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Biomimetic Buildings: Understanding & Applying the Lessons of Nature

(This is the second installation in a series of three articles.)

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"We do not seek to imitate nature, but rather to find the principles she uses."

—Buckminster Fuller

Global population is set to explode. In the coming century we will likely build more and faster than we ever have just to keep up. The question is, will we be able to do it without completely annihilating the natural environment? In 1996 we sent over 299 billion pounds of construction and demolition waste to the landfill, much of which could have been reused or recycled.[i] Energy-wise, our buildings swallow two-thirds of US electricity.[ii] And these numbers keep growing. In the words of William McDonough,[iii] "our culture has adopted a design stratagem that essentially says that if brute force or massive amounts of energy don't work, you're not using enough of it."! Can we keep building and building while at the same time slow our damage to the environment? Is there perhaps a way that building could have a restorative effect? RMI believes there is.

For years RMI has been promoting green building techniques (e.g., passive solar heating, daylighting, natural ventilation) to help decrease the environmental footprint of buildings. Now we are adding a new and extremely valuable tool - biomimicry - to our toolkit. Previously ("Building the Future of Buildings," RMI Solutions, Fall 2002), we introduced the topic of biomimicry as conceived by noted science writer Janine Benyus. We learned that biomimicry can be applied to buildings in three fundamental ways: (1) to make stronger, tougher, self-assembling, and self-healing materials; (2) to use natural processes and forces to accomplish basic building functions such as heating and cooling; and (3) to produce resources, rather than drain them, by utilizing the biomimicry principles of zero waste and co-evolution. In keeping with the natural capitalism model, we aim to show that incorporating natural materials and processes into a more holistic design paradigm for buildings is not only environmentally sensitive, but also eminently practical and profitable.

Biomimicry makes sense. Since time immemorial nature has been struggling with many of the same problems we now face (structure and support, coloring, heating and cooling) and has developed the most energy- and materials-efficient design solutions in order to survive. Whether we are designing or specifying building materials (e.g., insulation, interior and exterior color, fire protection, waterproofing) or building systems and processes (e.g., temperature regulation, fresh air, water supply, and cleaning) we can learn from nature.

A tremendous database of natural solutions is all around us, but to access it we need to pose the right questions and frame them in a way that biologists - the keepers of the database - can understand. With this in mind we at RMI have chosen six of today's gravest building problems and are seeking mechanisms in nature that might provide a solution to them. The problems include: scaling in pipes, toxic adhesives and clumsy fasteners, concrete production and use, interior and exterior coloring, cooling in hot, humid climates, and unhealthy interior mold growth. We do not presume to have solutions for any of these problems at this time, but with the help of a biologist we have entered Nature's library of solutions and browsed a few abstracts. In October 2002 RMI hosted a biomimicry brainstorming session involving Biomimicry author Janine Benyus and RMI's GDS team to catalyze a flow of biomimetic ideas and applications. Some of our results appear below.

Pipe scaling causes millions of dollars of damage each year, and attempts at removing it release disagreeable chemicals to waterways around the globe. It may not be immediately obvious that nature could offer a solution to this man-made problem, until we consider that scaling is simply the deposition of calcium carbonate onto the pipe. Knowing this, we can now look in nature's database for a creature that has learned to manipulate the landing and placement of calcium compounds. One creature particularly good at this is the deep-sea abalone. It forms a rock-hard shell by inducing calcium ions from surrounding seawater to fit exactly into its ionic blueprint. But why doesn't the shell keep on growing forever? When the shell is large enough, the abalone secretes specialized "stop" proteins that prevent further calcium ions from accreting. If we could coat our pipes with similar proteins (or mimic the shape of these proteins with another material), then calcium ions could no longer adhere. The problem of scaling would be eliminated, thus saving millions of dollars in chemicals and pipe replacements with a simple, preventative solution.

Another intriguing problem we are tackling is the energy-intensive production of concrete, specifically its key ingredients. Production of Portland cement, a key ingredient of concrete, is responsible for eight percent of world CO_2 emissions.[iv] Also, mining the raw materials that go into cement and concrete damages landscapes and ecosystems. Nature cannot afford a global network where one locale is stripped to provide resources for another, with fossil-fuelled transportation as the carrier between. Neither can we. So how would nature produce a strong, hard building material that can be shaped to any form? Termites do it with their own saliva and abundant local material: dirt. Perhaps more interesting, the versatile abalone goes through a process of self-assembly called "bio-mineralization." To form its XXX shell, twice as tough as ceramic, the abalone sets up a three-dimensional, electrostatically charged lattice (imagine scaffolding) that attracts calcium ions to fill in the gaps. This creates hard "bricks" of chalk, "mortared" by layers of squishy polymer that absorb impacts and halt cracks. The result is a repeatable, perfectly ordered, crack-resistant, nearly indestructible shell - all produced from a few proteins, a little seawater, and the selective pressure of otters pounding on the shells with rocks - a strong incentive not to crack and get eaten.

In an attempt to mimic the laminated hard/soft construction of natural abalone nacre, Jeff Brinker at Sandia National Labs has developed a rapid self-assembly approach. Common detergents organize inorganic and organic precursors (building blocks) into hundreds of alternating layers in a single step. The process currently produces coatings, but its extension to building materials might be envisioned. Imagine if we could spray a self-assembling template onto some basic scaffolding and then throw on buckets of seawater and watch it coalesce into a strong, sturdy wall. Seawater is a renewable resource and the process requires no external energy. There is even evidence suggesting that bio-mineralization sequesters CO_2. Conceivably, then, a biomimetic concrete might allow us to reverse global warming instead of accelerating it, and give us a more durable, versatile concrete as well.

Animal architecture is another database we can search for advanced materials and processes. From a whole-systems perspective, the African termite mound might be the supreme example of advanced animal architecture. It incorporates exquisite solutions to pervasive design problems (structural strength, elemental protection, ventilation, humidity control, etc.) that we also face. So far at least one building has been highly successful in mimicking this sophisticated ventilation system. The Eastgate building in Harare, Zimbabwe, uses the termites' innovative design to keep the building cool during the hottest days. Using nature-inspired design to circulate fresh air into the building in place of noisy, electricity-hogging air-conditioners and fans improves comfort and cuts energy bills. This makes for happy building occupants who pay less and are more likely to renew lease agreements.

So how do these ideas become reality? How are they developed from a hopeful possibility into an end product? Learning nature's secrets and then making the conceptual leap to biomimetic buildings and products will require a synthesis of fields. Architects, engineers, biologists, and designers all need to work together to both understand nature's innovations and collaboratively use these innovations to create healthy, usable environments.

This synthesis of fields makes the best use of each professional's experience for achieving a common goal: the non-violent overthrow of bad engineering. The trials humanity now faces are so interrelated in their scope that working together has ceased to be an idealistic dream - it is now a necessity.

Our buildings need to work together as well. If we were to design them with a specific ancillary function (i.e., an opera house that is also the community lung), we could then weave them into the fabric of a more robust, interesting neighborhood. This approach to biomimicry goes beyond the level of an individual building and what materials it contains to present an overview of a whole system working in harmony. After all, a forest is more than just a collection of individual trees.

The next article in this series will show how biomimicry can be applied to create these communities, and will tie together the nine principles of biomimicry into a complete solution for making buildings an effective restorative tool not only for local communities, but for local (and global) ecosystems as well.

Those further interested in biomimicry can order a copy of our newest publication "Bio-Inspired Design: Ideas, Wisdom, and Applications from Nature" on our website (http://www.rmi.org). The paper targets six top modern design and/or construction issues and provides leads on biomimetic solutions to these problems. It also provides a methodology for approaching problems in a biomimetic way. Funding for this paper and Onno's internship was generously provided by Mineral Acquisition Partners as part of their new Summer Energy Fellows program (www.maproyalty.com/sef.html).

[i] Franklin Associates, for US EPA, 1998, "Characterization of Building-Related Construction and Demolition Debris in the United States", page ES-2 available for download at http://www.epa.gov/epaoswer/hazwaste/sqg/c&d-rpt.pdf, viewed 17/1/03

[ii] Donald Aitken, UCS, 1998, "Whole Buildings: An Integrating R&D and Policy Framework for the 21st Century", pg vi. Full report available at http://www.ucsusa.org/clean_energy/renewable_energy/page.cfm?pageID=113, viewed 17/1/03

[iii] Tom Gibson (Editor), Progressive Engineer interview with William McDonough, "A Common Sense Environmental Approach" available for viewing at http://www.progressiveengineer.com/PEWeb%2010%20SepOct%2000-2/McDon.htm, viewed 17/1/03

[iv] Environmental Building News, Vol 2, No. 2, March-April, 1993.

Onno Koelman was RMI's inaugural Mineral Acquisition Partners (MAP) summer energy fellow researching biomimicry. He currently works with PAX Scientific, leading the way into the next industrial revolution using principles found in nature to streamline technologies across industries. He holds a BS in Mechanical Engineering from Stanford University.

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