100% All-Natural Inspiration

Finding engineering design solutions in the natural world is nothing new, but the idea is becoming a more formal discipline that meshes with the engineer's ethical responsibility for sustainable development.

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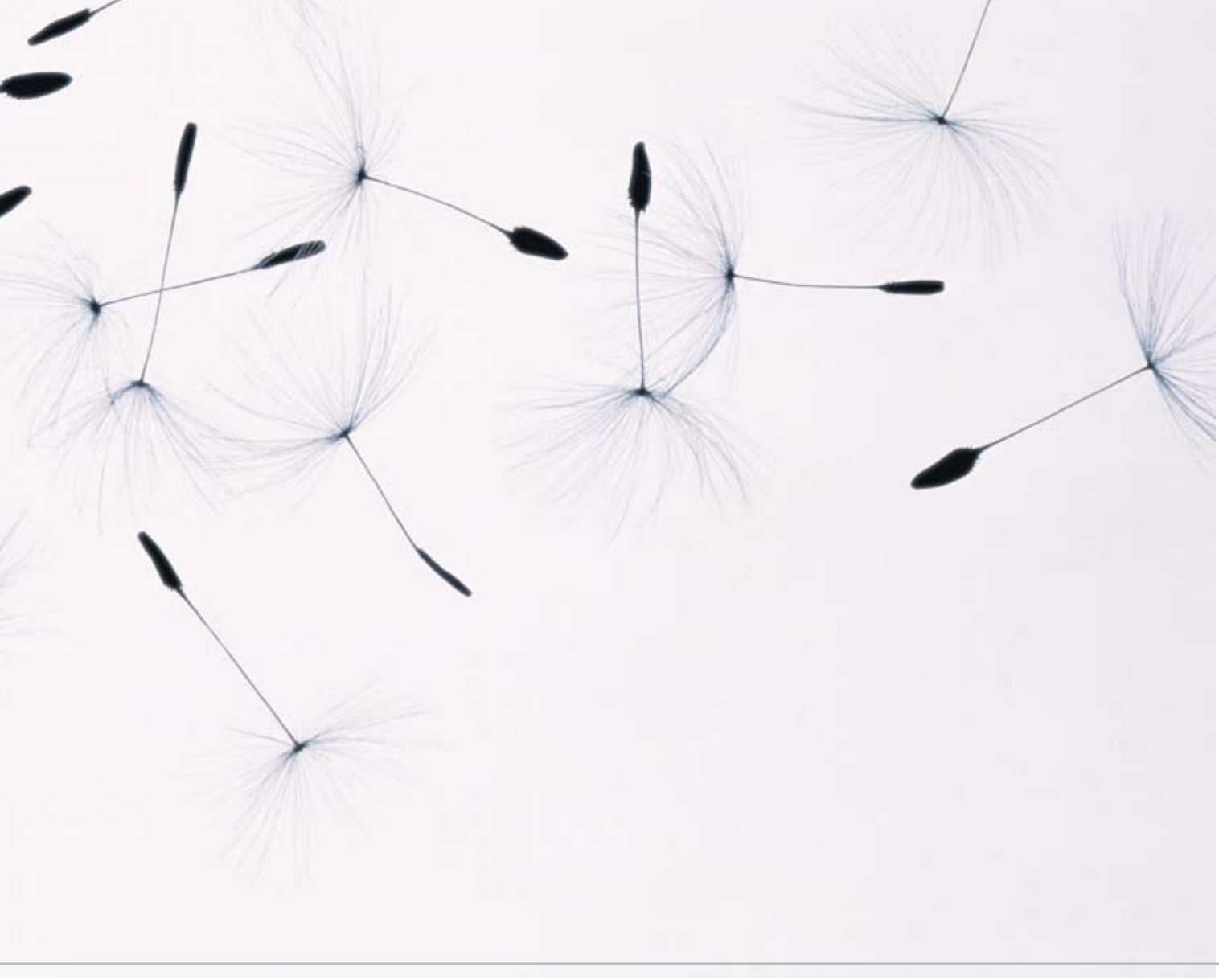

In addition to protecting the public health, safety, and welfare, professional engineers have an ethical obligation to safeguard the earth. In January 2006, NSPE became another voice in the chorus of engineering organizations that have added environmental protection statements to their codes of ethics.

As the engineer's responsibility to the environment becomes more recognized, it's less clear exactly how the individual should go about fulfilling that responsibility. An emerging field, however, is offering some answers. Biomimicry, sometimes called biomimetics, bionics, or bio-inspired design, is slowly but steadily gaining followers as not only a near-infinite source of ideas and inspiration, but also a path to sustainability.

Biomimicry can be defined broadly as design inspired by nature. Some have said that, if one believes in Greek legends, biomimicry can be traced to Daedalus, the father of Icarus, who looked to bird wings as a model for creating wings for his son to fly.

In modern history, the Wright Brothers were inspired by the way birds bank into a turn. And a Swiss engineer, observing the way burrs stuck to his dog's fur, invented Velcro in the 1940s.

"[Nature provides] a 3.8 billion-year research and development lab," says Janine Benyus, applied scientist and author of *Biomimicry: Innovation Inspired by Nature*.

Benyus, who defines biomimicry as a problem-solving method, explains that a lot of biomimicry engineering work comes out of Germany, Japan, and the United Kingdom. She adds that the U.S. is holding its own, partly due to the popularity of the approach with the defense industry and space program. For example, the Defense Advanced Research Projects Agency and NASA are studying the navigation and locomotion of insects to design future generations of robots and vehicles.

Benyus and her organizations, the nonprofit Biomimicry Institute and the for-profit consulting arm Biomimicry Guild, define biomimicry more broadly than insect-inspired robots. For her and her colleagues, biomimicry is not just using nature as a source of design ideas, but expanding its role to "model, measure, and mentor." That means replicating not only the organism or material but also the natural processes and ecosystems. It is this type of biomimicry that can provide engineers with important lessons about sustainability.

So while an aerospace company may examine the way geckos stick to surfaces to develop new adhesive products, the expanded definition of biomimicry would ask them to go further and examine how the rest of the product life cycle fits into the natural world.

"It gives you a universal tool to develop sustainable design," says Denise DeLuca, P.E., a contractor with the Biomimicry

Guild who is about to join the Institute's full-time staff to focus on engineering education. Trained as a civil engineer, then working in environmental compliance, DeLuca decided she wanted to be more proactive. Instead of helping companies clean up messes they created, she wanted to help them avoid making the messes in the first place.

When she attended a biomimicry workshop, she was struck with how

A "DAYLIGHTED" STREAM AT THE UNIVERSITY OF VIRGINIA WAS RE-CREATED BY NITSCH ENGINEERING TO ADDRESS STORMWATER MANAGEMENT AND RESTORE ECOLOGICAL BALANCE.

powerful the approach was and how it could pull together a lot of sustainable design concepts. She then became curious about adapting biomimicry to make it a more practical tool for engineers. As owner of Emergent Solutions, an engineering consulting company with a focus on sustainable resource management, she is writing a handbook for the Biomimicry Guild that will provide specific steps, procedures, and quality control for designers, including engineers.

"For many people who are worker bees and want to get the job done, [biomimicry] is conceptual and can feel eco-groovy. They say, 'It's cool, but I don't know what to do when I get back to my desk on Monday,'" DeLuca says.

Her book will help answer that question. One tool it will provide is the Biomimicry Design Spiral developed by the Biomimicry Guild. This iterative model spells out the steps engineers and other designers should follow in not only developing sustainable solutions based on nature, but also ensuring that the surrounding processes and ecosystems are sustainable.

Designers will work through the seven-step process repeatedly, DeLuca explains. "Each time [you go through the spiral] you learn more and become more innovative and sustainable."

The design spiral's steps are

- Identify: break the problem down to its core desired function;
- Translate: examine how nature does or does not do this;
- Observe: find the best models in nature, considering both literal and metaphorical models;
- Abstract: select the champions in nature with the most relevant strategies, abstract from the list the repeating successes and principles;
- Apply: develop concepts and ideas that apply the lessons from nature, mimicking form, function, and ecosystem;
- Evaluate: compare your ideas against successful principles of nature; and
- Identify: develop and refine your ideas based on lessons learned from evaluation of life's principles.

This process could, for example, inspire an engineer working toward a better water filter to look beyond traditional approaches to emulate how selected compounds stick to organic molecules on microbes, DeLuca explains. But it could also determine that the new approach has created negative effects and is not capturing the sustainability of life's principles. That would send the engineer back through the design spiral to modify the design.

Once the designer has determined that the product is biomimetic and sustainable, DeLuca says, more can be done by looking upstream and downstream. Where are the materials for the product coming from? Can we use more sustainable materials? How does energy, water, and material flow through the factory that creates the product?

And then, how will the product be distributed and used? "In nature, when something dies, it's to the benefit of the soil or some other creature that eats it," DeLuca says. "For us, most of our things when we're done with their design life are negative and a disposal problem." End-of-life questions may send the engineer around the design spiral again, looking at the materials or shape that can be used to make the product a benefit at the end of its life rather than a detriment.

Biomimicry principles can lead to some dramatic results. An airplane wing model developed by Applied Fluid Engineering and based on the scalloped edge of a humpback whale flipper reduced drag by 32%. Numbers like that pique the interest of engineers who know that a 1% drag reduction would result in phenomenal fuel savings, Benyus says.

The nose of Japan's bullet train was inspired by the beak of the kingfisher, enabling the train to go 10% faster and decreasing the energy load by 15%. And InterfaceFLOR Commercial has created carpet tiles that adhere through gravity rather than glue, reducing environmental impact by 95%.

Biomimicry is also helping to provide practical solutions for sustainability in the

building industry. Companies like Arup, a global design and business consulting firm, and Boston-based Nitsch Engineering, which provides civil engineering, land surveying, and planning services, are creating sustainable buildings and environments using biomimicry concepts.

Nicole Holmes, P.E., project engineer at Nitsch, explains how the company does stream daylighting, bringing urban storm drains back to the surface. The process mimics how a real stream allows plants and soil to absorb pollutants and lets water infiltrate the ground and recharge aquifers.

Nitsch has worked with several universities to create sustainable designs using biomimicry principles. At the Massachusetts Institute of Technology, Nitsch collaborated with a landscape architect on the Stata Center for Computer, Information, and Intelligence Sciences, creating a miniature replicated wetland area that recirculates and cleans the water and reuses rainwater to flush the building's toilets.

"It's easy to think of [public health, safety, and welfare] in terms of designing a bridge so it doesn't collapse," says Holmes. "But … I think it's really our responsibility as civil engineers to promote systems that don't continue [environmental] detriment and hopefully help improve it."

David Richards, environmental building engineer and a director of Arup in London, says his company often takes a germ of an idea from nature and expands on it. For instance, Arup designs building envelopes that mimic human skin. The outer building envelope is layered, consisting of a double skin of glass. The outer layer acts as a thermal flue, rain screen, and wind baffle. The inner skin lets building occupants choose natural ventilation or air-conditioning. The area in between the skins contains active solar blinds on the outside of the inner cladding.

Arup engineers have also designed a ventilation system for a building in Zimbabwe that was inspired by a termite mound's use of thermal mass.

Richards says it's important for engineers to know about biomimicry, not just in a technical sense but also in an inspirational sense to broaden their outlook. "Nature has managed to work out so many seemingly really difficult problems in very simple ways," he says. "As engineers, we sometimes don't go for simple solutions or dismiss them for being too simple. Nature reminds us it's not always like that."

To help find the simple solution, engineers involved in biomimicry can, and should, draw on the work of biologists. Experts point out the interdisciplinary nature of biomimicry and how engineers and biologists need to learn about each other's fields and work closely together. That team approach must start at the university level and continue into the work world, Benyus says.

This team approach is taking place at Georgia Tech's Center for Biologically Inspired Design, which aims to bring together the 21st century engineer and the 21st century biologist. The center is a workplace for engineers who can speak the language of biology and make use of its structures, processes, and principles, and biologists who can team up with engineers and physical scientists to examine biological structures, processes, and systems as evolved solutions and sources of engineered designs.

THE VENTILATION SYSTEM FOR THE EASTGATE CENTRE IN HARARE, ZIMBABWE, WAS INSPIRED BY THE VENTILATION OF TERMITE MOUNDS. THE BUILDING USES 10% OF THE ENERGY OF A CONVENTIONALLY COOLED BUILDING OF SIMILAR SIZE.

Students in the biomimicry course work on engineering projects in teams of both biologists and engineers. Craig Tovey, a center director and professor in the School of Industrial and Systems Engineering, says the students start out speaking different languages, but the change by the end of the semester is striking. In addition, several of the biology students from the biomimicry course participated last year in mechanical engineering senior design projects.

That model is also put to work at Nitsch Engineering. Nicole Holmes explains that when the company did stream daylighting at the University of Virginia, they hired a company of biologists and ecologists to do the physical design. And the Biomimicry Guild serves as biologists at the design table for companies such as General Electric, Herman Miller, and Nike.

The Biomimicry Institute hopes to create a prize for teams of biologists and inventors who work together to solve sustainability problems in fields such as agriculture, building, chemistry, energy, and manufacturing. Biomimetic solutions will have to demonstrate an improvement to existing technology.

To help designers and biologists collaborate, several organizations are putting together repositories of natural models that designers can consult when looking for solutions. The University of Maryland's Biologically Inspired Product Development program is creating one such bio-inspired design repository.

The Biomimicry Institute has developed a prototype of a similar portal, which Benyus calls "a Google of nature solutions." And a company called Biomimetic Connections LLC offers portfolios of biomimicry intellectual property developed by universities and available for in-licensing by corporations.

But nature is the real owner of biomimicry intellectual property. To uphold that idea, the Biomimicry Institute's Innovation for Conservation program encourages companies that have benefited from the ideas contained in the natural world to donate a portion of their proceeds to conserve those species' natural habitats. Because, after all, says DeLuca, if the vast library that is the natural world disappears, then nobody will be able to benefit from its wisdom. PE