Photograph by Vern Evans

Janine Benyus: The Thought Leader Interview

The biomimicry pioneer is teaching executives that the solutions to their most challenging problems lie in nature.

by Amy Bernstein

Within the current wave of corporate environmentalism, inspired by the threat of global climate change, large-scale thinkers are prominent. Many proclaim a new role for companies: to move beyond compliance with regulations to a leadership stance in the green, energy-efficient economy of the future. But in the long run, the most effective thinkers in this arena may well be those who start small, just as nature does. By emulating the patterns and designs and strategies in plants, animals, and ecosystems, they argue, corporations can become cleaner, leaner, and more consistently innovative. For the past decade, one of the most influential voices in this school of thought has been that of Janine Benyus.

Ms. Benyus was the first to identify the nascent discipline, which she dubbed "biomimicry" and galvanized with her groundbreaking 1997 book of the same name. Biomimicry, writes Ms. Benyus, is "the conscious emulation of life's genius." To practice biomimicry, a technologist must turn away from conventional "heat, beat,

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and treat" industrial processes, and study "what works in the natural world, and more important, what lasts." For example, ceramic manufacturing could emulate the self-assembly of abalone shells; adhesive tape could be patterned after geckos' feet; and computer chips could be designed to assemble themselves through crystallization, just as microscopic algae called diatoms assemble their shells. More important, each of these innovations (and many more) could be produced with a fraction of the environmental liability — and in many cases the cost — of conventional industrial processes. In nature's innovation and resilience, Ms. Benyus sees the keys to achieving sustainability, which former Norwegian President Gro Harlem Brundtland defined as the capacity of society and industry to "meet the needs of the present generation without compromising the ability of future generations to meet their needs."

A biologist by training, Ms. Benyus never set out to become a guru of sustainable business. In the course of writing several books on wildlife and animal behavior, she came to appreciate "the exquisite ways that organisms are adapted to their places and to each other." The observation led her to a profound realization: "In seeing how seamlessly animals fit into their homes, I began to see how separate we managers had become from ours," she writes. She set out to identify the people "who know that nature, imaginative by necessity, has already solved the problems we are struggling to solve."

What she found was like-minded individuals "working at the edges of their disciplines, in the fertile crescents between intellectual habitats." Sensing that there were broader applications at the intersection of ecology, commerce, technology, and materials science, she cofounded the Biomimicry Guild in 1998 and developed models for applying biomimicry to industrial design and systems. Among her growing list of clients are Levi Strauss, NASA, Nike, Patagonia, Procter & Gamble, S.C. Johnson, and General Electric.

When she wrote her book a decade ago, she noted that there was no formal biomimicry movement as yet, but that people responded to the idea with enthusiasm. "Biomimicry has the earmarks of a successful meme; that is, an idea that will spread like an adaptive gene throughout our culture," she says.

Ms. Benyus met with *strategy+business* at her house at the foot of the Bitterroot Mountains in western Montana, surrounded by the largest contiguous wilderness in the lower 48 states. Warmed by a stove burning wood pellets on a frigid February morning, Ms. Benyus explained why biomimicry is catching on with business and where it's going.

S+B: You say that there has been no formal biomimicry movement until now. Do you see one taking shape?
BENYUS: Absolutely. When I started working on the book in 1990, my source material was all small scientific journals. Very obscure. None of the people doing this kind of work knew each other, and they all had different terms for the same concepts and different ways of describing their work. But now, when they write grant proposals and research papers, they all talk about doing "biomimicry" or "biomimetic research." It's now a known term.

After the book came out, I started to get calls from the design, architecture, and engineering communities — which I wasn't expecting. They'd say, "We don't want to wait

for research. We're already doing our own R&D. We want to do bio-inspired work and we think it has business potential. But we're not biologists. Help us."

So in 1998 we started the Biomimicry Guild. This group sends biologists to the table with designers and engineers and architects at the moment of creation. Just in the last 12 to 14 months, we have seen a big rise in phone calls. We've got a client list of about 200. It includes the obvious folks, companies like Patagonia and Seventh Generation [a maker of nontoxic household products], but also companies like General Mills and Kohler [a maker of kitchen and bath supplies] without an obvious public reputation for environmental concern.

S+B: Describe how you work with your clients.

BENYUS: A large adhesives company comes to us with a challenge: "We know our products are toxic and not very good: They're brittle, they dry out, and they have to be reapplied. Furthermore, after we glue things together with our adhesives, they can't be easily disassembled for recycling. How can we fix all that?"

They come to us because they know we look to the natural world for answers. How does nature adhere? We look at how bacteria stick to the surfaces of a host body, how plants use tendrils to cling to walls, how sea kelp uses its holdfasts to adhere to wet rocks, and how a fly can walk across a ceiling.

The gecko is a beautiful example of nature's ability to come up with a super-strong adhesive. Do you know how geckos are able to hang on a wall? On the bottom of their feet, they've got fins that break up into millions of little bristles, like split ends. Each of those bristles adheres to the nooks and crannies of a surface using positive and negative molecular charges that create what's called van der Waals forces. They're the tiniest attractive force there is, but when you combine them by the billions you get one of the strongest adhesives known to man. You can suspend 280 pounds from a fully engaged gecko.

The strength of that adhesive force is only part of the story. When the gecko peels back its toes, it fully releases its bond at 30 degrees. Plus, the gecko can walk through sand and, within just a few steps, can cling to a wall; its toes are self-cleaning structures. The adhesion doesn't diminish in liquids or in a vacuum. Imagine the uses for a resealable adhesive like this.

S+B: How are we likely to see this understanding applied?

BENYUS: Two labs — at the University of California at Berkeley and at the University of Manchester — are making tape based on gecko toes. One use for this might be carpeting: Instead of gluing down carpet squares, you could have fibers on the bottom that are like gecko tape. When you lay down the carpet, it stays down, no matter what the floor beneath it is made of. And when you want to move the carpet to the next office, all you do is peel it up and there's not all that glue to create a worker-safety problem.

One important implication of this involves disassembly. Think about how products and appliances of all sorts — TVs, for example — are glued together so that we can't take them apart. What if the edges of product casings or parts had gecko tape? You could take them apart and dispose of them without the contamination caused by most glue. That solves a big problem and moves the entire industrial system closer to ecological sustainability.

Nature as Innovator

S+B: What companies are leading the charge on biomimetic products?

BENYUS: The first company I worked for is Interface, a $1.3 billion operation in Atlanta that has about 40 percent of the carpet tile market. Manufacturing carpet is particularly hard on the environment; it uses petrochemicals in every step of the process, consumes vast amounts of energy, and produces tons of waste. About 12 years ago, just as the green building movement was starting to percolate, Interface's CEO, Ray Anderson, committed to remaking the company as a model of sustainability. Interface's lead designer, David Oakey, who'd just read my book, asked Dayna Baumeister, who cofounded the Biomimicry Guild, to come in and conduct a workshop for their designers.

The question was, How would nature design a carpet? As we do with all our workshops, we started

by taking the group outdoors; we looked for Interface's answers in a forest. The group observed that when you pick up a leaf off the forest floor and you look back down, the forest floor is still beautiful. Everywhere the group looked, they saw that sort of organized chaos. No two sticks, no two leaves are alike, but together they're beautiful.

They used that observation to rethink their approach to carpet tiles. Carpets are woven on broad looms, so carpet rolls are 12 or 15 feet wide. There's a pattern on that broadloom, and when you cut it into tiles, you have to make sure that you lay the pieces down perfectly to match the pattern. The ends of the roll become waste, because they don't fit into the pattern. Another problem with carpet tiles is that they were never really as flexible as they were supposed to be. The original idea behind them was that when a square needed replacing, you'd pull it up and lay another one down and no one would notice the difference, even years later. Well, it didn't really work that way. When you put down the replacement tile, it was clearly new — it was slightly out of pattern or the colors didn't quite match. So people wound up tearing up the whole carpet.

Instead, Interface decided to follow nature's lead and give every carpet tile a different pattern and hue — to replicate the random beauty of leaves on the forest floor. You can replace worn or stained squares with new ones that don't stick out like a sore thumb. And Interface could use the ends of the rolls, so there wasn't so much waste. The new product, called Entropy [now one of several lines of similar products called i2], was revolutionary; no one had ever done anything like that before. In three years, it became their bestselling line, and now it makes up 40 percent of their carpet sales. Entropy and i2 are successful not just because they're "greener," but also because they give customers so much flexibility.

S+B: Do your clients tend to use sustainability as a selling point?

BENYUS: Some do, like Interface, but not all. S.C. Johnson, the family-owned cleaning products company, has quietly been trying to do a lot of sustainability work. I talked to them about a number of ideas: adhesives modeled on the gecko's foot, packaging modeled on beetle shells, and carbon dioxide sensors for the home based on human cells.

They're very interested in coming up with a line of formaldehyde-free glues modeled on the superadhesives produced by mussels. The problem with glues used in plywood or in particleboard is that many contain formaldehyde — a known carcinogen — to make them waterproof. The appeal of mussel glue is that it has zero formaldehyde; plus, it's more waterproof than the adhesives currently in use.

I don't think S.C. Johnson necessarily had me in there to promote sustainability to its customers. In fact, General Electric, Procter & Gamble, and other Fortune 50 companies come to us primarily to talk about innovation. They're interested in the way that we study adaptations in the natural world; they're looking for clues to completely rethink products and processes.

For example, we've worked with wastewater treatment experts from Carollo Engineers, a Phoenix firm that designs public-sector projects, trying to figure out a better way to recover freshwater without huge inputs of chemicals and energy. There are plenty of natural desalinators, for instance: human kidneys, mangroves, marine iguanas, and certain freshwater fish that can survive in the ocean. In 2001, we spent seven days in the Galapagos Islands snorkeling with water purification specialists to study how nature filters.

S+B: Corporate interest in sustainability is rising. What do you think is driving that? Customer demand?

BENYUS: It's complicated. I can think of half a dozen reasons, of which market demand is certainly one. The industry that came to biomimicry first was architecture and commercial interiors back in the mid-1990s. Their clients wanted to make a credible claim to being socially responsible. Similarly, Interface first got involved in sustainability because their commercial clients wanted "green" offices. You also see growing interest in green buildings from the same consumer base that has gone to alternative medicine and organic food.

Regulation is another important factor. Since the '70s, a lot of environmental laws have mandated phased-in restrictions. Now those latter phases are coming into play for implementation, and they're making it expensive to be dirty, to be hazardous. Dealing with solvents, for example, is getting very costly. But if you completely flip the industrial paradigm and conduct chemistry in water, which is what life does, you don't have to buy the sulfuric acid. You don't have to worry about workers' safety while the solvent is on the floor. And then you don't have to dispose of it. Green practices are saving compa-

"The Entropy carpet replicated the random beauty of leaves on the forest floor. It became Interface's bestselling line."

nies from all kinds of legal and regulatory trouble.

Sustainability is also saving companies money. By becoming green, you basically practice lean manufacturing. You're creating less waste to dispose of, thus saving your company money.

Institutional investors like CalPERS are starting to push, too. They are focusing on sustainability because they want to make sure that their clients get a return 20 years from now. They want a safe bet, and for big money investors, "safe bet" increasingly means clean; it means investing in companies that are proactive about dealing with environmental and health risks. In other words, the investors want to make sure that the companies where they put their money are here for the long haul and will not be sued into extinction. Insurance companies are taking the same approach. Reinsurers are saying, "Hey, I'm not going to insure you unless I'm sure we won't find ourselves in another situation like DuPont's with Teflon." [In 2004, the U.S. Environmental Protection Agency's science advisory board ruled that one of the chemicals used to make Teflon — perfluorooctanoic acid, or PFOA — was a likely carcinogen. Soon afterward, the chemical company paid $300 million to settle a lawsuit from residents living near DuPont factories in Ohio and West Virginia.] No insurer wants to have to have the liability 20 years from now for problems caused by some chemical that we now suspect as being harmful to biological tissue. Similarly, banks are beginning to consider a company's commitment to sustainability when they make lending decisions.

A Different "Biotech"

S+B: The technology industry has long found design inspiration in nature. Is nature an easy model for industries to follow?

BENYUS: Yes and no. In computers, the bio-inspired work has generally taken place on the software side. You see it in neural networks, in software that acts like an immune system, and in genetic algorithms based on natural selection that are used to optimize code for designs. Software is moving closer and closer to the biological model: It's becoming more self-aware, self-reliant, and self-healing.

But the hardware is archaic and uses toxic and expensive manufacturing processes. Silicon chip fabrication plants, with their "clean rooms," are a perfect example: They clean the chips with organic solvents or with inorganic reagents like sulfuric acid, which are dangerous and don't break down. This approach is starting to change, however, and we're going to see dramatic changes in chip technology. Chips are made of silicates — they're glass, basically. Scientists at Princeton and the University of California at Santa Barbara are looking for better ways to make chips by studying diatoms, algae with cell walls made of silica, which grows through crystallization — the same way silicates are grown for chips. The important difference is that the chemical process takes place in water. There's no need for toxic solvents or reagents. The diatom self-assembles its silicon shell using materials common in seawater. Industries that want to clean up their manufacturing should be investigating how they might transition to this new way of making silicon chips.

But that's not all. Researchers are looking at nature for ways to solve the overheating problem in electronics. There are people looking at how to mimic the heat-

"The abalone shell is twice as durable as the ceramics used in jet engines, and it's manufactured silently, in water."

dissipating structures of the butterfly wing and apply that to the computer chip structure itself. There's a company in San Rafael, Calif., called Pax Scientific that is studying the way nature directs flow using Fibonacci sequences — the logarithmic spirals that are found throughout nature, in structures ranging from nautilus shells to tornadoes — to design better computer fans. They're being tested now; they yield about 35 to 50 percent energy savings and are 75 percent quieter.

S+B: It sounds as if much of the progress in technology comes out of materials science.

BENYUS: The two fields that have the longest legacy of bio-inspiration are computing and materials. The traditional processes for turning materials into finished products are incredibly wasteful and polluting. They're called "heat, beat, and treat": You start with a bulk material, carve it down, heat it up, beat it with enormous pressure, and treat it with chemicals. What you get is 96 percent waste, 4 percent product.

Researchers are now looking at the processes that nature uses to make its materials — from ceramics like shell, bone, and teeth to the soft and yet amazingly durable materials like spider silk — to identify common principles. There are several primary differences. First, life does its manufacturing in or near its own body, so its methods have to be life-friendly. A spider spins its silk "on board." It can't take a chance with "heat, beat, and treat." It uses little energy; there's no waste and no hazardous byproduct. Second, nature conducts its chemistry in water. We conduct industrial chemistry in solvents like sulfuric acid. Third, our manufacturing processes use all the elements in the periodic table — even the toxic ones — and we use crude, brute-force recipes. But life uses a subset of the elements, just a few, and it uses very elegant, low-energy recipes.

One of the problems with "heat, beat, and treat" is that it tends to produce brittle materials that crack or break easily. The abalone shell, by contrast, is a model of flexibility and resilience. The mother-of-pearl inside is a layered structure of mineral plates and protein sheets that self-assembles out of seawater; the mineral layers are composed of hexagonal plates stacked and offset like bricks in a garden wall. In between the mineral layers are soft protein layers — a sort of "mortar" that holds the bricks together. The protein layer is what makes it so tough. When the mother-of-pearl is compressed, the layers of mineral slide on the protein rather than fracturing. When a crack starts, the soft intervening layers dissipate the energy of the fissure. The abalone shell is twice as durable as the ceramics we use in jet engines. The natural product works better. It's tougher. It's manufactured silently, in water. It doesn't use massive amounts of energy to keep kilns fired up; in fact, if you fired it, you'd destroy the soft part that gives it durability.

S+B: How much are we seeing current industries attempt to mirror the abalone's process?

BENYUS: Just about any ceramics manufacturer would be interested in a material that is twice as tough as what they're currently making. One major roadblock is that translating the natural self-assembly process into an industrial process is very challenging. However, it is being done in a variety of places, like the Sandia National Laboratories at Albuquerque, where Jeff Brinker [a

materials scientist at Sandia and the University of New Mexico] is creating self-assembling materials. He's working on optically clear glass that could be used in windshields for cars. He starts with the liquid precursors of glass — basically, liquefied beach sand. Then he puts in a detergent kind of molecule that herds the organic material together into layers. You dip an object into a pot of the precursors and when you lift it out of the pot, the liquid evaporates and all the other materials set up like oil and water. You wind up with hundreds of layers of optically clear glass, separated by a thin layer of organics. It's a very, very tough material — seven times tougher than our windshields.

It's happening in other realms as well. In electronics, any chip manufacturer is looking into self-assembly of components, including the work with diatoms that I mentioned. Similar work is being done with dye-sensitive thin-film solar cells, which will eventually make solar power more affordable. Another promising technique is solid free-form fabrication, also called rapid prototyping, which builds three-dimensional objects layer by layer without any need for molding or shaping. Right now, it's being used for product prototyping in all kinds of engineering and design studios, but some researchers are looking at how to scale the technique up to "print" a whole house. A CAD program would instruct a crane to lay down layer after layer of cement, or whatever building material you'd use, to build walls.

The researcher leading the charge on this, Rupert Soar at Loughborough University in Leicestershire in the United Kingdom, is finding all sorts of innovative applications for free-form fabrication. Right now he's taking a slice-by-slice scan of termite mounds to see how their tunnels are formed; those tunnels are of great interest because they help keep the mounds at a consistent temperature, no matter what the weather. Dr. Soar wants to use the free-form fabricator to emulate the channels of a termite mound in the walls of your house to create a passive air-conditioning system. Self-assembly is a huge paradigm shift, but it's the future of manufacturing.

Fringe to Mainstream

S+B: What will it take for manufacturing to abandon "heat, beat, and treat" for self-assembly?

BENYUS: It's hard to predict when companies will start jumping in. Rising energy costs will certainly help push things along. But to catch on, any new manufacturing technique has to offer higher performance, and it's got to be cost-effective. In biomaterials, people look for high-value products first. So, for instance, medical-products companies funded the research into mussel glue and have been investigating it for bonding knee ligaments and other surgical purposes. It was viewed strictly for high-value medical applications until they figured out how to make a mimic of the mussel glue inexpensively. Then it jumped over into very cheap products like plywood. Columbia Forest Products is now a big proponent of mussel glue.

A lot of companies are at the point where they've proven the concept and it makes sense for a manufacturer with a high-value application to fund the development costs. They need that next step of funding to bring it to industrial scale.

The real shift will happen when we see more breakthrough products that perform better, are cheaper, use less energy, and leave the company less exposed legally. Then designers and their engineers will start to learn the biomimicry methodologies. Still, it won't become the primary methodology; it'll become one of the tools in their tool kit. When they're trying to solve a problem, they'll ask the question, How would nature do this here? And out of that will come products that we can't even imagine yet.

S+B: Are you seeing any sign that the world's leading innovative companies are starting to incorporate biomimicry into their tool kits?

BENYUS: Absolutely. I'm working with GE designers right now, and they are inspired by CEO Jeff Immelt's Ecomagination, a green R&D initiative he launched last year. He pledged to double R&D spending to $1.5 billion by 2010 for research into environmental technologies such as wind turbines, hybrid locomotives, solar power, and low-emission aircraft engines. GE reported that revenues from the sale of energy-efficient and environmentally advanced products and services hit $10.1 billion in 2005, up from $6.2 billion in 2004; Mr. Immelt has said he wants that figure to hit $20 billion in 2010. He's putting GE's money where his beliefs are. And as part of that effort, they've invited biologists to their design table. They're serious about investigating biomimetic approaches to innovation.

Wal-Mart is also making progress. I think Wal-Mart realized that the next big wave of innovation and cost savings will be in the arena of sustainable technologies. Their

CEO, Lee Scott, decided it was time for Wal-Mart to do with sustainability what the company had done with information-led retailing and distribution — figure it out and perfect it. So in late 2005, he announced three environmental goals: "to be supplied with 100 percent renewable energy, to create zero waste, and to sell products that sustain our resources and our environment." He announced that within the next 10 years, all Wal-Mart stores would use only renewable energy, and in the same decade, they would double the fuel efficiency of their truck fleet. That's huge.

Further, within the next few years, Mr. Scott wants to give up using PVC packaging in all Wal-Mart-branded products; not only that, they're going to ask their tens of thousands of suppliers in 70 countries to work to reduce packaging so that at some point in the future there will be "no dumpsters at our stores and no landfills with Wal-Mart throwaways."

Even before that program is in place, Wal-Mart is going to start giving preferential treatment to the suppliers who have demonstrated a commitment to environmental sustainability, including recent plans to purchase wild-caught fresh and frozen fish from sources certified by the Marine Stewardship Council and to expand their offering of organic foods. That sort of pull going on in the supply chain means change is in store.

When two titans stake their reputations on these big, hairy, audacious goals, the big shift starts to look like it could really happen. I'm aware that Wal-Mart is still a huge company and that it still has work to do in other areas, like store-siting and labor issues, but, along with GE, it's making sustainability a serious criterion for judging its corporate performance. That was unheard of until now. They almost seem to be inviting their rivals to follow their lead. So we could get into a contest. Who is greener? Who is leaner? Who uses less energy? Who's more self-reliant? That's the kind of amplifier effect that could bring about a phase change.

S+B: How will we know when that shift has actually happened?

BENYUS: Keep your eye on how our culture changes. The power of taboo is still very strong, and so is the power of status, and you see them in the kinds of products that consumers lust after and in the kinds of things that people suddenly stop buying. I could imagine a time when you would say, "Oh my gosh, you don't have a hybrid energy drive in your car?" in the same way you go to some restaurants now and say, "Hmmm, there's nothing local on this menu." Five years ago that wouldn't have happened.

We'll know there's been a sea change when the consumer takes Wal-Mart's stand on PVC packaging as a given and carries it to other merchants: "Well, you know, all of their packaging is PVC-free. Why isn't yours?"

We're already seeing indicators in the organic food sector. You see it in labeling schemes; people look for Energy Star on appliances and dolphin-safe tuna. It goes from being fringe to the mainstream. Suddenly, it seems, those concerns are simply part of the way we make sense of our shopping experience, as tools for sorting, and as retailers begin to use them more to differentiate themselves and to pull customers in the door.

This always begins with the early adopters. But then the media makes a story of organic baby food versus nonorganic baby food, and suddenly being a good mom means buying organic baby food. And then a company like Wal-Mart starts carrying organic baby food. And of course, it's got to break over some point where the price becomes affordable. At that point, the customers change from the early adopters who will pay a premium to move the market, to the pragmatists — those who just want to buy something that works well and is as good as it can possibly be but is still affordable. I think we're starting to see that in some products, not all.

S+B: How does this dynamic play out for a company like GE?

BENYUS: GE is taking a big stand in branding sustainability not only as its differentiator, but as a statement of common sense: "Once we know how to build a clean locomotive engine, why would we do it the dirty way?" It's branding itself as an innovation company, and setting the standard for its competitors. Any other company selling the old technology will look obsolete. Eventually it will make enough clean

"Biomimicry looks for the best practices of the 30 million species trying to live on this planet without destroying what sustains them."

locomotives that the price will be affordable, and once that happens, any other company realizes, "We'd better figure out something that is at least as energy efficient, or even more so." And that's when you start to have one of these positive feedback effects.

S+B: So going green can set up a kind of virtuous circle, wherein a company's move toward sustainability sets off a greater demand?

BENYUS: Yes. I'm watching companies that are embracing sustainability depend very heavily on their customers for a new kind of loyalty — it's more than loyalty, it's what you would call a co-evolution. The customer who wants sustainable products is pushing the company to produce those products, and the company in turn is listening to that customer and trying to meet their needs, and also educating the customer about the next step in sustainability. This is what you see in complex ecosystems: symbiosis.

Right now, we don't think of Wal-Mart's customer base as demanding greener practices; we think of that customer base as sorting on price, and that's how Wal-Mart has branded itself. But it may come to the point, as the green supply chain educates Wal-Mart, that Wal-Mart in turn will push the green supply chain to get greener. There's a co-evolution there that can extend even further. Wal-Mart may begin to brand itself around the green offerings, and so it may begin to educate its consumers, and then its consumer base will start to push Wal-Mart even further.

It's really the story of evolution. You have organisms that are attempting to excel at what they're doing, while other species are always coming in and looking for opportunities to excel — and all of them have to be economical. So, there's a standard and that is always rising. Leader organizations can move that standard. Like GE and Wal-Mart, they put their stake in the ground and say, "Here's the new finish line." Or as Nike, another leader, says, "It's the 'no finish' line," because hopefully you keep moving that line. And everybody has to step up.

S+B: And the cost of not stepping up becomes prohibitive.

BENYUS: The cost of not stepping up is either regulatory burden or a loss in market share, or you end up buying other companies' carbon credits, and so forth. [See "Unrecognized Assets," by Molly Finn, Gary M. Rahl, and William Rowe Jr., *s+b*, Autumn 2006.] No one can really say how savvy consumers are going to be, but if you're a company that's not innovative in your processes, you might ask yourself, How long is it going to be until the eco-literacy of my customer base rises and my product is seen as a risk, and they go with the other company? At what point are the taboos going to be about *my* products? Some companies are trying to be the obvious leader in that space — the new space which is not just green but smart, hip, and innovative. They're saying to stockholders, "You should invest in me because your dollars will be safe with me." They're saying to customers, "Buy my products because it will encourage more of this kind of innovation, and *you'll* be seen as innovative because of what you've bought."

This gets back to that taboo-and-status aspect of consumerism. People are proud of their brand-new, energy-efficient clothes dryers, which happen to be the coolest-looking dryers on the market. Environmentally intelligent products are seen as "best in show," not

just for the sustainable-lifestyle consumer, but for anyone who cares about good design.

S+B: There's an essential optimism in your work compared to many who write about climate change or environmental damage.

BENYUS: I have chosen to focus on the solutions. I've chosen to align myself with companies that are moving toward sustainability. I would rather work out of hope — I'd rather get busy than get depressed. But the only reason you'd ever do this kind of work is that you know how bad things really are.

Dee Hock, the founding CEO of Visa International, says things are too bad and it is far too late for pessimism. So I have chosen to find what's working and make more of it. Because that's how life works. Everybody thinks of life as a big struggle; something's always dying out. And that does happen, through evolution. But I think of it as more than just failures dying out. What's really instructive is to look at what gets selected to live on in the next generation. The adaptations that work are the ones that survive.

That's all biomimicry is, when you think about it. It's about finding the things that work. Right now designers across the globe share best practices with fellow designers. They'll notice when someone in Sweden, let's say, is doing this innovative green thing. Biomimicry is similar, except that it looks for the best practices of the 30 million species out there that have been figuring out chemistry, engineering, and physics — trying to live on this planet without destroying the place that sustains them. We are in exactly the same situation. We're trying to live on this planet without destroying the things that sustain us. So let's share best practices from the overlooked, undervalued, underappreciated geniuses that surround us. When you realize that organisms are the embodied wisdom of living well in place, you begin to see nature in a whole new light.

And all it takes is building a structure to get the ideas from biology flowing into human design. Is that hopeful? Yeah, definitely. But don't forget that you can also use biomimetics to create a more dangerous weapons system. Or you could borrow the recipe from a spider to make a fiber as strong as spider silk. But you'd lose the holistic value of biomimicry if you turn around and make that fiber in a sweatshop and then put it on a truck spewing diesel fumes. Unless you biomimic everything — the product, the process, and the whole economy — you're not quite there. That's why I look at it as a three-part pursuit. You mimic the form for design, you mimic the process for manufacturing and chemistry, and you mimic the ecosystem within which companies operate — creating industrial food webs so that the waste of one company is the raw material of the next. If you were to apply nature's principles at each one of those levels, then you really might get something that approximated how well these systems work in nature. That's a big endeavor, and it takes more than just technological know-how from the natural world. It takes humility, will, and wisdom. +

Reprint No. 06310