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Back to nature

Missoula's Biomimicry Institute finds engineering inspiration in the most likely places

by Erika Fredrickson

Missoula's Biomimicry Institute sounds like something out of a sci-fi movie, where retinal scans open sliding silver doors into a crisp laboratory. In the institute's online database, "Ask Nature," you'll find descriptions of anti-counterfeiting technologies and water filtration membranes from places such as the University of Cambridge Nanophotonics Center and The Aquaporin Company. It all sounds so high-tech—and in many ways, it is. But the Biomimicry Institute, a nonprofit organization that employs 16 people, and has an annual budget of $1.4 million, is actually more of a back-to-nature enterprise, quite literally. Its philosophy holds that nature has been evolving designs for 3.8 billion years, and humans could learn a thing or two from them.

"All organisms on the planet today are exquisitely designed because they have continued to adapt better and better to their environment," says the Biomimicry Institute's executive director, Bryony Schwan. "Rather than reinventing the wheel, we should be looking to nature for solutions."

Nature serving as a model for human invention isn't exactly new; designers from Leonardo da Vinci to Alexander Graham Bell have turned to nature for inspiration for everything from flying machines to telephones. The speaker in a cell phone is patterned after the inside of the human ear. The principal mechanism of a chainsaw is patterned after the way beetle larvae chew logs. The Biomimicry Institute has simply taken this phenomenon and made it into a philosophy. Rather than looking at nature occasionally, Schwan says, the institute aims "to develop this into a practice where we have a really deep understanding of how to look to nature for solutions...I think that in many ways we've sort of forgotten how to do this."

Stevensville resident Janine Benyus, a writer and biologist, coined the term "biomimicry" in the 1990s. In her 1997 book Biomimicry: Innovations Inspired by Nature, Benyus refines the concept, offering examples of how humans can design technologies by looking to the ways nature creates structural forms, does chemistry, and establishes efficient ecosystems. Biomimicry isn't just about design, however; it's about designing with intent: to make the world a better and more efficient and harmonious place for all its inhabitants. In that sense, it has an ethical basis that you won't necessarily find in the mindset of some inventors and engineers. Similarly, the precepts of biomimicry can seem counter-intuitive, at least at first, because we've become so accustomed to setting technology in opposition to nature. Biomimicry aims to change that, using the institute to propagate its ideas in mainstream education and industrial practices.

The institute's open-air office, in a sustainable building just off the Hip Strip, feels more Missoula-laidback than high-tech, as you might expect. What you might not expect is that this small-but-growing, six-year-old organization has become the driving force for cutting-edge, worldwide programs that might one day change the way we design the world—and the world itself.

Kingfishers to carpet

Japan's electric bullet train had to be redesigned when it turned out that its 200 mile-per-hour speed was creating sonic booms in populated areas when it emerged from tunnels. The new designer happened to be a birder. At a birding meeting, he noticed that the kingfisher could gracefully dive from medium density air into medium density water without disrupting the water's surface much. "He looked at the shape of the kingfisher's beak," says Schwan. "He did some modeling around that and applied it to the engineering of the bullet train. They not only solved the sonic boom problem but it made the train 10 percent faster and it used 15 percent less fuel."

The bullet train is a graphic example of the way mimicking a form in nature can naturally leads to efficiencies. Other companies are still more deliberate about the environmental ethic of biomimicry. Columbia Forest Products in Oregon, for instance, wanted to find a less toxic process for manufacturing composite wood. Composite boards are typically put together with petroleum-based, waterproof glues and treated in high heat using formaldehyde indoors. The company ended up working with a chemist who used blue mussels as inspiration. The mussels

stick to rocks and other matter in the ocean with a natural adhesive. "Here you have a little organism that stick itself to rocks," says Schwan. "Talk about waterproof! Their glue is made in ambient seawater temperature. The company was able to look at the recipe the mussels were using and mimic that."

One of the more unusual examples of a biomimetic company is Interface, a carpet tile manufacturer in Georgia. Carpet tile is supposed to be an environmental and cost-saving alternative to wall-to-wall carpet. You get a hole in your carpet tile and all you have to do is tear up one and replace it with another. The problem, the company was finding, is that the tile replacement never quite matched the original—color batches always vary a little in shade, and it's hard to find a new tile that will perfectly match a patterned carpet. Customers would often end up tearing up all the tiles and replacing them.

Interface contacted the Biomimicry group, and some of its staff flew out to Georgia. Instead of sitting around a table to discuss solutions, the biomimicry staff took the carpet designers into a forest to study its floor. They picked up twigs and moved them around. They looked at the way that, no matter how much you change things, there's a seamlessness to the design. Why was that?

"It was because it has this mixture of patterning," says Sam Stier, the director of public education and conservation at the Biomimicry Institute. "It's semi-chaotic. It doesn't just have one color palette, it has a bunch of different colors that are more or less randomly distributed."

The carpet designers went back to their tile manufacturing machines and randomized their patterns. They used a wider variety of colors, too, so that matching dye lots no longer mattered. The new carpet tile line, Entropy, was a hit with customers, Stier says. That would have been a satisfying outcome in itself, but in fact Interface, the carpet company, was inspired to go further, Stier notes, setting a goal of having no negative environmental impact by 2020. "One of the ways they're pursing that is that they now take discarded carpet from other manufacturers and reprocess it into their carpet tile," Stier says. "They recycle the nylon, they recycle the backing and keep it out of the landfill—and that's sort of mimicking nature at the whole system level."

Burrs to spider webs

In 1941, Swiss engineer Georges de Mestral returned from a hunting trip in the Alps to discover his dog was covered in burrs. Curious about the seeds' tenacious grasp, he put one under the microscope and saw that its design was simple and perfect: the hundreds of tiny hooks and loops gave it the ability to grab hold of fur and clothing under all kinds of circumstances. De Mestral realized there was potential there for a design never explored by humans before. It took him years to figure out the engineering. But eventually, using loops of nylon, he turned the idea into Velcro.

"The cockle burr has to disperse its seeds to a mammal passing by at any direction, at any speed, under any weather conditions," says Stier. "It can't ask the deer to slow down while it carefully hooks onto its fur. And Velcro has its unique attributes because of the environmental conditions that those burrs had to evolve in to survive."

Stier often uses the Velcro example for young kids. Over the past few years, he's worked with organizations like the Montana Natural History Museum to develop K-12 material for schools interested in incorporating biomimicry. He's also helped create an online course for teachers, which is accredited in Montana, New York and Wyoming, and has been used by about 100 teachers across the country so far. Last year, Stier launched a youth challenge program in which students compete to devise technologies inspired by nature. Students at a Minnesota middle school came up with an idea for a self-warming boot modeled after the way blood circulates through a wolf's paw when it walks through snow. One of Stier's favorite submissions was from a 9-year-old boy who studied how human architecture can learn from the way spider webs are built in triangular segments. "He did it by stretching fishing line and applying force until the strings broke," Stier explains. "At the moment they broke he'd record how much pressure was being exerted." Ultimately, the student showed that the way spiders assemble webs is much stronger than the ways humans tend to build.

Other ideas for biomimicry education have come from outside. In 2008, Missoula singer-songwriter Amy Martin approached the institute about making an album based on biomimicry. She put together a group of kids dubbed the Coyote Choir and wrangled several well-known artists, including Brandi Carlile, Bruce Cockburn, Dar Williams, Ani Difranco and Grammy-winning children's songwriter Bill Harley. The album, Ask the Planet, with songs such as "Keep Our Cool," "No Such Thing As Garbage" and "I Want to be Like a Tree," conveys biomimicry to children, and there are also downloadable teachers' notes for each track. After it won three Parents' Choice Awards in 2009, the Biomimicry Institute was contacted by a teacher in Massachusetts whose students used the album to create a musical.

The Biomimicry Institute also works on less formal education projects. In Missoula, for example, Stier partnered with the Montana Natural History Museum to create four trail signs along the Clark Fork River that talk about organisms in the river habitat and ways they could inspire design. One, titled "How can bull trout teach us to design wind turbines," compares the way fish use water eddies for swimming upstream to energy potential in wind eddies.

Recently, the Monterey Bay Aquarium called Stier to help them solve a problem. They'd received a grant from the National Oceanic and Atmospheric Administration to fund a climate change

program, and they were struggling with how to pull it off without a gloom-and-doom tone. "They were worried because people come to the aquarium to have fun, not to hear about climate change," says Stier.

But then they discovered biomimicry—which led the aquarium to develop the program "From Whales to Windmills: Inventions Inspired by the Sea." Alison Barratt, an aquarium spokesperson, says that one segment details "how the design of the humpback pectoral flippers inspired people to make different types of wind turbines...People come to see how amazing nature is, how evolution has shaped animals to do different things and how inventors have been inspired. People are learning about those technologies but in a way that's not an in-your-face climate message, but just really getting people to think how we can do things differently."

Room-temperature chemistry

A couple of years ago, Stier got a call from a former Los Angeles comedy club owner, Chip Romer, who had become alarmed by the quality of California's public schools. Romer had sold his club and started three Waldorf-inspired charter schools in Sonoma County. Now he wanted to create a high school that was carbon neutral. Everything seemed fine until he woke up in the middle of the night in a panic about chemistry. "He realized they were going to be doing chemistry with Bunsen burners—as we all do," says Stier, "He said, 'Is there any way to do high school chemistry at ambient temperatures?'

"I just laughed," Stier recalls. "I told him, 'It's a good question, but nobody else is asking that.'"

In the industrial world, chemistry is done at high temperatures, using fossil fuels and, often, toxic chemicals. Concrete, for instance, accounts for 5 to 7 percent of global carbon dioxide emissions. It's made through open pit mining of limestone that's cooked at 1,400 degrees centigrade to change the atomic structure so that it's reactive with water. Classrooms full of budding chemists learn the ropes with such processes as their main—and usually only—model.

"We use petroleum to cook everything—every human material in this room is cooked," Stier says, speaking in a conference room at the institute. He points to a solar panel: "We think of solar panels as a clean energy but, in fact, the manufacturing of the panel takes a lot of heat and emits a lot of carbon dioxide."

But organisms in the natural world do chemistry all the time in ambient temperatures. Trees form leaves in 72-degree weather. The mother of pearl on the inside of an abalone shell is formed in similar temperatures, with just the ocean as its pressure range, and the result, says Stier, is "twice as strong as any industrial ceramic that humans can produce...Organisms had to evolve methods of doing their chemistry at low temperatures because they're doing all their chemistry next to their bodies."

Stier started searching for people who were doing green chemistry and found some companies and universities developing technologies that way. One, the Calera Corporation, makes concrete using the same process that corals use to build their skeletons in the ocean. "We thought it would be cool if we could do that in a high school lab," Stier says. "We literally came into this room and brought a bunch of jars and chemicals and we started to play around with them. And we figured it out."

Stier has been working on fine-tuning that process with Big Sky High School teacher Dave Jones. A few weeks ago they spent several hours on it, playing around with the ingredients, adding calcium chloride to raise PH levels. Dona Boggs, a biology professor at UM, has been volunteering a large chunk of her time to tailor the lab so that undergrad chemistry students can use it.

In April, on Earth Day, Stier flew to The Lovett School in Atlanta, Ga. to talk to 600 kids in an auditorium about biomimicry. He was nervous: He envisioned it as one big room full of 600 versions of his high school self. He wondered if he'd get tomatoes thrown at him. But Stier told the students about how nature-inspired design and chemistry work, and what its conservation implications are, and was surprised that the room was fairly quiet—and that afterward there were so many questions that he could barely get out of the lobby, he says. That also made a lot of sense to him. "In high school, they're hearing about all these intense environmental issues that we have. And it's kind of scary. Biomimicry is very exciting and hopeful and I think they just really need that."

Stier remembers what it was like when he first learned about biomimicry. He'd gotten his master's degree at UM in forestry, in a joint program with the Peace Corps. For four years he lived in the Philippines studying flying foxes and working as an environmental educator, and when he returned to Missoula he wasn't sure what to do next. He consulted for several organizations and started working toward his PhD. But he says he missed working in "the real world." In 2006 his wife showed him a job opening at the Biomimicry Institute. "I didn't know what biomimicry was," he says. "The application was terrible. It was, like, 10 essay questions. I said, 'Forget it.'"

But the same week he heard about the job, Janine Benyus was giving a presentation at the Urey Lecture Hall. So Stier went.

"It was the best talk I'd ever seen," he says. "It just turned everything that I thought upside down. I thought that humans pretty much could not live sustainably and that technology and nature were necessarily at odds with one another. I went back that evening and wrote the

whole application and got the job."

There's an allure to biomimicry. Its proponents describe their experience with it as almost a spiritual conversion. Stier, however, is quick to point out that it's not about drinking the Kool-Aid. "We don't try to overstate the value of nature-inspired design," he says. "It's a tool in your toolbox. It's just a source of good ideas. Some people will say, 'Oh, wait a second, it's not like nature's perfect. Evolution is not about making the best design, it's about making a design that's good enough.' And that's sort of meant as a criticism. But in my mind that's really one of the efficiencies of nature: it doesn't try to go beyond what's necessary to do what it needs to do."

Butterflies and painters

Last year, Raul de Villafranca, a professor at the Universidad Iberoamericana in Mexico City, took a group of textile students to the rainforest to spend the night. The Mexico City university, which is affiliated with the Biomimicry Institute, was on a mission to design an insulating quilt as part of a challenge proposed by Bozeman company Pacific Outdoor Equipment.

"With this challenge in mind, he had them experience what it's like to sleep in a sleeping bag," says Megan Schuknecht, the Biomimicry Institute's director of University Education and Relations. "Most of them were from Mexico City, they'd never been camping, and so it was exciting: They looked to the environment they were in to solve this challenge."

Results of the 2010 POE challenge haven't been announced yet, but universities like the one in Mexico City have taken biomimicry challenges seriously. In 2009, several worked together for eight weeks to come up with a tent inspired by the nests tent worms make. POE displayed the tent in its 2010 catalog.

The Institute's third student challenge comes this fall—and this year, the winner will get at least 5,000 dollars, and the institute is hoping to help the winners figure out how to market their product. Entrants must create a biomimetic design for energy efficiency. It's the first challenge that's open to any student anywhere in the world, rather than just the institute's affiliates and fellows. That means University of Montana students are now in the running. "I'm hoping that UM students will participate," Schuknecht says, adding that since the Biomimicry Institute is in Missoula, "they'll have easier access to us."

Schuknecht works with university faculty and administrators across North America, helping them to incorporate biomimicry into their curricula. Seven of those participating universities are developing degree programs in biomimicry. She also works with biomimicry fellows who use biomimicry in their classes although they don't have institutional resources or funding.

One of the challenges of incorporating biomimicry in universities is language. Biomimicry students must be able to understand design terms as well as terms of biology. "Even if you have the support to put together an interdisciplinary class, what we find is that the language issue is critical," Schuknecht says. "Even after a couple of years of biology, you have such a specialized language in that discipline—and the same with designers. That's a bridge all of our educators address: What is the most critical language that each group needs to learn in order to do that collaborative work?"

The language issue is also addressed in the Institute's online database, Ask Nature (www.asknature.org). There you can search for a function in nature, like creating color or collecting water. From that search you can find descriptions of various organisms—say, butterflies, or lipids—that create color or collect water. The database also lists, by function, products from manufacturers all over the world with designs that mimic nature. That it's organized and searchable by function is significant, since most naturalist information online and in print is organized by species or landscape. But Ask Nature is still heavy on the science, so the Biomimicry Institute is revamping it to make it just as accessible to designers, in conjunction with AutoDesk, the software company that creates high-end modeling programs for architects and engineers.

Biomimicry students are learning to strip away their preconceptions and see nature anew. At the Ontario College of Art & Design, in Toronto, which is also affiliated with the Biomimicry Institute, professors Carl Hastrich and Bruce Hinds train students to ignore their generic visions and draw exactly what they see in nature—the lines and the shadows, say, rather than their idealized notion of a tree or a leaf. In biomimicry, god and design breakthroughs are in the details.

In some ways this is a step back to the future. Of necessity, naturalists such as Audubon spent a good part of their careers drawing and painting the fruits of their research and observation. "All naturalists used to draw," says Schuknecht. "They didn't have the fancy tools they do today, so they had to write and draw and paint what they saw. I think that we've lost something in that sequestration of science in one silo and art in another silo."

Though biomimicry is often embraced—sometimes quite feverishly—Schuknecht says it's not always easy to get engineering programs on board with all its aspects. Bio-inspired design has a sexiness in the engineering world, but that doesn't mean it's always done with the intent of solving human challenges in sustainable ways. "Often those program might be designing cool robots that are inspired by how some organism in the natural world works. Afterward they might think of some application, like using the robot to search for earthquake victims in

collapsed buildings—but it's sort of an afterthought. It's not designing with intent. And that's what biomimicry is: It's asking up front what you want your design to do. We encourage students to work on greater challenges that matter to humanity rather than niche needs."

Floating islands

Like the origins of Velcro, the story of Floating Islands International begins with a dog. In 2000, Bruce Kania was out playing with his dog, Rufus, near an irrigation ditch that runs through Billings and ends at the Yellowstone River near Shepard. Rufus jumped in the ditch and came out red, coated from an algae bloom. Kania was horrified. But he was also intrigued. Algae flourishes because there are so many nutrients in water, but it tends to suck up oxygen and smother all other life. "This water was loaded with nutrients," he says. "One would think that those nutrients were moving through the food web. Boy, it would be incredibly productive out here if that were the case. But it wasn't. The water was almost dead."

Kania had an epiphany.

He'd lived in Montana since 1976, and his life had always revolved around healthy water. While attending college in Wisconsin he ran a recreation tabloid and was a fishing guide in the state's northern waters. He needed to take his clients to the best fishing spots, and he began to notice that wherever the record-breaking fish were, there were also naturally occurring floating islands. It wasn't until the day Rufus turned red that he started to connect the dots. Why were the waters near Shepard so much less productive than the ones in upper Wisconsin? And were the islands a missing link?

He had an inkling they were. He consulted with Janine Benyus, the Biomimicry Institute's guiding light, and, over the years, with staff from the institute. He worked with engineers, plant specialists and Montana State University's bio-film program. Ultimately, a team of experts used the floating peat bogs in Wisconsin as a model to construct floating structures made from post-consumer materials like recycled plastic bottles. The fibers of the islands grew bio-film but still let water flow through. And bacteria on the island, which the island used to grow plants, also consumed unwanted nutrients. Kania and the team patented the biomimicry water-cleaning technology as BioHaven floating islands.

"We're biomimicking how nature does it," Kania says. "Our bombs-and-bullets approach, the idea of just killing algae because it's getting in the way, is a failed system. That's not how it's done. Once you do that you're also killing, for example, the bio-film producing microbes that could out-compete the algae in the first place if they're given the opportunity to do so."

At Fish Fry Lake in Shepard, Kania put the islands to the test. The six-and-a-half-acre pond is between 25 and 30 feet deep. The top six feet of the water was full of nutrients and would warm to 88 degrees. Below that, the water was devoid of oxygen. With floating islands, say Kania, the water has cleared. "We're not just sustaining trout, we're sustaining Yellowstone Cutthroat trout, which are perhaps the pinnacle trout in terms of demand for high water quality. Yesterday we had seven little brothers and sisters with their bigs out here and they caught over 70 fish in the space of a hot Sunday afternoon."

Now David Mumford, public works director for Billings, is testing floating islands with sewer lagoons to see if they'll reduce nitrogen and phosphorous.

"It has been showing substantial improvements," Mumford says.

Mumford has also tried floating islands with storm drains, though those are proving to be tricky because of inconsistent water flow. And he's given Kania's company, Floating Island International, access to Billings' wastewater facility to test its technology. "Dave has been a champion of what we're doing," says Kania. "He's been fundamental to some very key research."

That's just Billings. Floating Island International now has eight licensed companies, including one in China and one in New Zealand, and 4,000 islands in waters all over the world. It's built a 39,800 -square-foot floating island for the U.S. Army Corps of Engineers. And Kania's not close to being finished. That saying that once you launch a boat it begins to sink? Once you launch an island, it begins to grow.

"We have islands in the ocean, islands in brackish water and lots of islands in fresh water," he says. "One day people will be growing their own islands to live on. The islands will not only be digesting the waste from the people who live on them, but cleaning up the waste associated with previous human activity—like the 390 dead zones currently in oceans around the world. We think we're at the beginning of what will become a new way of relating to our aquatic environment."