a biomimicry primer

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what's it about?

The first time I explained biomimicry to a stranger was not in a lecture hall or a workshop, but in a big-box bookstore just after *Biomimicry: Innovation Inspired by Nature* had come out. I was searching the shelves for the spine, always a breath-held-in moment for a writer. I checked the nature section, environment, design, and engineering, but it just wasn't there. Before I could slink away, the bookseller appeared, and I asked him where it might be shelved.

He came back with a perfectly normal but impossible question: "What's it about?"

After you finish a book, a pack of ideas race to your lips, nipping and barking to be the first one out. It's hard to choose. "OK. It's about looking to nature for inspiration for new inventions," I blurted. "It's learning to live gracefully on this planet by consciously emulating life's genius. It's not really technology or biology; it's the technology of biology. It's making a fiber like a spider, or lassoing the sun's energy like a leaf." The growing alarm on his face confirmed it; I was postpartum and probably shouldn't be out.

Then he lifted his palms as if weighing two packages and said something I will never forget. "Look lady, you've got Nature and you've got Technology; you've got to choose one." He was referring to the category scheme in the store, but I realized that the deep, deep separation between those two ideas in our culture was why biomimicry was squirming to be born.

The fact that you are reading this means you already suspect that organisms are the consummate physicists, chemists, and engineers, and that ecosystems are economies beyond compare. You're on your way to becoming nature's apprentice, learning from and emulating life's designs to solve worthy challenges. Around the world, biomimics like you are consulting life's genius to create new products, processes, and policies—new ways of living—that are well adapted to life on earth over the long haul. They're learning to grow food like a prairie, adhere like a gecko, sequester carbon like a mollusk, create color like a peacock, and run a business like a redwood forest. As apprentices, they, you, all of us are birthing what will be biomimicry's greatest legacy—a profound and deepening respect for the natural world.

The respect at the heart of this field is what differentiates biomimicry from past efforts to dominate, domesticate, or steal nature's secrets. Biomimicry ushers in an era based not on what we can extract from nature, but on what we can learn from her. This shift from learning about nature to learning from nature requires a new method of inquiry, a new set of lenses, and above all, a new humility.

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So, given its depth and breadth, how does one categorize biomimicry? Is it a design discipline, a branch of science, a problem-solving method, a sustainability ethos, a movement, a stance toward nature, a new way of viewing and valuing biodiversity? Yes, yes, and yes, which is why biomimicry

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is an idea that acquires people, a meme that propagates in our culture like an adaptive gene. Biomimicry captures our imagination because of its promise, because it is at once pragmatic and culturally transformative. At its most practical, biomimicry is a way of seeking sustainable solutions by borrowing life's blueprints, chemical recipes, and ecosystem strategies. At its most transformative, it brings us into right relation with the rest of the natural world, as students learning to be a welcome species on this planet.

Your own understanding of biomimicry is bound to expand as you practice, but as a starting point, here's something of a more formal definition:

Biomimicry is learning from and then emulating natural forms, processes, and ecosystems to create more sustainable designs. It's studying a leaf to invent a better solar cell or an electric eel to make a better battery. The core idea is that nature has already solved many of the problems we are grappling with: energy, food production, climate control, benign chemistry, transportation, packaging, and more. Mimicking these earth-savvy designs can help humans leapfrog to technologies that sip energy, shave material use, reject toxins, and work as a system to create conditions conducive to life."

what better models could there be?

For designers, architects, engineers, and innovators of all stripes, the answer to the question "What would nature do here?" is a revelation. There's not one new idea, but millions, ideas evolved in context, tested over eons, and proven to be safe for this generation and the next. This trusted source of inspiration arrives just as our species is counting the casualties of our industrial crash.

Yearning for something that works for instead of against life, professional innovators are heading outside to see how other species have managed to survive for 3.85 billion years. Their models are organisms that manufacture without "heat, beat, and treat," and ecosystems that run on sunlight and feedback, creating opportunities rather than waste. The resulting designs are functional, sustainable, and not surprisingly, beautiful as well.

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Beauty is a large part of why biomimicry resonates. Our search for mentors brings us back into contact with the living world, a place we were tuned to appreciate. Having spent 99.9% of our planetary tenure woven deep into the wild, we humans naturally admire the weaverbird's nest, the conch's shell, the scales of a shimmering trout. In fact, there are few things more beautiful to the human soul than good design. When it is good in all aspects—stirring to the senses, fit for its function, elegant in its material choice, gentle in its manufacture, we can't help but feel delight and the desire to do at least as well in our next design. That's what biomimics feel each time they see a swift slice the sky, or a butterfly float to a flower in bloom—a desire to be more like the organisms we admire.

The twin emotions of admiration and awe are as useful as they are powerful. Social reference theory predicts that the fastest way for us to change is to pick a new mentor—to change who it is we admire and want to emulate. When the young entrepreneur who has always modeled himself after Donald Trump suddenly compares himself to the founder of the city food bank, it's a potent life-shift. It's the

same with biomimics. When we compare our human-made technologies not with other humans' but with other species', we are humbled and inspired to move to a new design ethic. The Ghandian act of being the change we want to see in the world begins with finding a mentor who represents that change. For us, that mentor is nature.

At the cusp of every design decision, biomimics have 30 million elder strategists to advise them. Rather than flipping through a catalogue of human inventions, or going on a retail safari, biomimics turn to nature for inspiration. Their mentors are the bacteria, fungi, plants, and animals of this planet, the organisms that clothe the landscape, cycle the nutrients, cleanse the air, sweeten the water, and create soil from rock. They are beings that can fly around the world without an engine, dive down ocean Everests without a tank, drink luxuriously from a wisp of fog, or shelter a dune from a hurricane gale. They surf the opportunities in their habitat while respecting the limits, and in that frame, they perform what seem to us to be technological miracles.

Upon closer inspection, organisms manage these feats with a beguilingly simple set of common raw materials, procured locally, manufactured at body temperature and pressure, processed silently in water. At the end of their useful life, these materials are regathered and reconfigured by other organisms, upcycled again and again with the energy of the sun. The tightly-knit forests, prairies, corals, tundras, and grasslands of this planet are the envy of all of us who thirst for a sustainable and equitable world. As communities, they not only create, but continually heal and enhance their places. Our places, too. What better models could there be?

how biomimicry fits into other design paradigms

Because of its broad range, biomimicry contributes, both practically and philosophically, to many of the eco-design paradigms devised in the last 30 years, including the Natural Step, Natural Capitalism, Cradle to Cradle, Ecological Design, and Living Building Challenge. Biomimicry is what you do on Monday morning when you've committed to a sustainability framework like LEED or carbon footprint reduction, and now it's time to actually reinvent what you make and how you make it.

The biomimicry approach seeks nature's advice at all stages of design, from scoping, creation, to evaluation. Working with "biologists at the design table," innovators explore the true functions they want their design to accomplish, and then ask: what organisms or ecosystems depend for its survival on performing those functions? An "Amoeba through Zebra" survey of the biological literature reveals dozens of inspiring models, complete with physical blueprints, chemical formulae, process descriptions, and community strategies. To infuse life's systemic wisdom into the design of everything from carpets to cities, a list of Life's Principles serves as an overarching scoping and evaluation tool—nature's own eco-design checklist.

But products and processes are not the only human designs influenced by biomimicry. As more people see nature as a teacher rather than a warehouse, biomimicry is prompting policies that restrain our powers and allow us to say "thank you" by stewarding wild habitats. In this way, bio-inspired design is a sister meme to policy-making efforts like Biodiversity Protocols and the Precautionary Principle.

Biomimicry was lucky enough to come on the scene after dozens of sustainability pioneers had framed the problem space and built conceptual pathways through this evolutionary knothole. Nature-

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inspired innovation is but one of the solution-seeking paradigms in a "human immune system" pulsing with good ideas. Our hope is that it serves and complements these kindred movements.

inside the phrase "the conscious emulation of life's genius"

In 1990, when I had to name the very first file folder to house a journal article on artificial photosynthesis, I was at a loss. What was the mega-category that would encompass all instances of nature-inspired innovation? I turned to Webster's to find bios, which is Greek for life, and mimesis, which means to imitate. Biomimicry seemed a more melodious term, so I scrawled it on the tab, and from that moment, you might say, the idea acquired me. When I began to write and speak about the subject, another phrase became very important to me, because it captures both the letter and the spirit of biomimicry practice.

Biomimicry is the conscious emulation of life's genius. The word "conscious" refers to intent—it is not enough to design something without nature's help and then in retrospect say, "This reminds me of something in the natural world." That's called convergent evolution, but it's not biomimicry. Biomimicry implies conscious forethought, an active seeking of nature's advice before something is designed.

The nature of the consultation is also important. Seeking nature's blueprints and recipes is only part of the process; the intent should be to create products and processes that fit seamlessly within the larger natural system, that embody Life's Principles. This ensures that our designs are not shallow in their mimicry, but rather as fully life-inspired as they can be.

The word "emulation" is also carefully chosen, because it is more nuanced that mere copying or slavish imitation. Biomimics may study a spider to learn about sensing, fiber manufacture, adhesion, or tensegrity, but we are not actually trying to recreate the spider. What we're trying to emulate are the design principles and living lessons of the spider. How a spider meets its needs while helping to enhance its habitat is as important to a biomimic as how it spins its silk.

"Life's genius," a term rendered more controversial in the age of intelligent design, is also carefully chosen. It refers to the fact that these technologies are more than simply clever—they have the spark of true insight because they've evolved in response to earth's mandates. Life's true genius is in how its technologies contribute to the continuation of not just one life but all life on earth. Gleaning that kind of wisdom takes more than just recording the size and spacing of a whale's tubercles. It means contemplating the daily life of the marine denizen in its habitat, including its physiological, behavioral, and community strategies, all of which make it a net contributor to its habitat. To move from shallow to deeper biomimicry requires us to engage in an ongoing conversation with the organism, and to mimic what we learn on at least three levels.

three levels of biomimicry

The first level of biomimicry is the mimicking of **natural form**. For instance, you may mimic the hooks and barbules in an owl's feather to create a fabric that opens anywhere along its surface. Or you can imitate the frayed edges that grant the owl its silent flight. Copying feather design is just the beginning, because it may or may not yield something sustainable.

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Deeper biomimicry adds a second level, which is the mimicking of **natural process**, or how it is made. The owl feather self-assembles at body temperature without toxins or high pressures, by way of nature's chemistry. The unfurling field of green chemistry attempts to mimic these benign recipes.

At the third level is the mimicking of **natural ecosystems.** The owl feather is gracefully nested—it's part of an owl that is part of a forest that is part of a biome that is part of a sustaining biosphere. In the same way, our owl-inspired fabric must be part of a larger economy that works to restore rather than deplete the earth and its people. If you make a bio-inspired fabric using green chemistry, but you have workers weaving it in a sweatshop, loading it onto pollution-spewing trucks, and shipping it long distances, you've missed the point.

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To mimic a natural system, you must ask how each product fits in—is it necessary, is it beautiful, is it part of a nourishing food web of industries, and can it be transported, sold, and reabsorbed in ways that foster a forest-like economy?

If we can biomimic at all three levels—natural form, natural process, and natural system—we'll begin to do what all well-adapted organisms have learned to do, which is to create conditions conducive to life. Creating conditions conducive to life is not optional; it's a rite of passage for any organism that manages to fit in here over the long haul. If we want to keep coming home to this place, we'll need to learn from our predecessors how to filter air, clean water, build soil—how to keep the habitat lush and livable. It's what good neighbors do.

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how does biomimicry differ from other bio-approaches?

One of the most important ways to understand this meme is to understand what it is not. Sometimes people say to me, oh I'm doing biomimicry! I just put cork floors in my house. Or, I clean my wastewater with bacteria. Well, to clear up the confusion, we introduced the concepts of bio-utilized and bio-assisted, which are quite different from bio-mimicked.

Bioutilization entails harvesting a product or producer, e.g. cutting wood for floors, wildcrafting medicinal plants. It is also distinctly different from bio-assisted technologies, which involve domesticating an organism to accomplish a function, e.g., bacterial purification of water, cows bred to produce milk. Instead of harvesting or domesticating, biomimics consult organisms; they are inspired by an idea, be it a physical blueprint, a process step in a chemical reaction, or an ecosystem principle such as nutrient cycling. Borrowing an idea is like copying a picture—the original image can remain to inspire others.

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For those of us in western industrial culture, looking to nature for advice marks a new way of viewing and valuing other organisms. When we begin to see nature as a source of ideas instead of a source of goods, our respect for life and its adaptive ability grows. As more people practice biomimicry and realize what we might learn from living systems, the argument for conserving biodiversity becomes self-evident.

Finally, learning from instead of just about nature calls for a fundamentally different scientific approach, involving the study an organism, a subsequent attempt to emulate, and often a return to the organism with a new set of questions. This has been called "a deepening conversation with the organism" by plant geneticist Wes Jackson, who studies prairie patterns to come up with a more robust agriculture. This shift in stance, from conqueror to student, marks a new relationship between humans and the rest of the natural world.

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There's nothing like trying to emulate a leaf to make you tremble every time you walk through a forest. To learn the ropes of being an earthling requires that we choose nature not just as model, but also measure and mentor. Learning from life's genius involves these questions: What would nature do here (nature as model), What wouldn't nature do here (nature as measure) and Why? And Why not? (nature as mentor).

naturalizing biomimicry in the culture

When I first met Paul Hawken, the author of classics like Ecology of Commerce and Natural Capitalism, he asked me a shocking question: "What do you think you're doing?" and I answered just as surprisingly, "Waking Sleeping Beauty." By that I meant that biomimicry was not new to the human species; in fact there was a time when our very survival depended on noticing and mimicking successful organisms. What I meant was that this latest appearance of biomimcry is not an invention, it's a remembering.

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We fell asleep, or as Thomas Berry says, became autistic to the living world, perhaps because we felt we could take it from here, that we no longer needed nature's help. Well, we're awake now, and the question is how do we stay awake to the living world? How do we make the act of asking nature for advice a normal part of everyday inventing?

We can look at history to find examples of times that biomimicry emerged in the culture, usually in the form of a single inventor, like Leonardo da Vinci, Frank Lloyd Wright, Frei Otto, or Buckminster Fuller. Unfortunately, these were isolated instances, but not the start of a succession. There was no body of work, no scholarship, no cohorts of students trained to be nature's protégés. And so biomimicry went dormant again.

I don't think that is going to happen this time. When you Google biomimicry or its related terms, biomimetic(s), bionic(s), and bio-inspired, it's over 28 million hits and growing daily. The process of

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borrowing nature's blueprints is enjoying a resurgence due in part to our search for more sustainable methods of agriculture, manufacturing, chemistry, energy generation, health care, and business. Also contributing are the amazing lab techniques and imaging technologies that allow us to more fully characterize how nature's materials, processes, and ecosystems work. At the same time, our ability to mimic life's devices, especially at the nano and micro level, makes emulation more possible.

According to a study by Richard Bonser, the number of global patents containing the term "biomimetic" or bio-inspired in their title has increased by a factor of 93 from 1985 to 2005, compared to a factor 2.7 increase for non-biomimetic patents. Industry is accelerating this trend by seeking the consulting services of biologists like those in the Biomimicry Guild. Industrial networks such as BIONIS (UK) and BIOKON Bionics Competence Network (Germany) are also catalyzing commercial interest in Europe. The big change that I've seen in the last 15 years is in who is funding biomimicry. In the decades before the 1990s, the lion's share of the research was in academia and government agencies, and the funding was primarily from space, defense, and departments of energy. Now we see the meme jumping to industry R&D labs and private design engineering and architecture firms.

As the approach gains recognition, new interdisciplinary centers are forming, including the Bio-inspired Engineering Center at Harvard, the Biodesign Institute at Arizona State University, the Center for Biologically Inspired Design at Georgia Tech, the Center for Biologically Inspired Materials & Material Systems at Duke University, the Biomimetics Research Center at Doshisha University, and the Swedish Center for Biomimetic Fiber Engineering at the Royal Institute of Technology. New journals devoted to biomimetics, such as the Journal of Bionic Engineering, and an increasing number of symposia and conferences are further signs of the maturing of the discipline.

What will finally naturalize biomimicry in our culture for good? My hunch is that naturalization will come only as people try biomimicry and realize that it actually works—when they consult nature and get a new insight, a new model, a new way out of the box canyon of their thinking. What I see again and again in biomimetic inventors is "once a biomimic always a biomimic"—once successful, every one of their innovations is bio-inspired. It becomes a way of working. Our efforts at the Biomimicry Guild and Biomimicry Institute are guided by this belief, and we work together as a system to provide the training, the tools, and the ethical leadership to help naturalize biomimicry in the culture.

At the Guild, we help innovators consult nature, helping to green not just products but whole companies in nature's image. Our reports, excursions, inspiration installations, and workshops are bringing nature's wisdom to industries such as building, transportation, apparel, floorcoverings, furniture, kitchen and bath, food, and consumer goods. At the Biomimicry Institute, we train the next generation of biomimics, starting with K-12 curricula, a children's CD (complete with a howlingly good kid's choir), and zoo programs. At the university level, we have a growing list of faculty fellows teaching "biology taught functionally" courses, biomimetic design studios, and eventually a biomimicry minor for design, architecture, and engineering students. We're also committed to educating biologists to sit at the design table, filling a demand that is growing by leaps and bounds. Great believers in the interdisciplinary nature of this work, we've begun our own 2-year certificate course, which involves students from biology, business, engineering, and design.

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While we are amazed at our growing community, we still feel we can only touch so many people personally. We think it's time to blow on the dandelion wisher and parachute nature's ideas to world. In 2008 we launched a free, online library of nature's solutions called AskNature that allows an innovator to ask questions like "How would nature desalinate?" and learn about the strategies of mangroves, sea glands of seabirds, kidneys, and more. It's a moderated wiki, built for and by the community, part Google of nature's solutions and part social networking site. It's a place where designers with challenges can meet their mentors and communicate with the biologists who have studied these organisms for decades. Together scientists and innovators will find ways to emulate life's genius in sustainable products and processes.

Perhaps most exciting is the beginning of a movement to tie biomimetic design back into conservation. At The Biomimicry Institute, we've launched a program called Innovation for Conservation that asks companies to donate a percentage of their proceeds to conserve the habitat of the organism that inspired the product or process.

In the end, biomimicry has the potential to change our world view as well as our designs. The process of quieting human cleverness, listening, and then echoing what we hear is only the first part of the biomimicry process. The loop is not complete until we learn to say thank you in a meaningful way. The real legacy of biomimicry will be more than products and processes that help us fit in here. It will be gratitude, and from this, an ardent desire to protect the genius that surrounds us.

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is there a place for us?

Finally, indulge me while I add a postscript. Something that has always been a rhetorical quagmire for me is the fact that when I talk about learning from nature, I sound as if we humans are outside, something other, something alien. I don't believe that for a moment. I believe we are as ingenious, as fragile, and as beautiful as any of these creatures that enrapture us when we practice biomimicry. It's time to shed that lonely myth; the truth is we ARE nature.

In fact, biomimicry works precisely because there is no difference between what we do and what other organisms do—the boundary between us and the rest of the natural world is a false one that dissolves when you consider what is really important, what makes life worth living. We are in a long line of organisms that have sprung from this earth, each trying to figure out how to stay here, how to take care of the place that will that care of our offspring. We may be a toddler, 200,000 years old compared to 3.85 billion years, but we are part and parcel of this blue-green planet. It's our home and it's where we belong. Now it's time, with the help of our extraordinary planet-mates, to start putting down roots.