SHARING BIOMIMICRY WITH YOUNG PEOPLE
An Orientation for K-12 Teachers
Welcome to the wonderful world of biomimicry in education!

We are so pleased you have chosen to share this fascinating topic with your students. They will love it. (And you will, too!)

This document was created by the Biomimicry Institute to help K-12 educators like you establish a general foundation in biomimicry and provide ideas for introducing this new way of thinking and problem solving to your students. We begin with a general introduction to the “what” and “why” of biomimicry, along with some ideas for how to fit biomimicry into your education program. The Core Concepts section that follows the introduction provides added depth in key areas and offers additional suggestions and resources for sharing these concepts with students of varying ages. Finally, an appendix at the back will guide you in connecting with other educators who are using biomimicry in their teaching.

If you have any questions or feedback related to this content, feel free to reach out to us at: info@biomimicry.org

From all of us at the Biomimicry Institute, thank you again, and enjoy!

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INTRODUCTION

At the Biomimicry Institute we want to equip the next generation to contend with our planet’s toughest sustainability issues with a new way of thinking and problem solving—biomimicry. We believe that biomimicry-based education is not only a great way to engage K-12 students with real-world lessons in STEM and environmental literacy, but perhaps most importantly, it offers kids tangible solutions and a hopeful vision for the future of our planet. In this Introduction we provide a definition of biomimicry, along with our ideas about why and how to fit biomimicry into your education program.
WHAT IS BIOMIMICRY?

Biomimicry is commonly defined as “innovation inspired by nature,” or the practice of applying lessons from nature to the invention of sustainable technologies for people.

Biomimicry practitioners (or “biomimics”) study the strategies used by living things to perform specific functions and apply what they learn to improve the design of products, processes, and systems. For example, looking to a leaf for ideas about how to make a better solar cell, or mimicking how a peacock feather selectively reflects light to produce beautiful colors without pigment. The core idea is that the rest of nature has had a 3.8 billion year head start on humans so, we’d be wise to tap into that vast trove of “research and development” when looking for the ideas we need to solve our design problems.

Janine Benyus, co-founder of the Biomimicry Institute, biologist, and author of Biomimicry: Innovation Inspired by Nature (the book that brought biomimicry into the public eye), has defined biomimicry as the “conscious emulation of life’s genius.” To break that down a bit, she means that biomimicry is an intentional practice of learning from (not just copying) living things, and appreciating the “genius” in how life has evolved countless well-adapted solutions that have stood the test of time, within the natural constraints of our planet.

That last point about “well-adapted solutions” is important to how Benyus and the Biomimicry Institute approach biomimicry. We are interested in more than simply making faster, stronger, or “better” things. Rather, through biomimicry, we see an important opportunity to apply lessons from nature to begin creating human technologies that are as sustainable (well adapted to Earth) as the living systems that surround us. Although it may be some time before we humans can power our cities entirely on sunlight or recycle all of our wastes as nature does, we can still use biomimicry as a pathway for improvement by asking, “How has nature solved this problem before?”

Learn About Biomimicry:
• “A Biomimicry Primer,” essay by Janine Benyus.
• Biomimicry, a 25 min film by Tree Media.
• Janine Benyus’ TED Talks
• Asking Nature, the Biomimicry Institute blog.
• Zygote Quarterly, a biomimicry journal edited by educators.
THE POWER OF BIOMIMICRY IN YOUTH EDUCATION

Biomimicry is a rich framework for teaching that can be used to address a wide range of topics in science, engineering, and environmental literacy – all with a hopeful message that encourages students to be positive agents for change in the world.

As the growing field of biomimicry attests, there are countless opportunities to learn from the natural world around us, and doing so may indeed be the key to a livable future on this planet. But to get there, today’s young people must learn not just how to live and succeed in a complex world made by other humans, but to see and appreciate the complexity of the natural world around us, and how we are interconnected with it.

We like to say that students should be able to “read” a tree as effortlessly as they’d read a book. That is, to see that a tree is not just a source of fuel, or wood to build a house, but also an amazing technology in its own right—one that stores energy from the sun, moves gallons of water a day without motorized pumps, creates materials out of carbon in the air, and provides countless ecosystem services. When we learn to see technology in nature this way, our eyes are opened to the sustainable world that already exists, embodied in the plants, animals, and other organisms all around us.

It’s this eye-opening quality and an accompanying sense of wonder that captivate students and make biomimicry such a powerful framework for teaching. The compelling narratives and fascinating natural phenomena behind biomimetic innovations provide a refreshing entry point into many of the core scientific subjects educators are already teaching. And because it’s an inherently interdisciplinary field, biomimicry...
bridges the boundaries between school subjects and connects them to the real world beyond classroom walls. Students get excited by biomimicry because it’s about much more than learning facts. Biomimicry is visionary! It’s about reimagining human-made technologies and redesigning the human-built world. In this way it taps into young people’s innate creativity and desire to shape their world, while enhancing problem-solving skills through design and project-based activities.

**Name:**
Oak (Quercus spp.)

**Leaves:**
Simple alternate, with irregularly rounded lobes

**Range:**
Broad, temperate to tropical

**Uses:**
Furniture, veneer

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When students learn to see technology in nature their eyes are opened to a sustainable world that already exists, embodied in the plants, animals, and other organisms all around us.
There are many ways to bring biomimicry into your teaching. How you decide to do so should be informed by your learning goals, how much time you have, and what your students are ready for. For example, your goal for sharing biomimicry with your students may be simply to make your students aware of it as one of the many ways nature is valuable and interesting to people. Or you might want to use examples from biomimicry as a compelling way to introduce core ideas in science, engineering, and technology. If you have time, you may also want to have your students practice design and engineering skills through nature-inspired projects or challenges. These are all valid goals that could be pursued together or separately.

We suggest that all efforts in biomimicry education, regardless of age, should also aim to impart to students a new way of viewing and valuing the natural world. Students should come away feeling and understanding that nature is full of ideas about how to solve our own challenges, and that they are empowered to address those challenges to improve the world.

There are at least two more factors you will want to consider when planning for age-appropriate biomimicry education: choosing...
an appropriate vocabulary and level of complexity for discussing the topic, and choosing biomimicry examples that your audience can relate to.

In all cases, we strongly recommend introducing a definition of biomimicry together with examples, as these are key to helping all learners understand the topic.

For younger students, you’ll want to use a simple definition that captures the essence of biomimicry without using confusing terms. (e.g. “Learning from nature how to make things better.”) Older students will be able to grasp terms that are more conceptually difficult (e.g. “emulation”), and this allows you to make finer distinctions—perhaps even contrasting biomimicry with other “bio” terms (See the Core Concepts section, “Biomimicry and bioinspired design,” for more).

You can apply a similar progression of complexity when it comes to examples of biomimicry. An example that is almost universally familiar to students is Velcro®. Even very young children who have used Velcro® can grasp how it is similar to the hooked barbs on burdock seeds.

In general, younger students will find it easier to understand examples that involve phenomena they have experienced or for which there is a clear visual resemblance between the inspiring organism and the biomimetic solution. It’s a good rule of thumb to start with this type of simple example even for older students, and then introduce increasingly complex examples to illustrate how biomimicry can also be applied in more abstract ways. (See Core Concepts section, “Matters of scale,” for more).

Sources for Examples:

- **AskNature** - Many examples of biomimicry can be gleaned from the growing library of “Inspired Ideas” and education resources on AskNature.
- **Mother of Invention** - The Wild Center compiled over two dozen biological strategies are in this slideshow, along with great photographs and examples of applications for each.
- **Bio-Inspired Design: Scientist Audio Programs** - The radio program Pulse of the Planet produced this collection of 28 two-minute segments featuring scientists talking about natural strategies and bio-inspired design.
CORE CONCEPTS & TEACHING STRATEGIES

There are a handful of core concepts that are helpful to understanding and practicing biomimicry. Here we provide an overview of these concepts with some suggestions and resources for effectively teaching them. You can find many more resources addressing these topics in the Resources section of AskNature.

Note: Resources hyperlinked in the text are available with full citations and URLs at the back of this document.
WE ARE PART OF NATURE

*Humans and our activities are dependent on and interconnected with other natural systems on Earth.*

A simple concept that underlies biomimicry is the understanding that humans are part of nature, and that we are dependent on and interconnected with natural systems just like all other living things. Although humans have developed a variety of cultural adaptations that camouflaged our kinship with the rest of life, the truth is our similarities far outweigh our differences.

This is the basis for why biomimicry makes sense: humans need to do many of the same things that other organisms do. For example, acquiring resources, making and breaking down materials, processing information, and reproducing. We are also subject to the same resource limitations and habitat conditions as the other 8.7 million species on Earth. The more we understand about how our planet-mates have leveraged the resources and constraints of this place, over billions of years, the better equipped we are to create technologies and systems that will enable all life to flourish long into the future.

But our relationship with nature has more than just practical value. In the U.S., children spend an average of seven hours a day on entertainment media, including televisions, computers, phones, and other electronic devices. This is time that previous generations of children were more likely to spend outside, being physically active, and getting to know nature. Without this experience, young people may lack appreciation and even basic knowledge of their natural surroundings. Biomimicry is an opportunity to reconnect children with nature, take the classroom outdoors, and mend this fractured relationship.
**Teaching Suggestions:**

- Take students outside and encourage their innate curiosity and affinity for nature.
- Incorporate sensory exploration into outdoor experiences. Ask students to close their eyes and notice what they can detect about their surroundings through hearing, touch, and scent. Can they tell where the sun is? Which way is the wind blowing?
- Prompt students to make observations about what humans have in common with other organisms rather than what makes us different.

**Resources:**

- **“Wild Nature Survivor Guy”** - This fun Sesame Street clip parodies reality TV programs and demonstrates how nature is all around us and we are nature, too.
- **You Are Stardust** - A picture book emphasizing the connections between all life, from the formation of the universe to the present. A companion lesson plan and app for K-6 students are also available.
- **Sharing Nature** - This book by Joseph Bharat Cornell is a classic in environmental education and contains many great nature observation activities.
- **We Are Not Alone** - This activity prompts students to consider the ways in which humans and other organisms solve the same technological challenges.
- **Exploring the Way Life Works**, by M. Hoagland and B. Dodson - The second chapter in this illustrated popular science book focuses on what all life has in common. *(Out of print, but used copies can still be found online.)*
FUNCTION AND STRATEGY

Function is an important conceptual bridge between biological strategies and potential design solutions.

In order for students to grasp and use biomimicry, they need to understand the concept of function as it relates to both biological strategies and design solutions. Function, by definition, is the purpose of something. In the context of biomimicry, function refers to the role played by an organism’s characteristics or behaviors that enable it to survive. Importantly, function can also refer to something you need your design solution to do.

Organisms meet functional needs through biological strategies. For example, one function of polar bear fur is to keep the polar bear warm. The polar bear’s fur is a strategy it has to insulate, or conserve heat. But, more specifically, the characteristics of the polar bear’s fur make it especially good insulation in its cold, wet habitat. Studying how polar bear fur works could lead to the development of better insulation for human needs, such as outerwear, buildings, or other applications.

FUNCTION: The purpose of something. In biology, functions describe the role played by an organism’s characteristics or behaviors that enable it to survive. In design, function describes what a design solution does.

STRATEGY: A characteristic, mechanism, or process that performs a function (in design or biology).
to human technological challenges. This may seem like a very advanced concept, but even in preschool, children are already learning how things work (e.g. glue is a way to stick two things together). Their familiarity with simple functions and strategies humans use can be a gateway to understanding similar functions and alternative strategies in nature (e.g. burdock seeds—the inspiration for Velcro—stick to our socks and animals’ fur using hooked barbs).

### Teaching Suggestions:
- Build nature observation sensibilities in your students; take them outside and get them to look closely and notice the features and behaviors of different organisms.
- Help students look at the natural world in terms of how it functions; have them form questions and suggest their own answers (hypotheses) for what the strategies they observe might be doing for the organism.
- Prompt students to make the connection between biological function and possible technological applications.

### Resources:
- **Hunting and Gathering For Ideas** - The hands-on activity in this resource gives students practice in identifying function in the biological world and relating it to human design challenges.
- **Seeing Function** - In this activity, students learn to “see” function in natural objects by encountering, describing, and considering natural objects while blindfolded.
- **AskNature Collections** - AskNature is the Biomimicry Institute’s database of biological information organized by function. Collections are featured sets of records, many of which are organized by a particular function or challenge (e.g., “Cooling Down in the Heat”). Collections can be useful for helping students understand the concept of function and how organisms and ecosystems can accomplish the same function in many ways using different strategies.
- **The Biomimicry Taxonomy** - AskNature’s list of functions found in biology, which humans also seek to perform. The Taxonomy is a helpful reference for teachers to use when planning activities based on function. Older students working on a design challenge can also use it to help them hone their research questions.
- **Biomimicry Toolbox** - This resource includes sections that discuss function and strategy. Written for a university and professional audience, the Toolbox is best utilized by older students, or teachers looking to deepen their understanding.
BIOMIMICRY AND BIO-INSPIRED DESIGN

Biomimicry is one type of bioinspired design, but not all bioinspired design is biomimicry.

As you begin to explore biomimicry, you may come across a number of other “bio” prefix terms used in referring to design and engineering inspired by nature. It can become confusing because some of these terms have overlapping usages or are applied inconsistently.

By way of clarification, “bioinspired design” is a term that is generally accepted as an umbrella category for design and engineering approaches, including biomimicry, that use biology as a resource for solutions. However, while biomimicry is a type of bioinspired design, not all bioinspired design is biomimicry. An important factor that differentiates biomimicry from other bio-inspired design approaches is the emphasis on learning from and emulating the sustainable solutions living systems have for specific functional challenges.

Within the family of bioinspired design, a common misunderstanding that we encounter is mistaking biomorphism for biomimicry. Biomorphism refers to designs that visually resemble elements from life (they “look like” nature), whereas biomimetic designs focus on function (they “work like” nature). Biomorphic designs can be very beautiful and beneficial, in part because humans have a natural affinity for nature and natural forms—what E.O. Wilson called
“biophilia.” But it’s important to realize that “looking like” nature is not a reliable indicator of biomimetic design because a biomimetic design might or might not look anything like the organisms that inspired it. Rather, the important indicator is function.

A similar point of confusion occurs between bioutilization and biomimicry. Bioutilization refers to the use of biological material or living organisms in a design or technology. For example, using trees as a material (wood) for furniture or using a living wall of plants to help clean the air in an office building. Bioutilization can be beneficial—organisms can do a lot of things we can’t—and biomimetic designs sometimes incorporate bioutilization for this reason. However, just because a design or technology uses a natural material or living organism, doesn’t make it biomimetic. Again, the distinctive feature of biomimicry is the study and emulation of functional strategies to create sustainable solutions.

Depending on your student population, it may or may not be appropriate to explicitly define these alternate terms. We provide this information primarily to ensure that you are able to help your students avoid common misconceptions about biomimicry.

Teaching Suggestions:
- Guide students in discerning whether various technologies “look like,” “work like,” or “use” elements from natural organisms.
- When discussing an example of a bioinspired design, ask students if they can identify whether it has an advantage that makes it more sustainable than previous technologies or designs?
- Engage students in critical thinking exercises on the sustainability and ethical implications of various bioinspired technologies.

Resources:
- “Biomimicry, Bioutilization, Biomorphism: The Opportunities of Bioinspired Innovation” - Perspectives from a leading sustainable design consultancy on the applications and differences of various bioinspired design approaches.
- “Bio-Inspired Buzzwords: Biomimicry and Biomimetics” - An experienced biomimicry practitioner discusses her views on the difference between the terms “biomimicry” and “biomimetics.”
- “Fritz Vollrath: Who wouldn’t want to work with spiders?” - This article and video from The Guardian looks at efforts to unlock the secrets of spider silk. It could be used to anchor a discussion about the difference between biomimicry and bioutilization.
- “14 Best Inventions Using Biomimicry” - This set of case studies, published by Treehugger, explores both truly biomimetic as well as bioinspired designs. Videos accompany many of the examples.
MATTERS OF SCALE

Scale is a conceptual framework that can help students understand, apply, and describe biomimicry.

There are two ways we can talk about scale in biomimicry: (1) we can use scale in a literal sense to describe the relative size of organisms, physical parts, or other components of a biological strategy or technological design, and (2) we can use scale to describe increasing levels of complexity in the application of biomimicry.

The first sense of scale is important to discuss because some strategies only work at one scale and cannot be “scaled up.” During a design project it can be very tempting for students to make assumptions that strategies that work at one scale or in one context in nature will work in another. Translating strategies between scales should be done only with a good understanding of the science behind the phenomenon at play. For example, the gecko has millions of microscopic hairs on its toe pads, which enable it to “stick” to and climb up vertical surfaces using attractive forces between molecules. Because these forces only work at the molecular scale, simply enlarging the hairs will not produce the same adhesive effect. Designs for synthetic adhesives based on the gecko’s hairy toe pad strategy apply the main mechanism for adhesion at the same scale as the gecko. To apply gecko-inspired adhesion to larger and heavier objects, additional design features must be used to scale up the technology.

The second sense of scale is useful when it comes to categorizing our thinking about how biomimicry can be applied. When we look broadly at biological strategies, or at the various examples of biomimicry, they tend to fall into one or more of three scales of application: forms, processes, and systems.

Many of biomimicry’s most well-known case studies describe biomimicry of form. It could be emulating the microstructure of a surface, such as a lotus leaf, or a larger physical trait that can be observed with the naked eye, such as the kingfisher’s beak. These examples are some of the easiest to understand and are therefore appropriate for younger students.
**Process** biomimicry is somewhat more complex. Scientists that mimic the way an abalone creates the durable nacre (mother of pearl) lining its shell through self-assembly are emulating a process; so are computer scientists who create algorithms (step-by-step procedures for calculations) based on lessons gleaned from the way foraging ants or swarming bees coordinate their movements as a group. Process examples can help older students understand the potential depth of biomimicry by underscoring how biomimicry is a practice of emulation, not simply physical copying.

**Systems** are about relationships and are usually made up of many forms and processes working together. System-level biomimicry is the most complex and, consequently, these examples are fewer in number. **Eco-Machines** that treat wastewater by mimicking how wetland ecosystems strip nutrients from water are an example of system-level biomimicry. The “circular economy” concept is another example. This alternative economic and industrial model is inspired by how matter and energy flow in living systems. Ultimately, in order for human societies to be truly sustainable, we will need to learn how to mimic nature at this systems level.

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**Teaching Suggestions:**

- Encourage students to consider how functions and strategies in biological and designed systems may change with scale.
- Prompt students to identify whether an example of biomimicry is emulating a form, process, and/or system.
- Guide students in discussions of what it would take for a given example at the form or process level of biomimicry to become more biomimetic at the systems level.

**Resources:**

- **“Aiken Eco-Machine”** - This video by the University of Vermont Rubenstein School provides a detailed profile of how an EcoMachine works.
- **Ellen MacArthur Foundation: Teaching and Learning Resources** - The Foundation is one of the leading organizations working toward a circular economy.
SYSTEMS THINKING

Our world is composed of systems—from ecosystems in nature to organizations and technologies in human society.

Systems are made up of interacting parts and the relationships between those parts. Our own bodies are systems of cells, tissues, and organs. We, in turn, interact with other systems every day, whether we are aware of it or not.

Systems thinking means thinking about the whole system and its interacting parts. The good news is that children have an intuitive sense of systems. Educator Linda Booth Sweeney, has said, “I put up a picture of a cow and ask, ‘If you cut a cow in half, do you get two cows?’ Even four-year-olds will shout out, ‘No way!’ They understand the cow has parts that belong together. They have to be arranged in a certain way to live.” (Bennett, 2013)

Learning to see, understand, and think in systems is essential to biomimicry. In order to appreciate the intricacies of living systems and become good problem solvers, students should be encouraged to look at the “big picture” and understand how the parts and pieces that constitute a whole interact and impact each other. This is especially important because some of the biggest challenges facing our world today are the product of systems failures,

An Earth systems visualization by NASA.
and require a systems view to solve. One of those challenges is our dependence on nonrenewable resources that are obtained at great expense. We can learn important lessons about how to solve these problems and redesign our world by looking at how systems work in nature. For example, in a healthy ecosystem, materials are acquired locally and constantly reused and recirculated among different organisms in the system, leaving no waste. The relationships within that ecosystem may provide clues for how to sustainably source and manage resources in our own designed systems.

Teaching Suggestions:
- Engage students in conversations about the relationships between things (in nature or design), not just the qualities of things themselves.
- Discuss cause and effect relationships.
- During a design challenge, ask students to identify the resource flows that impact their design. Where do needed energy and materials come from? Where do they go? What is the product life-cycle?

Resources:
- “Learning to Connect the Dots: Developing Children’s Systems Literacy” - In this article, Linda Booth Sweeney describes why systems literacy matters and offers several ways that adults can help foster this skill in children.
- Systems Literacy Collection - PBS Learning Media and Linda Booth Sweeney created this collection of classroom-ready resources and professional development.
- Biomimicry Toolbox - This resource includes sections that discuss systems thinking in the context of biomimicry. Written for a university and professional audience, the Toolbox is best utilized by older students, or teachers looking to deepen their understanding.
Patterns in Nature

Identifying and interpreting patterns is useful in biomimicry because patterns in nature can suggest solutions to common problems.

Patterns are everywhere in nature, at every scale. They can be observed in shapes and structures as well as in repeating events and relationships. Being able to identify patterns is a particularly important skill in science and engineering. When we notice a pattern, it often triggers questions about how and why it might occur. Answering these questions can eventually lead to better understanding in science and improved designs in engineering. Patterns in nature can also be a great starting place for biomimetic design. That’s because these patterns may represent effective strategies for solving common functional challenges within the context and constraints on planet Earth.

A great example of design emulating a pattern found across nature is the Swarm Logic™ energy management system, developed by the clean technology company Encycle™. Encycle’s founder, Mark Kerbel, designed Swarm Logic technology to help commercial buildings reduce their electricity demand and costs. The technology is inspired by and named after the way many groups of organisms—from colonies of social insects, like ants and bees, to flocks of birds and schools of fish—coordinate their actions. Each member of the swarm follows a set of simple rules in how they behave and interact.

A school of yellow-tailed goatfish.
with one another. As a result, the group can accomplish complex tasks and produce seemingly intelligent behavior without any single individual leading.

Similarly, Swarm Logic technology uses wireless power controllers to connect individual appliances in a building so that they can communicate with each other and determine the best time for each to turn on and off. As a result, the whole building reduces its peak electricity consumption and costs, and puts less strain on the electric utility grid.

**Teaching Suggestions:**
- Ask students to group and identify patterns from among different objects of colors and shapes, or clippings from a magazine, or within their physical movements.
- Have each student throw a shoe into the center of the room. How can students begin to classify the shoes and create order out of chaos?
- Encourage students to identify patterns in nature or in a school garden. Patterns might involve size, shape, color, sound, branching, arrangement, relationship and so on. Ask them to hypothesize why those patterns might exist.

**Resources:**
- *Exploring the Way Life Works*, by M. Hoagland and B. Dodson - The second chapter in this illustrated science book focuses on broad patterns in living systems, describing “Sixteen Things You Should Know About Life.” (Note: this book is out of print, but used copies can still be found online.)
- “Doodling in Math: Spirals, Fibonacci, and being a plant” - This three-part video series playfully explores the mathematics of spirals, and the patterns found in plants and reveals the simple rules that optimize how plants grow and the value of looking for patterns.
- “Innovative Paths to Energy Efficiency: REGEN Energy” - A case study on Encycle™ (formerly called REGEN) and their Swarm Logic™ technology.
- Biomimicry Toolbox - This resource includes sections that discuss natural patterns in the context of biomimicry. Written for a university and professional audience, the Toolbox is best utilized by older students, or teachers looking to deepen their understanding.
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RESOURCES

Organized by section and alphabetized.

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PATTERNS IN NATURE


APPENDIX


APPENDIX

CONNECTING WITH COLLEAGUES

There is a rapidly growing community of people teaching and practicing biomimicry. The following groups are a great place to connect:

BIOMICRCRY EDUCATION NETWORK:
The Network offers opportunities to find and share with other educators. Get connected by joining the group on AskNature. A (free) AskNature account is required.
- Biomimicry Education Network group page
- Join AskNature

REGIONAL NETWORKS:
Find biomimics in your neighborhood! There are dozens of affiliated organizations in the Biomimicry Global Network. Visit the Biomimicry Institute website to find a nearby network or get information about starting your own.

LINKEDIN GROUPS:
Meet colleagues and follow discussions about what’s new in biomimicry. Here are a few of our favorites:
- Biomimetics Forum
- Biomimicry & Innovation
- Biomimicry Practitioners Network

*Items hyperlinked in the text above are available with full citations and URLs in the Resources section.*