3 over
thousands of generations of the species involved. How can we help push
industry forward? The adoption of open standards can help here, so that
components are more interchangeable between products and industries—
this helps manufacturing systems develop long-term stability standards
needed for building webs of interdependencies. Likewise less dependency
on new cutting-edge technologies makes it easier to fit into existing webs.
An important corollary of ‘waste = food’ that Janine Benyus makes is ‘don’t
draw down resources, live off the ‘interest’. It is a financial analogy, describing
how mature (type 3) ecosystems don’t need new income since they are living
off of the interest from the great biological wealth they have acquired over time.
Mining or harvesting too much of the world’s existing natural resources is like
spending the capital you’re trying to live off the interest off, and it will catch up to you.
Evolve Solutions, Don’t Plan Them

This means design without authorship and letting go with dignity. Many designers may not be fond of this third principle because it strives away from the traditional process of artists and their work. It is now about creating the right context for possibilities to emerge from. As Jeremy Faludi explains, the most direct example is genetic algorithms. Their huge success has proven the usefulness of this technique and principle. This in turn falls back onto the idea of design being iterative and continuous. That is making multiple prototypes, user-testing them to find the favorites and most successful, then mixing and matching elements from each to create another generation of prototypes which are in turn user-tested, ad infinitum. Incidentally, this is the method advocated by IDEO, one of the most successful design firms in the world.

Adapt to Changing Conditions, Adjust to the Here & Now

This fourth principle directly applies to Darwinian evolution; true evolution in the sense that a design is never done, it is only a means of adaptation. As Janine Benyus says, effective adaptation requires organisms to be information-driven, with local expertise. It also requires timely expertise. Species that range across dramatically different habitats must adjust themselves to the new locales, and those that stay in the same place but whose habitat changes (say, from summer to winter) adjust as well; i.e. hibernation. In the product world this means customizing for different users and different circumstances, to extend the product life-cycle. In more advanced implementations, it means the products adjust themselves without need for user intervention.

Respect Diversity, Diversify to Fill Every Niche

Respect diversity can be very broad, covering a global level but it can also be scaled down to be compared to the industry, market and product level. In regards to the global level, it is showing a wide scope of respect and honor to all cultural, ethnic, racial, sexual, religious and spiritual diversity of beings within the context of individual responsibility. To respect and maintain biodiversity or a diversity of living species for a chance to change and evolve through natural selection.

On the market level, traditional industry already adapts to this. However, on the product level, mass-customization does a similar thing. The biomimetic-design lesson here ties in with the second principle, ‘Waste = Food.’ It is to find untapped niches where waste is being created, where it could instead be used as a resource. Smart manufacturers close their own resource loops; smart entrepreneurs close other peoples’ loops. Solving a problem using a single solution, with no diversity, may make it vulnerable to outside influences.

Self Appropriate Technologies

This sixth principle is fairly simple: use the right tools for the right job. Making sure you use the right tool and material the first go around not only ensures time and cost efficiency, it also prevents the act of re-design. This also ties in with the first and second principles, ‘self-assembly from the ground up’ and ‘waste = food.’ In self appropriating technologies, it confirms less waste which means less cleanup; less conflict; fewer costs.
Be Resourceful

Being resourceful may seem like another fairly broad principle to apply, but generally speaking it encompasses gathering and minimizing efficient energy and materials needed to produce a successful design solution. In regards to gathering efficient energy and materials, you do not necessarily need to study nature to get the importance of this, but it has a cornucopia of strategies you may have never tried. For example, ants have been studied to improve shipping schedule algorithms, plant leaves have been studied for solar energy absorption, mollusks have been studied for building shells out of seawater without even moving.\(^{10}\) The list goes on...

As for minimizing energy and materials to be resourceful, nature has an abundance of great examples. Plants and animals always try to use material and energy efficiently, because for them energy and material costs are the only costs. Successfully minimizing mass and energy use requires thorough optimization to the problem at hand, so organism structures are highly information-driven. On the other hand, industry’s costs are primarily financial, so it usually finds it easier to simply use more material or energy than spend the extra time researching how to use it well. Yet, minimalist designs can be the most successful and cost-effective in the industry.\(^{11}\)

Optimize Rather than Maximize

Optimize rather than maximize, centers around the concept of creating designs that are multifunctional, always fitting form to function. This is general systems-thinking advice, but Benyus points out its ubiquitousness in biology. Creatures always have to balance multiple cost/benefit dimensions, there are no single-minded goals like being bigger or faster. A quick rule of thumb here is perform as many functions with as few components as possible, tying in the seventh principle of ‘being resourceful’ when it comes to selecting and gathering your materials. It is a good exercise to explicitly lay out all the factors you are trying to balance and organize. For instance, graphic designers can maximize the number of pages in a piece or the size of the paper which will probably allow for a more easily achieved eye-catching composition and attract more viewers; yet the functional design of the piece may be compromised if it’s now too large for users.\(^{12}\) Always remember to optimize all variables.

Use Life-Friendly Chemistry

This principle, from both Benyus and Vogel, is fairly self-explanatory. Benyus describes the way we manufacture products is by ‘heat, beat, treat.’ She claims it has become the de facto slogan of our industrial age; it is the way we synthesize just about everything. Nature, on the other hand, cannot afford to follow this strategy. Life can’t put its factory on the edge of town; it has to live where it works. As a result, nature’s first trick of the trade is that nature manufactures its materials under life-friendly conditions— in water, at room temperature, without harsh chemicals or high pressures.\(^{13}\)
This tenth principle, organize fractally, looks at self-similarity in the way of planning for several different scales at once. Fibonacci spirals do not occur all over the place in nature because they’re pretty, they occur all over because they are an algorithm that allows perpetual growth to any size without having to readjust or plan ahead. Fractal structures do not have to be as ‘smart’ as other structures which require different planning for different scales. This ties in with design having form and multi-functionality.

The Entire System is Greater than the Sum of Its Parts

People tend to design one function at a time, creating separate elements for each task and then creating the product by assembling all the pieces. There are many advantages to this, but in these products the whole will only be the sum of its parts. One of the hallmarks of complex systems, which includes everything that is alive, is ‘emergent phenomena,’ the fact that the whole is greater than the sum of its parts.14 An example of ‘emergent phenomena’ is looking at how an individual bee has a small brain and simple behavior, but a swarm of bees is like a sophisticated organism all its own. Emergent phenomena are hard, if not impossible to predict, and in the built world mostly happen by accident. However, designing with it in mind can not only help avoid unintended consequences, but can open new opportunities– the democratizing force of the internet being a prime example.15 The key to this principle is designing lots of little, simple things that together can do sophisticated things; this can be a biomimetic design tool because it lets you build robust systems without infrastructure, build smaller and smarter stuff without super-high technology.

Inter-relatedness and leveraging interdependence systems relies on learning the lessons from the ecosystems that we are a part of. This principle basically outlines what the biomimetic + graphic design process tries to do. We need to learn how to work with the cycles of the sun, water, wind, and geothermal energy rather than depleting finite resources that can be more effectively used elsewhere.16 In doing this, we can help to create a continuous locally attuned feedback loop that allows for the renewing of resources, recycling of all materials, and self-organizing of systems; all of which allows the fostering of cooperative relationships– the thirteenth design principle of nature. Natural eco-systems are able to sense boundaries and changing conditions, whereas humans are not so well adapted in doing. It is crucial that we look to these systems and feedback loops in order to solve our design problems in the most economical fashion.
Foster Cooperative Relationships

Just as in a natural eco-system where one organism lives off another, providing the nourishment it needs to survive; graphic designers use print manufacturers to ensure their jobs and designs survive. It is using the same cycle of give and you shall receive. Both need each other in order to survive within the creative design industry. So, fostering cooperative relationships means we need to encourage creative thinking and cultivate relationships with other designers and manufacturers in the industry in order to keep this continuous cycle going.

For instance, a stock photography company allows a printing shop to give its clients (graphic designers) access to its database account. A client can use any photograph as long as it uses the printing shop for printing. In turn, the stock photography company receives more revenue/exposure, the printer receives more services, and the client receives complementary or reduced-cost photos. It is actively seeking out a relationship to ensure positive business practices to get things done, benefiting all in the process.

Don’t Foul your Nest

This last principle is another genius idea of Benyus. ‘Don’t foul your nest’ is saying that in the grand scheme of things, don’t use or design with harmful materials or effluents. Do you really want to live in a home that gives off harmful gases such as formaldehyde or dioxin? This sounds simple and obvious, but if engineers, architects, and other builders actually started following this principle alone, it would cause a revolution. This also refers to design in the sense that you shouldn’t ‘foul your design’ with any unnecessary components.
GRAPHIC DESIGN

Universal Principles & Elements
When looking at graphic design and the contemporary trends happening today, it is apparent that the graphic design and visual communication fields continue to increase in complexity due to the expansion of new technologies. With these technological and societal advances, emphasis is now placed on directing design and visual information toward new applications including tablets, mobile devices, e-books, etc. The major focus is no longer on pure form generation which has been the case in the past but instead, the focus is placed on other elements such as device, user needs and involvement, affordability, resources, and environmental concerns. Although, this is not to say that form generation is not an important aspect to the field anymore; there are just other elements that designers today need to be aware of that designers in the past did not. With that being said, although these digital technologies afford greater freedom and flexibility with design, they can often cut short the creative window for concept development and creative thinking. People, places, thoughts and things become familiar through repeated exposure.\(^1\) There is too much temptation to turn directly to the computer and type in Google search, which often results in images or ideas that are tired and trite. In order for designers to adapt to these technological changes, it is still important that they remain technically savvy in order to do so; however, it is just as important that they do not get trapped in the technological pitfall of leaving little to no imagination or bypassing the old creative brainstorming process of sketching and ideation.

Biomimetic design in itself is an ideation process that requires analyzing and examining forms and organisms found within nature and emulating how they function within their natural ecosystems. Therefore, the creative process and being aware of the universal elements and principles of design that are also found within nature is crucial. In order to accurately portray or emulate a system, designers must be willing to go out and experience; become familiar, observe, and analyze nature’s design principles within their brainstorming process. When designers reduce the organism or system down to its basic elements, looking at form, function and shape, this is where the universal elements and principles of design come into play and intertwine with nature’s design principles.

Although every designer has his/her own creative process, all are based on the foundation of knowing the basic elements and principles of design including balance, rhythm, proportion, dominance, unity, form, shape... However, there are other principles that designers should remind themselves of like Hick’s Law, Ockham’s Razor, etc. Since graphic design is a discipline directed towards the development and distribution of information in a visually creative way; instead of the all of the focus being directed towards distributing the information in the best manner to please clients; the larger focus should now be how can we experiment with this visual language, while integrating nature in a way that still gets our message across. This is in hopes of ultimately producing a form of universal design. Good design has often been labeled as being based on a type of logic, grid system and structure with a well thought out plan. For instance, a well designed logo is usually a progression of ideas and forms, sketching and re-sketching until the final design is achieved. What needs to be stressed is that there is a level of importance in sketching and process that unfortunately in modern design practices with the acceleration of technology, is getting lost due to immediate satisfaction with internet access. It is important we reassess and look back to the basic principles in order to move forward.

---

\(^1\) Ellen Lupton & Jennifer Cole Phillips, Graphic Design The New Basics
The following 14 Universal Design Principles and Elements are an extension of Nature’s 14 Design Principles to show how both relate and correspond to each other within the biomimetic design process.

Each design principle falls into 1 of the 3 categories:

**Form**
- Form Follows Function
- Mimicry
- Self-Similarity
- Symmetry
- Uniform Connectedness

**Systems**
- Convergence
- Feedback Loop
- Hick’s Law
- Hierarchy of Needs
- Life Cycle

**Thinking**
- Depth of Processing
- Five Hat Racks
- Mental Model
- Ockham’s Razor

---

**Form**

1. **Form Follows Function**
   
   Beauty in design results from purity of function. The form follows function axiom is interpreted in one of two ways— as a description of beauty or a prescription for beauty. The descriptive interpretation is that beauty results from purity of function and the absence of ornamentation. The prescriptive interpretation is that aesthetic considerations in design should be secondary to functional considerations. When making design decisions, focus on the relative importance of all aspects of the design—form and function—in light of the success criteria.

2. **Mimicry**
   
   The act of copying properties of familiar objects, organisms, or environments in order to realize specific benefits afforded by those properties. In nature, mimicry refers to the copying of certain properties to hide from or deter other organisms. For instance, the viceroy butterfly mimics the less tasty monarch butterfly to detect predators. In design, mimicry refers to copying properties of familiar objects, organisms or environments in order to improve the usability, likeability, or functionality of an object. There are three basic kinds of mimicry in design: surface, behavioral, and functional. Mimicry is perhaps the oldest and most efficient method for achieving major advances in design. Consider surface mimicry to improve usability, ensuring that the perception of the design corresponds to how it functions or is to be used.

---

For more detailed synopsis of the principles, reference Universal Principles of Design by William Lidwell, Kristina Holden and Jill Butler (descriptions seen here are excerpts from this book).
Self-Similarity

A property in which a form is made up of parts similar to the whole or to one another. Many forms in nature exhibit self-similarity and as a result it is commonly held to be an intrinsically aesthetic property. Natural forms tend to exhibit this at many different levels of scale, whereas human-created forms generally do not. This naturally occurring self-similarity is usually the result of a basic algorithm process called recursion. Recursion occurs when a system receives input, modifies it slightly, and then feeds the output back into the systems as input. The ubiquity of self-similarity in nature hints at an underlying order and algorithm, and suggests ways to enhance the aesthetic composition of human-created forms and perhaps their structural composition as well. Consider self-similarity in all aspects of design: story boarding, visual displays and structural compositions. The reuse of a single, basic form to create many levels of metaforms mimics nature’s tendency towards parsimony and redundancy and can create interesting organizations at multiple levels of scale.

Symmetry

A property of visual equivalence among elements in a form. Symmetry has long been associated with beauty, and is a property found in virtually all forms in nature. It can be seen in the human body as well as plants and animals. Symmetry in natural forms is largely a function of the influence of gravity and the kind of averaging of form that occurs from merging genetic information in reproduction. There are three basic types of symmetry: reflection, rotation, and translation. Use symmetry in design to convey balance, harmony, and stability.

Uniform Connectedness

Elements that are connected by uniform visual properties, such as color, are perceived to be more related than elements that are not connected. This is one of the Gestalt principles of perception, asserting that elements connected to one another by uniform visual properties are perceived as a single group or chunk and are interpreted as being more related than elements that are not connected. There are two basic strategies for applying uniform connectedness in design: common regions and connecting lines. Common regions are formed when edges come together and bound a visual area, grouping the elements within the region. Connecting lines are formed when an explicit line joins elements, grouping the connected elements. Use uniform connectedness to visually connect or group elements in a design. Employ common regions to group text elements and clusters of control elements, and connecting lines to group individual elements and imply sequence.

The System > the Sum of Its Parts

Elements that are connected by uniform visual properties, such as color, are perceived to be more related than elements that are not connected. This is one of the Gestalt principles of perception, asserting that elements connected to one another by uniform visual properties are perceived as a single group or chunk and are interpreted as being more related than elements that are not connected. There are two basic strategies for applying uniform connectedness in design: common regions and connecting lines. Common regions are formed when edges come together and bound a visual area, grouping the elements within the region. Connecting lines are formed when an explicit line joins elements, grouping the connected elements. Use uniform connectedness to visually connect or group elements in a design. Employ common regions to group text elements and clusters of control elements, and connecting lines to group individual elements and imply sequence.
Convergence
A process in which similar characteristics evolve independently in multiple systems. Natural or human-made systems that best approximate optimal strategies afforded by the environment tend to be successful, while systems exhibiting lesser approximations tend to become extinct. This process results in the convergence of form and function over time. The degree of convergence in an environment indicates its stability and receptivity to different kinds of innovation. Consider the level of stability and convergence in an environment prior to design. Stable environments with convergent system designs are receptive to minor innovations and refinements but resist radical departures from established designs. Unstable environments with no convergent system designs are receptive to major innovations and experimentation, but offer little guidance as to which designs may or may not be successful.

Feedback Loop
A relationship between variables in a system where the consequences of an event feed back into the system as input, modifying the event in the future. Every action creates an equal and opposite reaction. When reactions loop back to affect themselves, a feedback loop is created. All real-world systems are composed of many such interacting feedback loops—animals, machines, businesses, and ecosystems. There are two types of feedback loops: positive and negative. Positive feedback amplifies system output, resulting in growth or decline. Negative feedback damps output, stabilizing the system around an equilibrium point.

Hick’s Law
The time it takes to make a decision increases as the number of alternatives increase. Hick’s Law states that the time required to make a decision is a function of the number of available options. It can be used to estimate how long it will take for people to make a decision when presented with multiple choices and has implications for the design of any system or process. Keep Hick’s Law in mind when designing systems that involve decisions based on a set of options to increase efficiency, resulting in less waste.

Hierarchy of Needs
In order for a design to be successful, it must meet people’s basic needs before it can attempt to satisfy higher-level needs. This principle specifies that a design must serve the low-level needs (it must function) before the higher-level needs (creativity) can be addressed. Good design follows the hierarchy of needs principle, whereas poor designs may attempt to meet needs from the various levels without building on the lower level of hierarchy first which results in a waste of resources. There are five key levels of needs: functionality, reliability, usability, proficiency, and creativity. Functionality needs have to do with meeting the most basic design requirements. Reliability needs have to do with establishing stable and consistent performance. Usability needs have to do with how easy and forgiving a design is to use. Proficiency needs have to do with empowering people to do better things than they could previously. Creativity is the level in the hierarchy where all needs have been satisfied and people begin interacting with the design in innovative ways.

Leveraging Interdependence
The following design principles pertain to entire systems of design and how they function over time.

<table>
<thead>
<tr>
<th>PRINCIPLE</th>
<th>DESCRIPTION</th>
<th>RELATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Convergence</td>
<td>A process in which similar characteristics evolve independently in multiple systems. Natural or human-made systems that best approximate optimal strategies afforded by the environment tend to be successful, while systems exhibiting lesser approximations tend to become extinct. This process results in the convergence of form and function over time. The degree of convergence in an environment indicates its stability and receptivity to different kinds of innovation. Consider the level of stability and convergence in an environment prior to design. Stable environments with convergent system designs are receptive to minor innovations and refinements but resist radical departures from established designs. Unstable environments with no convergent system designs are receptive to major innovations and experimentation, but offer little guidance as to which designs may or may not be successful.</td>
<td></td>
</tr>
<tr>
<td>Feedback Loop</td>
<td>A relationship between variables in a system where the consequences of an event feed back into the system as input, modifying the event in the future. Every action creates an equal and opposite reaction. When reactions loop back to affect themselves, a feedback loop is created. All real-world systems are composed of many such interacting feedback loops—animals, machines, businesses, and ecosystems. There are two types of feedback loops: positive and negative. Positive feedback amplifies system output, resulting in growth or decline. Negative feedback damps output, stabilizing the system around an equilibrium point.</td>
<td></td>
</tr>
<tr>
<td>Hick’s Law</td>
<td>The time it takes to make a decision increases as the number of alternatives increase. Hick’s Law states that the time required to make a decision is a function of the number of available options. It can be used to estimate how long it will take for people to make a decision when presented with multiple choices and has implications for the design of any system or process. Keep Hick’s Law in mind when designing systems that involve decisions based on a set of options to increase efficiency, resulting in less waste.</td>
<td></td>
</tr>
<tr>
<td>Hierarchy of Needs</td>
<td>In order for a design to be successful, it must meet people’s basic needs before it can attempt to satisfy higher-level needs. This principle specifies that a design must serve the low-level needs (it must function) before the higher-level needs (creativity) can be addressed. Good design follows the hierarchy of needs principle, whereas poor designs may attempt to meet needs from the various levels without building on the lower level of hierarchy first which results in a waste of resources. There are five key levels of needs: functionality, reliability, usability, proficiency, and creativity. Functionality needs have to do with meeting the most basic design requirements. Reliability needs have to do with establishing stable and consistent performance. Usability needs have to do with how easy and forgiving a design is to use. Proficiency needs have to do with empowering people to do better things than they could previously. Creativity is the level in the hierarchy where all needs have been satisfied and people begin interacting with the design in innovative ways.</td>
<td></td>
</tr>
</tbody>
</table>
Life Cycle
All products progress sequentially through four stages of existence: introduction, growth, maturity and decline. This roughly corresponds with the natural life cycle of birth, adolescence, adulthood and death. For example, a new tablet is envisioned and developed, its popularity grows, after a while its sales plateau, and then finally, the sales decline. Understanding the implications of each of these stages allows designers to prepare for the unique and evolving requirements of a product over its lifetime. The introduction stage is the official birth of the product. The growth stage is the most challenging stage where most products fail. The maturity stage is the peak of the product life cycle. Finally, the decline stage is the end of the life cycle. Always consider the life cycle of a product when planning and preparing for the future. Always work closely with early adopters to refine and tune products in the introduction phase. During the growth phase, focus on scaling product supply and performance. Also focus on customer satisfaction through performance enhancements and improved support during the maturity phase. Then, once you hit the decline phase, focus on facilitating the transition to next generation products.

Depth of Processing
A phenomenon of memory in which information that is analyzed deeply is better recalled than information that is analyzed superficially. Thinking hard about information improves the likelihood that the information will be recalled at a later time. This phenomenon of memory results from the two ways in which information is processed known as maintenance rehearsal and elaborative rehearsal. Maintenance rehearsal simply repeats the same kind of analysis that has already been carried out. For instance, someone repeats a phone number aloud back to the themselves to help them remember; no additional analysis is performed on the phone number. Elaborative rehearsal involved a deeper, more meaningful analysis of the information. For instance, when someone reads a passage from a book aloud and then has to answer questions about the meaning of it; additional analysis as to word and sentence meaning require additional thought. Consider depth of processing in design contexts where recall and retention of information is important. Use unique presentation and appropriate tools to engage people to deeply process the information relevant to an audience.

Five Hat Racks
There are five ways to organize information: category, time, location, alphabet, and continuum. The organization of information is one of the most powerful factors influencing the way people think about and interact with a design. The five hat racks principle asserts that there are a limited number of organizational strategies, regardless of the specific application, so optimization of each category in the simplest manner is key in users understanding and processing information.
People understand and interact with systems and environments based on mental representations developed from experience. They do this by comparing the outcomes of their mental models with real-world systems and natural environments. With regards to design, there are two basic types of mental models: mental models of how systems work (system models) and mental models of how people interact with systems (interaction models). Design with people’s differing interaction models in mind. If there is a standard mental model for how something works, try to design leveraging that model.

Given a choice between functionally equivalent designs, the simplest design should be selected. Ockham’s razor asserts that simplicity is preferred to complexity in design. Many variations of the principle exist, Aristotle explaining it as “Nature operates in the shortest way possible.” Implicit is the idea that unnecessary elements decrease a design’s efficiency and increase the probability of unanticipated consequences. Use Ockham’s razor to evaluate and select among multiple, functionally equivalent designs.

Below is an informational chart to help demonstrate the combination of the 14 Universal Graphic Design Principles + 14 Design Principles of Nature, which help to form the Indirect Method of the biomimetic design process, theory and system.

### Synthesis

<table>
<thead>
<tr>
<th>Universal Design Principles</th>
<th>Design Principles of Nature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Form Follows Function</td>
<td>Be Resourceful</td>
</tr>
<tr>
<td>Mimicry</td>
<td>Adapt to Changing Conditions</td>
</tr>
<tr>
<td>Self-Similarity</td>
<td>Organize Fractally</td>
</tr>
<tr>
<td>Symmetry</td>
<td>Use Life-Friendly Chemistry</td>
</tr>
<tr>
<td>Uniform Connectedness</td>
<td>The System &gt; the Sum of its Parts</td>
</tr>
<tr>
<td>Convergence</td>
<td>Foster Cooperative Relationships</td>
</tr>
<tr>
<td>Feedback Loop</td>
<td>Leveraging Interdependence</td>
</tr>
<tr>
<td>Hick’s Law</td>
<td>Waste = Food</td>
</tr>
<tr>
<td>Hierarchy of Needs</td>
<td>Self-Assembly from the Ground Up</td>
</tr>
<tr>
<td>Life Cycle</td>
<td>Evolve Solutions, Don’t Plan Them</td>
</tr>
<tr>
<td>Depth of Processing</td>
<td>Self-Appropriate Technologies</td>
</tr>
<tr>
<td>Five Hat Racks</td>
<td>Optimize Rather than Maximize</td>
</tr>
<tr>
<td>Mental Model</td>
<td>Respect Diversity</td>
</tr>
<tr>
<td>Ockham’s Razor</td>
<td>Don’t Foul your Nest</td>
</tr>
</tbody>
</table>
PROCESS

Integrating the Disciplines,
Direct Method
This graphic design + biomimetic process is born from new ideas, yet conceived from old ideals. It is taking nature’s time-tested ideals over a period of approximately 3.8 billion years and introducing and integrating them with modern design practices. It is a synthesis of graphic design + biomimicry. The Direct Method, unlike that of the indirect method using abstracted principles of how nature designs, is exactly what it states: directly going out into the environment and seeking a natural system and organism; finding an example and defining the problem in its context, then finding the organisms with a similar problem and context to see what they do. The goal is to find many divergent organisms to see which has the best and most relevant strategy.4 Within this process, it is vital designers take into account their time and resource constraints, in order to optimize rather than maximize materials, so they can then appropriately assemble and implement the materials efficiently within their design solutions. This is the core of the biomimetic discipline.

The direct method is what you usually hear about—where the designer or engineer can point to an organism and say ‘it’s like that’. The value of this method is that even the most creative people still get stuck thinking along certain lines. In fact, a method called TRIZ 5, which has been developed to catalog and analyze problem-solving techniques, claims there are just 40 methods that people have ever used to think up new inventions. Since evolution works differently from our brains, nature has used many more. Julian Vincent, author of Structural Biomaterials, at University of Bath has been working on extending TRIZ to biology, cataloging and analyzing the ways other organisms have ‘invented’ new solutions to problems. But so far the best way to find ideas in nature is to go look for yourself; arguably it always will be.

**New Oxford American Dictionary 3rd ed © 2010**

1. Jessica Jones, excerpt in Sustainable Graphic Design, Wendy Jedlicka

2. Jeremy Faludi, Biomimicry for Green Design: Worldchanging: Change Your Thinking

3. Jessica Jones, excerpt in Sustainable Graphic Design, Wendy Jedlicka

4. TRIZ is the (Russian) acronym for the Theory of Inventive Problem Solving. G.S. Altshuller and his colleagues in the former USSR developed the method between 1946 and 1985. TRIZ is an international science of creativity that relies on the study of the patterns of problems and solutions, not on the spontaneous and intuitive creativity of individuals or groups.
When looking at the visual process of biomimetic design, it can be shown in three different models: linear, circular, and branching. It is necessary to show the process in different forms to stress that it overlaps other frameworks and disciplines. The process of integrating the two differing methodologies is bringing nature’s wisdom not just to the physical design, but also to the manufacturing process, the packaging, the shipping, distribution, and take-back decisions. We use the three different models to emphasize the reiterative nature of the process to make clear that it evolves in more pattern than one—after solving one challenge, then evaluating how well it meets life’s principles, another challenge often arises, and the design process begins anew.

There are six stages within this new process: define, analyze, observe, select, implement, evaluate.

Defining the problem well is always a challenge in design, but then finding organisms that have relevant strategies is a trick in and of itself. Some examples are easy to find just by going for a walk and paying attention; other examples are more obscure, and require research—online, in books and academic journals, or even by hiring a biologist to consult (a BiDIT). It’s especially useful to find many examples from wildly divergent sources, like when looking for structures, don’t just look at animal bones, but also insect exoskeletons, the branches of trees, or the stems of grasses so that you have design alternatives. Just because a certain strategy evolved in one place doesn’t mean it’s the best solution; the power of biomimicry is that you can find many different solutions that you’ve never thought of. However, it is always a good thing to remember that good biomimetic design is inspiration from nature, not a slavish imitation of it.

As Michael Pawlyn, an architect and advocate of biomimicry, states “If you look beyond the nice shapes in nature and understand the principles behind them, you can find some adaptations that can lead to new innovative solutions that are radically more resource efficient. It’s the direction we need to take in the coming decades.” In essence, within the graphic design + biomimicry process, what is trying to be stressed is that the natural world is a cauldron of research and development, trial and error, where technologies that fail are called fossils and technologies that succeed survive to fight another day.

Why reinvent the wheel, when nature has figured out how to slither, walk, hover and fly in so many different ways? Who can deny that nature got here first? Note, within each of these stages, there are small sub-stages like research, ideation and usability testing that also occur.

For more information on Michael Pawlyn, see his book, Biomimicry in Architecture. You can also visit TED, www.ted.com, to see him give various TED talks on biomimicry and its virtues.
There are also three different lenses through which you can evaluate and explore this biomimetic design process through: form, process and system. Carl Hastrich, a professor at OCAD University in Toronto and previous toy designer, describes looking at biomimicry as placing a heavy emphasis on the system as context, and broader inspiration into why an adaptation from an organism occurs. “Ecosystems are an emergent property of biological organisms and the environment, and in order to really understand it we need to look at the full context. The weakness of some investigations at a systems level occur when there is no deeper understanding of the biological mechanisms that occur for systemic relationships to form. Therefore it is inherently complex to research and a difficult story to tell.”

Below are other organic interpretation models showing design’s role and value within society, as well as the reverse, exploring society’s value to design. Carl Hastrich took Charles Eames 1968 diagram, explaining the design process as achieving a point where the needs and interests of the client, the designer, and society as a whole overlap, and re-designed it to fit his own mode of thinking regarding biomimicry and design.

1 Charles Eames, 1968, for the exhibition ‘What is Design’ at the Musée des Arts décoratifs, Paris, France
2 Humble Evolution of Charles Eames definition of Design; Carl Hastrich’s attempt to define “Biomimicry Design” http://bouncingideas.wordpress.com/

*For more inspirational ideas and topics from Carl Hastrich, visit his blog, Bouncing Ideas at http://bouncingideas.wordpress.com/
To fully understand this graphic design + biomimicry process, it is important to show an example of the process and a final design system solution. The example shown here falls in the Graphic Design category of branding and identity.

### Define
To create an identity mark that clearly represents the biomimetic design process. It must incorporate both natural and organic forms, as well as geometric and mathematical undertones. There must also be a functional quality present within the identity and implied in some fashion.

### Analyze
What would nature do? How would nature begin? How would nature solve this particular problem and in what context? What tools would nature use? How would nature delegate? How would nature assess?

**Answers**
Nature would strive to find one form at increasingly smaller scales, optimizing the amount of resources and materials. It would begin with looking at nature’s 14 design principles and seek out an organism or system that best describes this problem in order to emulate it. After finding this organism, it would look for materials and tools that were found locally within the system. It would then assess its design by looking at how it fits in with the rest of the ecosystem.

### Observe
Go out into the environment and look at natural systems and organisms. Which ones best fit within the context of this problem, can be implemented in the simplest way, and can be found locally?

**Inspiration**
Sand Dollar & Snowflakes

### Select
Choose the best form within the organism or system to emulate. It also needs to imply the overall function of the system and meaning behind the mark.

**Inspiration**
Golden Ratio & Spiral Growth Patterns of Pine cones and Sunflowers

Modified pentagon pattern found within sand dollars and snowflakes. Represents the geometrical and mathematical half of the identity mark.

Curve taken from the golden ratio proportion and spiral growth pattern of pine cones and sunflowers. Represents the natural and organic half.

1 Define | 2 Analyze | 3 Observe | 4 Select
Use the same pentagon form throughout, multiply it at different scales to preserve resources, time and materials. Apply it to the natural grid pattern, ensuring both the geometrical/mathematical and organic/natural sides are met.

How would nature assess this design? Does it use Nature’s 14 design principles?

Answers

It shows the methodologies of both graphic design (geometric/mathematical) and biomimicry (natural/organic), represented through continuation of the pentagon form along the golden ratio, curved grid pattern. It optimizes the amount of resources and materials by using the same pentagonal shape throughout at differing scales and using only 1 color at differing hues and tones. It also represents and shows the function of the biomimetic process in representing the evolving stages of the biomimetic process, as well as the continuous pattern of the life cycle of design found within nature.

3 CAVEATS | Where Nature’s Principles Will Not Help

Although this entire reference book’s premise relies on the biomimetic design process and design principles of nature, it is important to be realistic about where these life principles and strategies will and won’t help you. This is not to completely destroy the defense of this thesis or the principles just mentioned, but there are definitely some drawbacks to the way life designs, which you probably do not wish to emulate. However, these drawbacks are necessary in order for there to be progress within the evolutionary process.

1 Evolution can only find local optima, not global optima. Put in another way, evolution requires every generation to have an immediate advantage—when transitioning from one strategy or principle to another, you cannot get worse for a few generations, knowing that in the end you’ll get better than you could have with the original strategy. Thus nature shuts out many design possibilities that we humans can find.

2 Second, natural products need continual maintenance and/or rebuilding. This can easily be turned into an advantage for products meant to biodegrade or planned to obsolesce. Most often it is simply a reminder to not imitate too slavishly.

3 Finally, organisms can’t borrow designs from others, they have to evolve from what they have now. Human designers, however, can mix and match freely from different products in whole other genres. There’s nothing wrong with making a building whose walls insulate like penguin feathers but are structured like a crab shell. Some companies are doing things like this in biology with genetic engineering, but the law of unintended consequences has frequently shown it to be a bad idea.

1 These stumbling blocks are based off the work of Steven Vogel, Cats’ Paws and Catapults, and Jeremy Faludi, World Changing: Change Your Thinking.
CASE STUDIES

You've analyzed the methodologies of both biomimicry + graphic design, and now know the stages of the biomimetic design process. The following case studies demonstrate how the process was applied to actual design scenarios.

LOGO CONCEPTS: IDEO

IDEO has a very novel and intriguing logo. It is simple and that makes it easy for them to reshuffle information within the design and yet still retain the function of the logo—to recognize and associate with the brand. They are able to evolve to survive and adapt to changing conditions by integrating the unexpected and replicating strategies that work. For example, when colors become dated their designers can easily change the color because the distinct shapes will still provide the functional need. The logo can also easily adapt to fit the piece’s shape (square, zig zag, or elongated).

Nature’s Principles of organizing fractally and optimizing rather than maximizing has the highest potential to create more sustainable designs.

I’m not sure if the IDEO logo design is inherently life-friendly but I’m sure this concept could be applied elsewhere. If IDEO were striving to help their clients create more life-friendly products, then the logo indirectly would help give IDEO an advantage over the competition who may not be striving to incorporate sustainability into their policies. Graphic designers can choose which companies to create a positive image for.

QR CODES

Nature uses many senses to communicate. It uses chemistry, and more specifically scent, as one avenue for sending signals to receiving antennae. Each chemical is a certain shape and when received, fits together just perfectly with the receiver’s chemical shape. However, humans of course have come to depend mostly on our eyes as our main sense. So it’s only natural that the coding system we develop is a visual one. It’s interesting though that this code does not talk to our visual antennae directly but rather indirectly through our smart phones.

If nature needed to send a signal made up of simple, common, building blocks and by using low energy processes and reshuffling information, would it create this QR code to use as a signaling device? I think it’s on the right track. But I think the QR code definitely has a lot of room to evolve and adapt as well.

Can the coding incorporate other Life’s Principles somehow? Can it be more visually appealing, use less space, and contain more information? Should we even be focused on developing a visual code? Or will our smart phones be able to someday pick up senses that we cannot? How can we stop viewing it as just another means of advertising and use it more functionally and efficiently?

How could these codes help us be more sustainable in graphic design?

http://designmomentum.wordpress.com/
Eco Printers

Nothing in nature is permanent—everything is in a state of dynamic non-equilibrium. Nature adapts constantly to fit its context for use or it faces extinction. It seems that humans aren’t as in touch with earth’s operating conditions anymore. We create things only how we ‘perceive’ they should be created and not based on pressing needs or contexts. We are not forced to find other more context specific ways of creating because we already have a plethora of inventions that could work and we have access to inexpensive energy.

Papermaking fibres can typically be recycled only five-to-seven times before they become too short to be recycled again. The Eco Printer, designed by Sharsha Lee for Liteon Technology Corp, is a new mutated breed of printer well-adapted to a certain context and was designed to extend the life of paper.

It can remove ink in order to reprint on the same sheet many times over. Increasing the lifespan of paper is the main aim of the Eco Printer. This device uses special ink composed of photographic materials that can be made to disappear after UV irradiation. It contains a UV irradiation device in the paper input tray. Printed paper is irradiated with UV light before it is re-printed. This process takes the ink out of the paper, making it clean and ready to be printed on again. The Eco Printer can be used to print temporary documents and significantly reduce paper wastage.

For more information on the Eco-Printer, visit red dot at http://www.red-dot.sg/

Find other innovative printer ideas here: http://www.ecofriend.com/

The Pencil Printer, designed by Hoyoung Lee, uses Eco Printer concepts and actually prints as well as erases. It feeds on scrap pencil and eraser pieces. It extracts the ‘ink’ from the pencil graphite and erasing material from the rubber in the eraser pieces. This radical new printer not only prints through one of its ends but has a special exit for erasing the same printed paper too. Environmental conservation at its best!

If nature was in the business of designing typefaces, it would probably look similar to this EcoFont. Except that nature might reverse how it built its letters with ink. Instead of cutting out dots from the line it might create the line with dots. This refers back to the 1st Design Principle of Nature, Self-Assembly from the ground up, and the leaf cut out of paper analogy told by Jessica Jones (Benyus).

Test results for Ecofont Arial 12pts show ink and toner savings of 28%. In using this as opposed to traditional typefaces, you are being resourceful and material and energy efficient.

Ecofont Arial

1 For more information on the Eco-Printer, visit red dot at http://www.red-dot.sg/

2 Find other innovative printer ideas here: http://www.ecofriend.com/
RIT TAGA 2011

The RIT Taga 2011 researched and investigated the effects that font choice, typographic design, and page layout have on the conservation of ink and paper.1 This is one part of a broader concern with the environmental sustainability of digital printing. Measurement of ink and paper consumed in the printing of documents must take into account not only choices of fonts but also their spacing and arrangement within the defined parameters and pragmatic goals of specific documents. The typefaces and layouts common in academic printing were not designed with the goal of reducing ink and paper consumption, but moderate changes in typographic format and can result in substantial savings in ink and paper. It was concluded that compared to thesis composition in Arial, the use of Times New Roman or a modified Déjà vu Sans font can result in savings of ink from 19-25%. Compared to typical RIT thesis guidelines, thesis formats designed for economy can result in paper savings of 27-48%. When dealing with students whose average page consumption numbers in the thousands, such as the graduate students at RIT, a reduction of even 27% (around 270 pages out of 1000) can be a huge savings.

http://taga.rit.edu/2011/

<table>
<thead>
<tr>
<th>Typeface</th>
<th>Points</th>
<th>Ink Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arial Regular</td>
<td>1811</td>
<td>-</td>
</tr>
<tr>
<td>Déjà vu Sans Book</td>
<td>1064</td>
<td>54%</td>
</tr>
<tr>
<td>Déjà vu Sans Light</td>
<td>1517</td>
<td>33%</td>
</tr>
<tr>
<td>Déjà vu Light Text</td>
<td>802</td>
<td>54%</td>
</tr>
<tr>
<td>Times New Roman</td>
<td>1064</td>
<td>54%</td>
</tr>
</tbody>
</table>

1 For more on Interface Carpet visit http://www.interfaceflor.com/
Beginning

Defining

Analyzing

Observing

Selecting

Implementing

Evaluating

Progressing

Made in America from recycled aluminum, the WineHive is an eco-friendly honeycomb wine rack, with infinite add-on capability. It was designed by John Paulick in Philadelphia, PA. The WineHive is made with just a single part, that repeats itself to form an infinite array of honeycomb structures. It can be customized to fit anyone’s growing wine bottle collection. The WineHive pack consists of 12 parts. It can form a 5 bottle wine rack or combine with other packs to form larger configurations. The more packs you have, the more configurations you can make.

Paulick recently graduated from Biomimicry 3.8’s Biomimicry Specialist Certification Program said that he was inspired by fractal honeycomb patterns found in nature.

http://www.kickstarter.com/projects/999bottles

The 999 Bottle is not just another water bottle. It is a beautifully designed system that helps you track and visualize the positive impact you can have on the environment by drinking from re-usable bottles instead of disposable ones. The stainless steel bottle features a clever three numbered dial along its length to help you track how many times you re-use it. Each time you refill, simply advance the dial one notch. The numbers steadily add up!

An accompanying iPhone app tells you what the numbers mean, giving context to your conservation through insightful visuals that graphically depict and share the impact of your efforts. The app also allows you to join forces with your friends and track your combined impact. Most people understand and agree that disposable water bottles are expensive, a very inefficient use of resources and harmful to the environment. But that understanding doesn’t necessarily translate into action. According to CNBC, Americans buy 51 billion bottles of water a year, and recycle less than one quarter of them. The remaining bottles end up in a landfill or as litter jeopardizing wild life and creating unforeseen consequences to human health and the environment.

http://www.artefactgroup.com/
Mimicry is perhaps the oldest and most efficient method for achieving major advances in design.

WILLIAM LIDWELL
PATTERNS & SURFACE MIMICRY

Animal Camouflage
In talking about basic communication patterns and techniques, nature uses mimicry as its form and technique when it comes to particular pattern making and design. As mentioned before when discussing the Universal Design Principles and Elements, mimicry is the act of copying properties of familiar objects, organisms, or environments in order to realize specific benefits afforded by those properties. In nature, mimicry refers to the copying of certain properties to hide from or deter other organisms. \(^4\) This is where animal camouflage, or surface mimicry, plays a significant role in evolution and survival of the fittest. However, camouflage is not strictly about chameleons changing the color of their skin in an instant; it’s also about polar bears being white and not brown like grizzlies. In order to understand animals with this ability of mastering the art of deception, it is important to know why animals have this cunning ability. A major concern of animals is to protect themselves from predators in order to survive, reproduce and pass off their genes to a future generation. Many animals have evolved adaptations known as ‘anti-predator devices’ and use camouflage to blend in with their natural environments and patterns in an attempt to be unrecognizable by predators. However, there are exceptions: animals which are dangerous to eat (i.e. wasps) advertise with warning coloration. Animal camouflage can relate to design in the sense that mimicry refers to copying properties of familiar objects, organisms or environments in order to improve the usability, likeability, or functionality of an object. Design and nature create with three forms of mimicry in mind: surface, behavioral, and functional. Surface mimicry (camouflage) is making a design look like something else; Behavioral mimicry is defined as making a design act like something else; and Functional mimicry is defined as making a design work like something else.
FRACTALS & SIERPINSKI TRIANGLE

Natural Algorithms
Fractal, by definition, means a curve or geometric figure, each part of which has the same statistical character as the whole. Fractals are useful in modeling structures (such as eroded coastlines or snowflakes) in which similar patterns recur at progressively smaller scales, and in describing partly random or chaotic phenomena such as crystal growth, fluid turbulence, and galaxy formation. Fractals have a number of characteristic properties, and some of the best known examples of fractals possess the intriguing feature of self-similarity which is usually the result of a basic, natural algorithm process called recursion. Recursion occurs when a system receives input, modifies it slightly, and then feeds the output back into the system as input. Fractals exhibiting self-similarity and recursion show the same structure on all scales.

The term ‘fractal’ was first used by mathematician Benoît Mandelbrot in 1975. Mandelbrot based it on the Latin frãctus meaning ‘broken’ or ‘fractured,’ and used it to extend the concept of theoretical fractional dimensions to geometric patterns in nature.

However, before Mandelbrot coined the term ‘fractal,’ there was an earlier Polish mathematician by the name of Waclaw Sierpinski that was studying fractal patterns, just in a different manner and by a different name. In 1915, Sierpinski published the first set of pictures of what is now known as the Sierpinski triangle. The Sierpinski triangle is composed of three smaller triangles, each of which is just a copy of the original Sierpinski triangle.

What Sierpinski was trying to illustrate was that this process may be repeated ad infinitum: each of the smaller triangles consists of three scaled down copies of itself. If you look closely, you will see that any one of the smaller triangles in the Sierpinski triangle is the original triangle. One of the remarkable features of fractals, like the Sierpinski triangle, is that they can often be produced using very simple instructions or algorithms. The novelty of these instructions is that they are based on choosing a sequence of random numbers.

A random iteration algorithm for obtaining arbitrarily close approximations to the Sierpinski triangle is as follows:

1. Begin by choosing an equilateral triangle in a plane
2. Label the vertices A, B, C and pick a point inside the triangle (outside will work as well– the end result is just the same)
3. Now randomly choose one of A, B, or C. If say B is chosen, move the point halfway to vertex B, and mark the point. Similarly, if A is chosen, move the point halfway to A, and the same for C.
4. Now, repeat the process to obtain a sequence of points that can be plotted

Put simply:
1. Begin by choosing an equilateral triangle in a plane
2. Shrink the triangle to ½ height and ½ width, make three copies, and position the three shrunken triangles so that each triangle touches the two other triangles at a corner
3. Repeat step 2 with each of the smaller triangles

The actual fractal is what would be obtained after an infinite number of iterations.
The algorithm for constructing the Sierpinski triangle was based on fixing an equilateral triangle or, more precisely, fixing the vertices of that triangle. It is natural to modify the algorithm a little by replacing the triangle with a square or indeed by any one of the regular polygons. For instance, suppose we had initially chosen a regular pentagon in the plane. After choosing an initial point inside of it, you could have defined the algorithm by making random choices of vertices and at each stage of the iteration, move halfway towards the vertex. Thus creating the algorithm and fractal pattern, which are both found naturally recurring throughout nature.

The purpose of showing fractal patterning and the Sierpinski triangle is to demonstrate that patterns and design systems within nature do not occur unmethodically over time, but due to the naturally occurring algorithms. The ubiquity of self-similarity in nature hints at this underlying order and algorithm, and suggests ways to enhance the aesthetic composition of human-created forms and perhaps their structural composition as well.

Relating this back to the earlier discussion of the surface mimicry of animals, if you take a close look at the hide, skin, or texturing patterns of animals, you will find that it is a structured, well thought-out pattern based upon a logical grid system and fractally organized algorithms. One of the best known and most beautiful system of patterning seen in nature is the hexagonal conformations most notoriously connected with the honey bee’s cell. The hexagonal symmetry in plants and animals “doth neatly declare how nature Geometrizeth and observeth order in all things.”

---

8 Michael Field and Martin Golubitsky, Symmetry in Chaos: A Search for Pattern in Mathematics, Art and Nature

9 D’Arcy Wentworth Thompson, On Growth and Form
GRAPHICAL SOLUTIONS

Tessellation Patterns
The word "tessellation" means to fit or join polygons into flat, continuous patterns. A tessellation pattern is created by joining three or more sides of a set of polygons. The point where the sides meet is called a vertex; the sum of the angles around a vertex equals 360°. Regular tessellations are created by combining regular, congruent polygons in a uniform manner. The only three regular, congruent polygons that can possibly be used in regular tessellations are the triangle, the square, and the hexagon; sometimes pentagon because only they have interior angles that divide evenly into 360°.

A semi-regular tessellation is uniform and consists of more than one type of regular polygon. There are uniform/uniform and periodic/non-periodic tessellations. In a uniform tessellation all vertices are congruent and the organization of polygons around each vertex is the same. In a periodic tessellation a group of regular polygons can be moved to a new position within the tessellation, where it will fit together exactly with a similar group of regular polygons. The hexagonal honey bee cell is one of the best known tessellation patterns and the interest here is looking into how using these joined or fit polygons can create a continuous, unique pattern design, similar to mosaic tiling, and how they can relate to the surface mimicry of animals and fractals. They all share similar methodologies and principles: the use of symmetry, the Sierpinski triangle, and the concept of implementing natural algorithms and self-similarity that occur within nature. It is organizing fractally, while also optimizing the amount of materials needed to create these patterns.

Tessellation Grid Patterns

To the right are 7 tessellation patterns designed and inspired by surface mimicry, animal camouflage, fractal patterning, the Sierpinski triangle and natural algorithms.
Graphical Solutions, Pattern Design

To make these pattern designs, the biomimetic design process was used. The first stage began with defining the problem: What would Nature do? How would nature create these specific patterns and in what context? How would it utilize form within function? After asking these questions and going through the appropriate stages of defining, analyzing, and observing, the selection of which animals to emulate was the next step. The animal skins and camouflaging/surface mimicry techniques that were chosen were the giraffe, leopard, chameleon, iguana, tortoise, monarch butterfly, and cephalopod (Blue-ringed Octopus). After the animals were chosen, the implementation stage of the process could now begin, which is where images of the same hue and mimicry patterns were chosen to be repeatedly placed beneath each polygon. The images seen looking through each polygon act as a window, showing various color hues, changes and patterns similar to those seen on the animal’s transformed-camouflaged skin. In evaluating the designs, it is apparent that by using the tessellation and fractal techniques, taking either a singular polygon or multiple, different polygons and repeating them throughout at differing scales, was successful in creating individual grid-like patterns. The functioning aspect is in the form of deception to emulate the animal and disguise the form by creating shapes for specific pattern purposes. By incorporating the biomimetic + graphic design process, it is evident that these patterns are derived from nature through the use of polygon forms and images of nature, while also showing subtle hints of the geometric and mathematical side of design in creating grid systems. What is shown for each graphical solution is the final pattern design, the underlying mathematical and geometric grid system, as well as the natural inspiration and surface mimicry of the specific animal.

1 A good example of how nature would go about doing this is seen in the hexagonal honey bee cell.
Semi-Regular Non-Uniform Periodic Pattern using 2 polygonal shapes: hexagon and triangle | Leopard

Semi-Regular Non-Uniform Non-Periodic Pattern using 2 polygonal shapes: triangle and square | Chameleon
Regular Uniform Non-Periodic Pattern using the same triangular shape throughout at differing sizes | Iguana

Semi-Regular Non-Uniform Non-Periodic Pattern using 3 polygonal shapes: hexagon, triangle and rectangle | Tortoise
Semi-Regular Non-Uniform Periodic Pattern using 3 polygonal shapes: hexagon, triangle and square | Cephalopod

Regular Uniform Non-Periodic Pattern using the same rectangular/square shape throughout | Monarch Butterfly
CASE STUDIES

After learning the principles and techniques of surface mimicry, fractals and tessellation patterning, it is easier to understand when applied to an actual design scenario. The following packaging design case study clearly demonstrates the third stage of the biomimetic design process, observing.

VISUAL MIMICRY

Just as some flies mimic wasps to better ward off predators, off-brands can mimic well-known brands to appeal to a pre-targeted market.1 Many of these generic store brands have become pretty successful at mimicking the appearance and packaging of the dominant, flourishing, and popular name brand. The designers of the store brand use the time saved coming up with and testing the initial brand strategy for researching other biomimetic strategies.2 While designers still have to spend some time learning and imitating, they can stay current on trends when conditions change and can imitate the best designs, altering them ever so slightly.

To learn from past designs, designers can look through design magazines, blogs, and other materials that relate to their specialty. Just as organisms adapt to what works to keep them alive through the process of evolution, graphic designers, through trial and error, learn significantly from past mistakes and successes. Keep abreast of current design context shows how others are responding, or not responding, to these changes.

Another scenario is in looking at ‘fake’ spots on wildlife and the camouflaging tactics many use. Just as these attributes can misdirect or even attract prey by startling them into believing they are something resembling their predator, graphic design pieces can alert users to view specific elements of a design target first.3 Many direct mailers do this using bold typography or images clearly visible yet putting fine print at the bottom telling the whole truth. Users will easily learn the trick and a new design must be attempted. If the goal is sustained communication, endeavor to form designs that help foster cooperative relationships, not ones that fool the user.

1 Jessica Jones, DesignMomentum-Blog
2 Jessica Jones, Sustainable Graphic Design, Wendy Jedlicka
3 Jessica Jones, Sustainable Graphic Design, Wendy Jedlicka

http://designmomentum.wordpress.com/

This case study perfectly exemplifies some of Nature’s Design principles:
1 Evolve Solutions, Don’t Plan Them
2 Adapt to Changing Conditions
3 Foster Cooperative Relationships

This means forgoing authorship and accommodating to the times by creating design solutions that will be sustainable and better the end user and target audience.
Creativity can solve almost any problem. The creative act, the defeat of habit by originality, overcomes everything.

GEORGE LOIS

What Tools Would Nature Use?
The fourth stage in the biomimetic design process after observing is selecting. In context, this is all about the selection of tools and materials necessary to produce the final design solution. It is asking the questions, what tools would nature use? How would nature start the selection process? It is first necessary to look back at why our current consumption cycles began and how we can prevent the drought of the finite resources available. Since the industrial revolution began in the 1800s, the world has been on an unprecedented consumption binge. Since 1950 alone, the world’s people have consumed more goods and services than the combined total of all humans who ever walked the planet. Nature would never let this happen and cannot afford to.
LIFE-FRIENDLY MATERIALS

Reducing our Carbon Footprint
As a result, nature’s first trick of the trade is that nature manufactures its materials under life-friendly conditions—in water, at room temperature, without harsh chemicals or high pressures. As we would call ‘limits’, nature manages to craft materials of a complexity and a functionality that we can only envy. Nature has the innate capability to customize materials through the use of templates. Whereas we muddle by in our industrial chemistry with final products that are a mishmash of polymer-chain sizes, with most too long or too short to be of ideal use, nature makes only what she wants where she wants and when she wants. There is no waste on the cutting-room floor. As designers, we are one step ahead in the right direction, using templates and grid systems in our designs to effectively and efficiently use the resources available to us. However, society as a whole tends to maximize when they perceive there is an inexpensive abundance of materials readily available to them. Yet, the Earth has limits and boundaries, and there is a finite amount of resources at our disposal. It is important to see the entire system and become aware of costs to others when designing or choosing supplies. In terms of choosing supplies, we’ve seen that, in theory, picking an eco-material is a better move than picking an un-eco one. But if a designer doesn’t know why a material is eco, how to implement it correctly, or even if it actually is ‘eco’, taking a typically shallow replacement approach can end up with impacts far worse than the things being replaced. This is where possessing the knowledge and skills of how to effectively select the right tools and materials is crucial. Relying on the sixth design principle of nature, self-appropriate technologies, will help to do so. As graphic designers, even though we can’t directly change how paper is manufactured, we can voice our concerns, suggest alternatives, and hope that people upstream and downstream catch hold of and implement our ideas. Today, we assume that the way we’re doing it is the best way, but it might not be.
The fatal flaw of technologic and human thinking, especially in the years since WWII and the industrial revolution is that modern technology is a two-legged stool. “Our science was well founded in physics and chemistry, but flawed by a missing third leg—the biology of the environment.”10 It is crucial that society and modern industries today recognize and understand our routine of over consumption and how it is detrimental for future generations. David Tilford in his article, “Sustainable Consumption: Why consumption matters” explains in the simplest way how we are over-consuming goods and services and negatively impacting natural ecosystems:

Our cars, houses, hamburgers, televisions, sneakers, newspapers and thousands upon thousands of other consumer items come to us via chains of production that stretch around the globe. Along the length of this chain we pull raw materials from the Earth in numbers that are too big to even conceptualize. Tremendous volumes of natural resources are displaced and ecosystems disrupted in the uncounted extraction processes that fuel modern human existence. Constructing highways or buildings, mining for gold, drilling for oil, harvesting crops and forest products all involve reshaping natural landscapes. Some of our activities involve minor changes to the landscape. Sometimes entire mountains are moved.11

Recognizing that we need to reduce our ecological and carbon footprint is the initial step towards a more sustainable future. An ecological or carbon footprint is defined as the amount of productive land area required to sustain one human being.12 As most of our planet’s surface is either under water, there are only 1.9 hectares (about four football fields) of productive area to support each person today (grow food, supply materials, clean our waste). That might sound like a lot but our collective ecological footprint is already 2.3 hectares. This means that, given the needs of today’s human population, we already need 1.5 Earths to live sustainably. But this assumes all resources are divided equally. Those with the largest carbon footprint— the biggest consumers of global resources—are US citizens, who require 9.57 hectares each to meet their demands.13 If everyone in the world consumed at that rate, 5 Earths would be needed to sustain the population. People in Bangladesh, in contrast, need just 0.5 hectares; for people in China today, the footprint is 1.36 hectares.14 Part of why the US carbon footprint is so large has to do with trade access to more than the country’s balance of natural capital. Much of this natural capital comes from countries that have some resources but not much else from which to earn cash.15 Due to corruption, or desperation, many of these countries are selling off their resources quickly, regardless of the long-term consequences. After six months, 99% of the resources to make things we use is converted to waste— disposed of as finished goods, but mostly as process waste.16

The main point to understand about the selection of tools and materials within the biomimetic design process is that whatever is naturally here is all we have. Whatever humans make does not go ‘away.’ We need to eliminate the concept of waste which means to design things— products, packaging and systems— from the very beginning on the understanding that waste does not exist.17 Nature has relied on this mind-set and because of that, has flourished on this planet for billions of years. Yet, this may not be the case in the near future if we continue our bad habits. Ways to shift these bad habits towards good ones would be to constantly ask yourself these fundamental questions: Does it make us or the planet sick? (Don’t do it!) Are you picking your material because it’s the best one for your application or the same as it’s always done before/your competitor is using it? Can we be happy without having more and more stuff?

10 David Wann, Biologic: Designing with Nature to Protect the Environment
11 Dave Tilford, Sustainable Consumption: Why Consumption Matters
12 Wendy Jedlicka, Sustainable Graphic Design
13 Statistical data from www.footprintnetwork.org
14 Wendy Jedlicka, Sustainable Graphic Design
16 William McDonough & Michael Braungart, Cradle to Cradle: Get certified! www.100percentwell.com Cradle to Cradle certification provides comparison with the means to tangible and credible material achievement in environmentally intelligent design and design for material邠ities such as recycling
The following biomimetic design case studies clearly demonstrate how in self-appropriating technologies and selecting efficient materials and resources, you can still achieve quality designs that are sustainable, as well as conducive to life.

1 Celery Design Collaborative, www.celerydesign.com
2 Jessica Jones, DesignMomentum blog

### CASE STUDIES

#### CELERY DIVIDER TABS

Celery Design Collaborative seeks out beautiful and innovative ways to make things. The more interesting the challenge for them is to use design as a means of effecting change. So, they took on the design challenge to try and come up with a simple solution to eliminate the waste created when a divider tab is cut out of a larger sheet of paper. And they did it. In the end, Celery designed a simple die-cut pattern where the tab can be folded out of the middle of the paper and placed through a slot to hold the tab in place. This consequently influences where a graphic designer places their designs and what message it communicates. This is a very good example of how nature would design using the principles of graphic design. These divider tabs also illustrate how graphic designers can have impact on an entire system. First, the designers had to recognize a status quo— they don’t have to work with pre-made divider tabs that create waste when manufactured. And then they need to take that thought and design challenge to come up with a successful solution.

#### CERTIFICATE CASING

Instead of buying a plastic diploma or certificate case off of the internet, Biomimicry 3.8 designed their own. This is the first prototype with even more potential to make it more life-friendly in the next iteration. As all designers know, there are time and resource constraints in which a project must be completed, so most projects will not be completely life-friendly the first go around. Biomimicry is inevitably iterative just as nature is constantly adapting and evolving.

This adopts the following design principles of nature:

6 Self Appropriate Technologies
7 Be Resourceful
8 Optimize Rather than Maximize
9 Foster Cooperative Relationships

The case doubles as a clip board and a mat for framing, and of course a protective casing for getting it back home. Biomimicry 3.8 didn’t want the end users to just stick it in their bookshelf (where most plastic diploma cases end up) but instead showcased on a wall. The graduates are part of a larger network and meme and by providing a pre-made mat this encourages them to frame it and remember this bigger idea. The clipboard also suggests continued learning and collaboration toward a greater goal. The laser cuts were also made on a personal laser cutting machine. Local connections are a leverage point for designers in cultivating cooperative relationships.

http://designmomentum.wordpress.com/
Perhaps in the end, it will not be a change in technology that will bring us to the biomimetic future, but a change of heart, a humbling that allows us to be attentive to nature’s lessons.

JANINE BENYUS

How Would Nature Delegate?
The fifth stage in the biomimetic design process after selecting the appropriate tools and materials, is implementing. It is here where the collaboration at the design table begins. BaDT’s, architects, designers, business men, CEO’s all come together. Using the language of change, businesses are now asking what natural capital is and how it is spent. What economic lessons can be drawn from nature? How do market forces shape the way we live, work, and play? How can we nurture the corporate green thumb? Today’s leaders understand the interplay between governments and people, stockholders and stakeholders, humans and the environment and how all things interconnect and direct how and what we need to create.1

1 Wendy Jedlicka, Sustainable Graphic Design
BIOMIMICRY + CORPORATIONS

Network & Facilitate
Bringing biomimicry into every corporation around the world is a dream for biomimetic designers. In doing that, it would enable for more interdisciplinary team work where biologists would work with architects, designers, and CEO’s, ultimately cultivating and fostering cooperative relationships around the globe. Today, business attitudes are already acting on this and implementing the biomimetic design process within their corporations. The reason biomimicry is such an important aspect to integrate within businesses and corporations and why this topic is being stressed is because of the power and ability these corporations have and hold in changing the mind-set of their consumers; which in turn has the power to generate change and the mind-set of society in general. In an interview Janine Benyus, she explains why biomimicry now is so vital and why it is the key to bettering our future: We humans are at a turning point in our evolution. Though we began as a small population in a very large world, we have expanded in number and territory until we are now bursting at the seams. There are too many of us, and our habits are unsustainable. Having reached the limits of nature’s tolerance, we are finally seeking for answers to the question: “How can we live on this home planet without destroying it?” Just as we are beginning to recognize all there is to learn from the natural world, our models are starting to blink out—not just a few scattered organisms, but entire ecosystems. A new survey by the National Biological Service found that one-half of all native ecosystems in the United States are degraded to the point of endangerment. That makes biomimicry more than just a new way of viewing and valuing nature. It’s also a race to the rescue.1

So, in order to act on this biomimetic design process in hopes for bettering the future, what is need is a shift in mind-set, including a shift in the way we live and work within businesses. Many innovators are starting to grasp this concept. One of them being, Michael Pawlyn, a world renowned architect, who established the architecture firm Exploration in 2007 to focus on environmentally sustainable projects that take their inspiration from nature and biomimicry.2 He recently published a book, Biomimicry in Architecture, that not only gives examples of where biomimicry has been used in corporations, but also answers some of the issues that naysayers raise.3 Pawlyn argues that a lot of the technology needed to make this integration of biomimicry within corporations happen is already available. In the book, he points to George Chan’s sorghum brewery in Tsumeb, Namibia, which was built to deliver ‘good beer, no pollution, more sales and more jobs.’4 Pawlyn enthuses:

For me, biomimicry is just one of the best sources of innovation to get to a world of zero waste because those are the rules under which biological life has had to exist. And it hasn’t just existed in a really miserable, self-denying way, but in a celebrated, abundant and regenerative way. I think we need to move to a far more positive way of talking about the future. A lot of sustainable design has got very stuck in very familiar solutions and even familiar materials and forms, and so there’s so much more to it. If you look beyond the nice shapes in nature and understand the principles behind them, you can find some adaptations that can lead to new innovative solutions that are radically more resource efficient. It’s the direction we need to take in the coming decades.5

1 For more information about Michael Pawlyn and his work with Exploration, go to http://www.exploration-architecture.com
2 Katie Scott, Biomimicry in Architecture and the Start of the Ecological Age, 2012/2013 http://www.wired.co.uk
3 Katie Scott, Biomimicry in Architecture and the Start of the Ecological Age
4 Katie Scott, Biomimicry in Architecture and the Start of the Ecological Age
5 Katie Scott, Biomimicry in Architecture and the Start of the Ecological Age

1 For the full interview with Janine Benyus, go to http://www.biomimicryguild.com/janineinterview.html

2 For the full interview with Janine Benyus, go to http://www.biomimicryguild.com/janineinterview.html

1 For the full interview with Janine Benyus, go to http://www.biomimicryguild.com/janineinterview.html
CREATIVE SESSIONS

Cross-Disciplinary Design Tables
Ultimately, Graves was impressed with the way biomimicry reframed their internal issues. “Biomimicry is a great tool to integrate into the design process of an innovative company or organization,” he says. “We saw it as a way to have a different lens on challenges we have been working on for some time.”

The second challenge focused on Smart Design’s ideas for cities to conserve water as part of IBM’s SmarterCity initiative. IBM itself is no stranger to a biomimetic approach, says Ian Abbott-Donnelly of IBM Big Green Innovations, pointing to a recent computer chip using the same self-assembling nanotechnology that builds snowflakes and seashells. But the fact that Smart Design was able to examine biomimicry at city-scale, using larger principles based on an ecosystem’s feedback loops, proved that biomimicry can work for their initiative working at the civic level. “This work gives some well thought-out stories of how to apply biomimicry to cities which can easily be discussed with teams operating in cities,” he says. “I am hoping that this new thinking will enable cities to explore and implement solutions which have the right insight to be effective.”

The Biomimicry Guild is currently working on a concept called the Biomimicry Innovation Process, which can help take the process from this charrette point into conception and marketplace in the most sustainable way. Bringing business and biomimicry closer together will be due to the variety of participants in the Biomimicry Professional Certification program, an intensive biomimicry training program. The latest round of graduates in the two-year program included biologists, engineers, designers and even four people with business backgrounds and it’s that kind of diversity and cross-disciplinary approach that will ensure that biomimicry can be embraced by various walks of life.

One of the largest, contributing factors when integrating biomimicry into corporations is the use of cross-disciplinary design tables during creative brainstorming sessions. This is where innovators and professionals from all fields come together and sit down to discuss the potential biomimicry has in helping their businesses and corporations thrive in the marketplace and co-exist with the surrounding eco-systems. Two major design companies, IDEO and Smart Design put biomimicry and BaDT’s (Biologists at the Design Table) to the test, tackling design problems for real-world clients alongside biologists from the Biomimicry Institute. The magazine, Fast Company, posted the following case studies and wanted to do a follow up check in with both IDEO and Smart Design to see if they thought biomimicry as a new tool could help advance their businesses. Below is a section of the article from fastcompany.com, shown to best illustrate what the companies thought of the entire process:

Richard Graves, vice president of the community for the U.S. Green Building Council, said he was skeptical at first that having IDEO take a biomimetic approach to redesigning their organizational structure and if it would prove useful beyond just theory. “To be honest, I was not sure how much we would get that would be usable, but I see many ideas that can be explored and developed,” he says. “I was surprised at how many of the ideas seem very practical and implementable.” One particular solution that stood out to him was an idea to signal the health of USGBC chapters that was inspired by a pink flamingo: The ‘health’ of the flamingo— or how much shrimp it eats—is outwardly reflected in the shade of pink of its feathers. “Having a simple, clear characteristic that reflects the health of an organization would be very useful in the chaotic world we live in,” he says. “How to achieve this?”

1 See the Case Studies section at the end of this chapter for further information on these companies and their biomimetic process and approach towards design problems.

2 For the full article, go to http://www.fastcodesign.com/1661865/could-biomimicry-build-a-better-company-than-your-boss

3 For more information about applying for the Biomimicry Professional Certification Program, go to http://www.biomimicry.net/ProfessionalPathways/certification.html
Below are the two case studies with IDEO & the USGBC, as well as Smart Design’s IBM SmarterCity Initiative, that were previously mentioned. Both show how by incorporating the biomimetic design process within your own corporation’s creative sessions can lead to new, innovative ideas and design solutions.

**IDEO & THE USGBC**

The United States Green Building Council (USGBC), most notably founded the LEED certification system that rates structures by sustainability. With 80 local chapters nationwide, they struggle with challenges like making group decisions and the ability to keep members motivated and involved.

The USGBC wanted to investigate redesigning their organization in a way that was more closely aligned with their mission to protect and celebrate nature. In their words, they wanted to be more ‘resilient and organic’ in how their organization communicates with stakeholders. 

IDEO’s Boston office took on this hefty problem from the USGBC, which would essentially require a system-wide redesign for the way that their members communicate. Yet after interviewing USGBC stakeholders, IDEO’s team reframed the statement to broaden the focus to the organization’s structure itself and how different parties would connect within it, including the tools that would help make these connections.

The reframed challenge became to ‘design an organization strategy to improve the effectiveness of a locally distributed effort, while staying aligned to the national USGBC mission.’ A biomimetic approach was particularly intriguing to the IDEO team because the firm is so well known for their human-centered design process. But instead of dismissing their own approach for a strict biomimicry approach, the IDEO team and their assigned biologist at the design table (BaDT) Tim McGee had a better idea. Working with IDEO’s project lead, designer Eleanor Morgan, McGee weaved biomimicry into IDEO’s human-centered approach, resulting in a ‘mash-up’ that incorporated biomimicry thinking into IDEO’s existing design pathways.

The result was almost paradoxical, says creative director Jane Fulton Suri. "We were really happy just to go along with their process and throw ours out the window," she says. "But in talking with Tim it was clear we'd all benefit from learning about how these two processes could effectively meld together."

McGee thinks the hybrid approach revealed some insight into the Biomimicry Guild’s process. “I think IDEO’s outstanding insights into human centered design can actually help define and drive what it means to do biomimicry,” he says, “because at the center of our relationship with nature is ourselves.” For IDEO, the challenge gave the team a new set of tools they hope to apply to future projects. "It really does feel like an amazing untapped resource,” agreed Fulton Suri. They also realized how biomimicry in general could be a part of their own mission to create positive impact, says Morgan. “If we could distribute these BaDTs around the world we could be in a better place.”
SMART DESIGN & IBM’S SMARTERCITY INITIATIVE

IBM’s SmarterCity initiative is a program that uses the company’s information technology to help municipal governments create healthier, more intelligent urban environments for their residents.1 Using their ability to collect and analyze data, IBM is able to provide information about elements of daily city life ranging from weather and traffic to water usage and air quality. But what they’ve done with that data has largely been used to make policy and economic decisions. IBM asked how they could use nature to understand how these overlays of information could help guide residents toward making better personal decisions for the good of the city. A New York-based team at Smart Design accepted this challenge.

After having a discussion with IBM, and walking through some day-in-the-life exercises that explored issues facing urban dwellers, Smart Design chose to focus on water conservation. Because of the complexity surrounding its systems, water is often misunderstood, says Tucker Fort, Smart’s director of industrial design. “But unlike something like energy, it’s a finite resource.” Water was also something that residents interacted with everyday, and since IBM’s goal was to make cities more responsive and resilient, using a biomimetic approach for encouraging more responsible water usage could have a real impact when implemented across an entire municipal area. Smart zeroed in on urban water consumption to explore how nature could inspire relevant, everyday solutions for city inhabitants to conserve water.

To immerse themselves in a biomimetic mindset, Fort, along with director of interaction design Ted Booth, and their team were introduced to the emerging discipline of biomimicry by their BaDT (biologist at the design table) Mark Dorfman. After a biomimicry primer, the team engaged in a blindfolded exercise where they were encouraged to smell, taste, touch, and listen to nature—anything that would break them of their reliance on vision. This is something Dorfman calls “quieting our cleverness.” “If I were to show you a pine cone, you would see it and immediately know what it is, and that might be the end of your curiosity and exploration,” says Dorfman. “But if you’re blindfolded and handed a pine cone, you’ll have to explore its shape, texture, small, before figuring out what it is.”

The hope is that this process will open the designer’s mind to viewing living things through a functional lens—a way that is particularly relevant to solving design challenges. Examining this representation of nature’s complex systems, the designers realized that their solution would not come directly from an organism, but from this entire system as a whole: These core principles for life could work as a metaphor for a city, inspiring and informing solutions to make a healthier and smarter environment. For this solution, it also helped them to realize a simple truth: That some of the world’s largest challenges will be overcome by changing the behavior of each individual within a larger system. “The modern city is just like an ecosystem,” says Fort. “It seems so obvious, but if you just go right below the surface, there are all these inspirations and connections that are so meaningful.”

http://www.fastcompany.com/
How Would Nature Assess?

The last stage in the biomimetic design process after implementing the solution, is evaluating. This is the point where a designer should step back and really assess the final design solution, asking incremental questions such as: Are the 14 design principles of nature evident and appropriately used? Did I understand and implement the solution to its fullest potential? In asking these questions, it is therefore, very important that designers understand and realize how we, humans, process information visually. There is a psychology and depth of processing involved within the change of the biomimetic mind-set; changes in which we evaluate nature, how we design and ultimately, how we live our day-to-day.

We must be the change we wish to see in the world.

MAHATMA GANDHI
THE BIOMIMETIC MIND-SET

Psychology of Processing
Throughout this book, the focus has been on the design methods and theories that encompass the biomimicry + graphic design process. The focus now is on the biomimetic mind-set, which is equally just as important. In order to understand the previous stages of the process, it is crucial designers know how individuals process information. Likewise, in order for an individual to understand a design solution based off the biomimetic design process, they need to know the ‘biomimetic’ thinking behind the designer. Otherwise, they may think that any biomimetic design is ‘just a form mimicking a natural form’, which is superficial thinking. It is much more involved. There needs to be an evaluation of the final design solution, as well as an evaluation of how we consume, teach, live, spend, work, play, and design. Are we doing all of these things in the manner that is the most conducive to life here on this planet? How would nature assess our daily habits? In applying the biomimetic mind-set, it opens up the possibility to make the necessary changes to live sustainably.

With that being said, in order to change your mind-set, perception, and outlook, you need to expand the possibilities and your creativity. This is the beauty of integrating biomimicry and nature’s design principles within graphic design; coming up with ideas or solutions that you may have never stumbled upon otherwise. In order to expand your creativity, you need to affirm your own individual creativity. Although many facets of human creativity are similar, they are never identical. All pine trees are very much alike, yet none is exactly the same as the other.1 This is the benefit of having BaDT, combining creative minds of all types and backgrounds to create a unique design solution.

Along with expanding possibilities and creativity, focus is also key. All too often we are bombarded with information; an information tidal wave of sorts. Due to our minds processing techniques and abilities, ordinarily we do not make the fullest use of our ability to see. We move through life looking at a tremendous quantity of information, objects, and scenes, and yet we look but do not see.2 However, before you start looking for ideas, you need to know what you’re looking for and what your goal is.3 The important step to take next is to set the problem or design challenge down in writing. Since our attention is constantly shifting, you may become indecisive about what, if anything, you should focus on. Psychologists have demonstrated that we are able to keep only about five – nine pieces of information in our mind at a time.4 Therefore, keeping sketches and thoughts down is essential in order to ‘bake’ them into your shared consciousness. As designers, we rely heavily on the possibility system. Moving ahead with our ideas and information we gathered to create hypotheses and visions. These give us the framework through which to look at things (nature) and also something to work towards (biomimetic design solution). Therefore, our perception is the most important part of our thinking...how we look at the world, what things we take into account and, ultimately, how we structure our world.

Perception works as a self-organizing information system, just as within nature, building on the smaller parts and creating larger sub-systems. Such systems allow the sequence in which information arrives to set up patterns; these patterns being the environments in which we encounter and organize to create recognizable systems for processing information. There is a life cycle with which we process.5 As designers, it is pivotal we know this to understand how our viewer is perceiving our design solutions. The more we accept responsibility and dedicate ourselves to generating ideas found within nature, the higher the probability of reaching an innovative solution. Thinking is the ultimate human resource. The quality of our future will depend entirely on the quality of our thinking and of our mind-set.
Many organizations are beginning to adopt the biomimetic mind-set within their creative processes, understanding the implications it has on people's ability to process information in an easier and more efficient manner. One organization, in particular, has strived to do this since its origin. With a call-to-action, in July of 2007, dubbed the Kyoto Treaty for design, the Designers Accord was founded as a global coalition of designers, educators, and corporate leaders, working together to create positive environmental and social impact.1 Since then, the Designers Accord has become one of the fastest moving and most influential organizations within the creative community: It has been adopted by over 170,000 members, representing each design discipline.

In 2008, Fast Company wrote that it is "on a path to change the culture of the creative community from bottom to top, and with it, the way everything is made."

Creatives from all over the globe are working to integrate the principles of sustainability into all aspects of design: from education, to practice and production, and ultimately consumption. They are catalyzing new thinking by collectively building our intelligence around issues of climate change and social justice, and tackling those challenges with optimism and creativity.

The Designers Accord provides access to a community of peers that share methodologies, resources, and experiences around environmental and social issues in design. This encapsulates the unifying philosophy of the Designers Accord: open source. They advocate inverting the traditional model of competition, and encourage sharing the best practices so everyone can innovate more efficiently, quickly and effectively. This relates to the third design principle of nature: Evolve Solutions, Don’t Plan Them. This means design without authorship and letting go with dignity, allowing for open source.

http://www.designersaccord.org/
PROGRESSING

The Future of Biomimetic Design
At this point in history, as we contemplate the very real possibility of losing a quarter of all species in the next thirty years, biomimicry becomes more than just a new way of looking at nature. It becomes a race and a rescue. Here at the beginning of the twenty first century, environmental reality is setting in, pushing us to find saner and more sustainable ways to live on Earth. Equally important is what is pulling us towards biomimicry— that is, our deepening knowledge of how the natural world works.

Biological knowledge is doubling every five years, growing like a pointillist painting toward a recognizable whole. For the first time in history, we have the instruments— the scopes and satellites— to feel the shiver of a neuron in thought or watch in color as a star is born. When we combine this intensified gaze with the sheer amount of scientific knowledge coming into focus, we suddenly have the capacity to mimic nature like never before.1

Janine Benyus

As aspiring designers, we must continue to push the envelope well past just sustainable and green graphic design and think with the biomimetic mind-set and attitude, ultimately practicing with greater holistic awareness. There needs to be a basic, mutual understanding by all designers and creatives alike, that by putting biological systems and nature’s design principles into modern design practices results in ground-breaking, innovative design solutions. This biomimetic design process has the potential, if implemented correctly, to create and revolutionize an entirely new market of technological devices and designs that are unparalleled of those seen today.

It is incremental that designers apply what they learn from nature and this biomimicry + graphic design process documenting their expansive, growing portfolios with their intellectual property and findings within their own process. There also must be an eagerness and willingness among designers to collaborate with other innovators of different disciplines. One can only hope that corporations and businesses will demand there be BaDT’s present at every cross-disciplinary design table in the near future. Nature teaches us the virtues of flexibility. Leaves, large algae, and feathers show us how to economize on material, how to change shape as environmental forces change, how to enlist the environmental forces themselves to produce those changes.2 It would be irresponsible of us if we do not choose to listen and learn from nature’s time tested ideals since it is there where we will find the answers to the problems we are currently grappling with today.

In regards to biomimicry moving forward within educational institutions for future generations to learn about the power of biomimicry + design, Benyus is most certain that Biomimetic design labs are going to start appearing in schools very soon. “The future is that biologists will have a seat at the design table. But it starts with education and then trickles out to the workplace. Looking back, we had human factors, and now that’s commonplace in a design conversation. I’m optimistic biomimicry will enjoy the same consideration in the coming years.”3 It is a very exciting time as biomimicry continues to gain mainstream acceptance, with institutions and collaborations blossoming. The design industry and the planet need biomimicry integrated into the design process and it’s going to take positive, hopeful, eager and willing designer’s to act on it. As Benyus says, “the design challenge of our century is we need a way to remind ourselves of those geniuses and to somehow meet them again.”

1 Janine Benyus, interview http://www.biomimicryguild.com/janineinterview.html
2 Steven Vogel, Cats’ Paws & Catapults
3 Read more about Janine’s thoughts on biomimicry and education at http://www.fastcompany.com/1710686/evolve-nature-baking-biomimicry-ca

157
## COLOPHON

### DESIGN
Margaret McKosky

### TYPOGRAPHY
- Univers LT Std
- Light, Bold, Condensed, Bold Condensed
- Memphis LT Std
- Medium

### PRINTING

### PAPER
- Pages: Mohawk Fine Paper, 80# Standard Paper
- Endsheets: ProLine Light Grey
- Linen: ProLine Oatmeal Linen (made of 100% renewable cotton, never bleached, coated or dyed)

---

### GRAPHIC DESIGN + BIOMIMICRY
Final Print Application

School of Design
College of Imaging Arts and Sciences
Rochester Institute of Technology