

BioDesign

By William Myers

“It will be soft and hairy.”

-Salvador Dali, on the future of architecture, in response to Le Corbusier

1. What is BioDesign?

BioDesign is the integration of design with biological systems, often to achieve better ecological performance. In contrast to design that mimics nature or draws on biology for inspiration, BioDesign incorporates living organisms into design as building blocks, material sources, energy generators, digital storage systems and air purifiers, just to name a few possibilities. BioDesign is both opportunistic and logical in recognizing the tremendous power and potential utility of organisms and their natural interaction with larger and ever-changing ecosystems around them. BioDesign can also be a means of communication and discovery, a way to provoke debate and explore the potential opportunities and dangers of manipulating life, particularly through synthetic biology, for human purposes.

This new approach is often a response to the growing urgency to build and manufacture more sustainably in light of the climate crisis. This, in turn, leads to unprecedented collaborations between designers and life scientists, such as biologists who increasingly understand how organisms function to the molecular level. The recent proliferation of such cross-disciplinary activity is occurring in schools, labs and even in garage work benches around the world. One important outcome of this new approach

to design has been the development of critical and narrative objects that blur the border between art and design and which envision the effects of new technologies and scientific research on human behavior and culture. But while BioDesign does have enormous implications for the future of human interaction, it most immediately demonstrates its potential when the architect or designer taps into the expanding ocean of knowledge created by biologists and working in collaboration with them, try to solve some of the world's most pressing design problems.

Biology stands out among the sciences for its frequent, accelerating and fundamental progress in recent years. The first industrially useful genetically modified organism was a bacterium made some thirty years ago to be a reliable and inexpensive factory for insulin. Only nine years ago the human genome was mapped at significant expense and effort over many years, and now a \$1,000 genome sequencing technique appears to be around the corner, certainly within two years. And just in the fall of 2012 it was discovered that among the 98% of human DNA long thought to be "junk" left by our evolutionary legacy are in fact numerous, essential switches that control gene behavior. Meanwhile, the cost of genetic synthesis is falling rapidly, roughly following the phenomenon described by Moore's Law, which holds that the number of transistors on integrated circuits doubles every two years, helping computers become continually cheaper and more powerful.

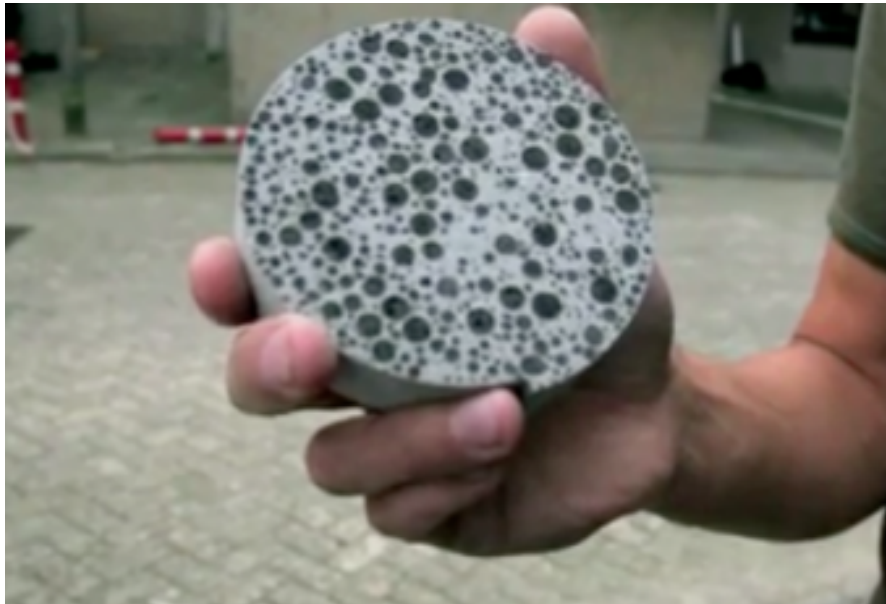
One significant area of development is in the study of microbes, particularly types that can survive in inhospitable places. The ever expanding zone of habitability for life holds great promise for new discovery and application. The first of these major discoveries about forty years ago, that of the bacterium *Thermus aquaticus*, is the source of an enzyme now called Taq DNA polymerase that enables the amplification of DNA samples like a photocopier and has become a common and essential tool in almost every biotech lab around the world. It was even more recently that microbes were found in such forbidding environments as the deep sea bed and upturned conventional wisdom about the requirements for sustaining life. Now it is understood that within rocks, and inside frozen, toxic and fantastically hot places, life indeed thrives. This has led to the addition to a new branch on the tree of life to describe these hyper-resilient microorganisms: Archea.

Why is this important for design? Their existence has been invisible throughout much of human history, but the potential for designers and scientists to develop new and useful applications with this previously unknown form of life is significant. The astounding attributes of these ultra-specialized species might be harnessed for numerous practical applications. Their unique genes might be inserted into other organisms to produce useful outcomes. For example, microbes have been found within nuclear reactors that have developed the ability to continually protect and repair their own DNA as it is bombarded by levels of radiation that would be otherwise lethal. Harnessing such a mechanism might inform a future cancer treatment to retard growth. Another extremophile was able to survive on the outside of the International Space Station for 553 days, in the freezing vacuum of space. Respect – and awe – for these invisible specks of life is fitting: consider how the human body is now known to be made up of 100 trillion cells, 90% of which are foreign microbes living on and inside us symbiotically.

The structures, prototypes and concepts emerging in the field of BioDesign, including proposals that rely on the newest technologies, prompt several questions. What are the implications and likely outcomes of turning to living organisms for human ends? Do these experiments, demonstrating an embrace of natural systems and collaboration with the life sciences, amount to a paradigm shift in design practice, akin to the industrial revolution's embrace of physics and chemistry, or a return to an age of consilience as seen before the Scientific Revolution, when architects like Christopher Wren were also scientists? If so, how does it compare to other field-changing shifts in the trajectory of technological developments, from industrialization to the invention of computers?

As answers to these questions unfold, space and support for cross-disciplinary collaboration and creativity prompted by scientific research will only expand, propelled by global imperatives such as the urgency to develop and implement cleaner technologies and the rise of do-it-yourself “homebrew” biology. This convergence of fields, as well as of the expert and the amateur, is ultimately necessary to alleviate the negative impacts of the legacies of the Industrial Revolution. And it will lead to the reconception of the primary design principles of value generation, growth and sustainability. By highlighting BioDesign, my intention is to accelerate its development, sound a cautionary note about possible unintended consequences but ultimately encourage more collaboration across disciplines.

New techniques of BioDesign are being created rapidly. Recent highlights include:



Bio Concrete

This experimental material technology developed by Henk Jonkers at the Technology University of Delft utilizes *Sporosarcina pasteurii*, a robust bacterium that naturally secretes limestone in specific conditions. These bacteria are mixed with nutrients in concrete before it dries and, as wear and age form cracks in the concrete, the bacteria animate and secrete limestone, effectively repairing the cracks. This biologically-integrated material may well extend the service life of concrete while lowering the cost of maintenance, resulting in a smaller carbon footprint for one of the world’s most common building materials. At present, concrete is responsible for up to 5% of all human-made carbon emissions.



Building Botany

This technique of building with trees as supporting structure was developed at the University of Stuttgart by Ferdinand Ludwig, Cornelius Hackenbracht and Oliver Storz. It utilizes growing trees as load bearing materials, most often aggressive rooting and fast growing species such as willow. These demonstration structures highlight the adaptability and beauty of incorporating natural systems. The supporting branches and trunks actually strengthen over time in response to stress, as would a human muscle. Among the architects' intentions are to reveal the actual impermanence inherent in all architecture and also to display a new aesthetic characterized by constant change, surprise and uncertainty.



EcoCradle

This material technology by Ecovative Design in the United States is commercially available and is a competitive alternative to petroleum polymer foam used for packing – material that typically lasts hundreds or thousands of years, represents 25% of waste landfill sites by volume and often contains toxins such as benzene. In contrast, this material is made from mycelium, a structural part of a fungus that is characteristically rigid and dense. This material is thus grown using local agricultural wastes and can be formed in molds to generate whatever shape is required.



Microbial Home

This concept for the home was developed by Philips in the Netherlands and comprises several integrated appliances that heat, refrigerate and generate food, as well as digest waste products using living microorganisms. The individual units are designed to work as a cycle that resembles an ecosystem and utilize bacteria, fungi and other naturally occurring organisms to enable each process. For example, the Methane bio-digester accepts food scraps and generates gas to power the stovetop.



Latro Lamp

This experimental design for a lamp by Mike Thompson illustrates how we might generate light in the near future. Recent experiments in biotechnology using nanosized gold electrodes inserted into algae to draw an electric current from the process of photosynthesis suggests how we might develop algae-powered light sources in the future. Thus, we may keep communities of contained organisms as symbiotic pets, caring for them in return for their energy and illumination.

2. What is NOT BioDesign?

BioDesign is not biomimicry. Biomimicry is a thoughtful approach to design and engineering that looks to nature as inspiration, measure and mentor. Janine Benyus describes this approach in detail in her outstanding book on the subject from 1997.

BioDesign is instead a strategy to achieve core underlying goals of Benyus and other champions of ecological design, notably William McDonough and Michael Braungart. An analogy to think of biomimicry or Cradle to Cradle design is to imagine an architect observing a tree and admiring its strength, adaptability, and function in supporting the surrounding ecosystem. Here is a “machine” that

produces leaves and fruit and clean air and plays host for countless other species, from birds to bacteria. It obtains all its energy from the sun and leaves behind no wastes: all of its components can safely reenter the ecosystem. The architect might say “how can I design a building that *resembles* that?” And that architect would be on a noble quest indeed. BioDesign, however, leads the architect to ask a different question: “how can I design these living trees *into* my building?”

A problem with biomimicry or “nature design” is that these labels are applied vaguely and sometimes take no account of intention or outcome. Design that follows nature in form or material usage simply for symbolic, decorative or metaphoric effect is divorced from the idea of BioDesign as a method of ecosystem integration.

The following items are not BioDesign, although they may be quite useful or beautiful in their own right:



Tord Boontje, Midsummer Light, 2002



Mercedes Benz, Bionic Concept Car, 2005



Tonkin Liu, Shi Ling Bridge, 2009

3. Why BioDesign Now?

“Our objective is to use bio-based materials and processes for civil engineering to reduce environmental pressure.”

-Dr. Henk Jonkers, University of Technology, Delft

BioConcrete provides a ready example of how BioDesign is developing. The history of concrete is long and closely intertwined with that of architecture, economics and technological development. A glance at how and when this common material has changed from the time of ancient Rome to the present day illuminates how BioDesign has emerged and why it will be essential in the near future.

Concrete was first widely used in the 4th century BC and was integral to the Roman Architectural Revolution, a phenomenon that spanned several centuries and left us with structures that still stand today. Soon after the fall of Rome in the fifth century however, the formula for concrete, calling for particular proportions of calcium oxide, rock, clay, ash and water, was lost for thirteen centuries. For all that time, no concentration of wealth and political and economic power matched that of the Roman Empire and so did not create the conditions for concrete’s rediscovery. This changed at the dawn of the Industrial Revolution, an era of accumulating wealth and fundamental changes in society that would in turn make concrete an extremely useful commodity.

Approximately one hundred years after concrete was rediscovered in England in 1756, reinforced concrete was developed in France by François Coignet and was deployed to create several types of structures that are familiar today. This type of reinforcement was characterized by adding iron bars within the material to increase its tensile strength and enabled such structures as lighthouses, aqueducts, bridges and ever taller commercial and residential buildings. Thus, concrete was an answer to many of the most pressing issues of the time as it helped enable economic growth, urbanization and even colonialism.

Today, a new and compelling need is emerging to reduce the environmental impact of human activities, including building, and concrete is again an illustrative medium with which to observe it. With the rapid urbanization of the world – now counting over 7 billion people, more than half of which reside in cities – the production and application of concrete is soaring. Notably, each ton of concrete produced generates a roughly equal amount of carbon emission; total world production in 2011 was 3.4 billion tons. The use of concrete thus represents approximately 5% of all human-made carbon emissions globally. Abundant evidence makes plain that current systems of design and production reflected by this trend simply cannot continue in a world where many more billions of people are becoming prosperous consumers. The environment cannot endure this pressure and simultaneously continue to sustain life as we know it.

BioConcrete (see photo above) utilizes specialized microbes to make concrete self-healing. This enhancement can extend concrete’s service life while lowering the costs of maintenance. If it can be perfected and widely adopted, it alone would represent a tremendous step toward lowering the impact of human activities on the environment. Such a goal is becoming a critical priority for humankind.

Understood in this way, BioConcrete is a type of reinforced concrete for a different goal: microbes replace steel and ecological performance replaces strength.

Given this mounting pressure on design, building and manufacturing, designers are turning to the lab, to the study of organisms and ecosystems that can be harnessed to enhance the objects we rely on. Finding technologies, designs and models that integrate nature into human activity in a way that is beneficial to both, whether by microbes embedded in infrastructures, trees supporting our homes, or algae generating our energy, will be difficult but may be the best, smartest and most achievable way to avoid global ecological ruin. In sum, biology represents both the best set of tools to reach our design goals and the most important resource for our mutual, long-term survival.

4. How do I learn more about BioDesign?



Recommended books and articles:

Myers, William. *BioDesign: Nature + Science + Creativity*. New York: Museum of Modern Art, 2012.

Dyson, Freeman, "Our Biotech Future." *The New York Times Book Review*, July 19, 2007.

The Economist, "Some Like It Very Hot." June/July 2012.

Aldersey-Williams, Hugh. *Zoomorphic*. New York: HarperCollins, 2003.

Antonelli, Paola. *Design and the Elastic Mind*. New York: Museum of Modern Art, 2008.

Dyson, Freeman. *The Sun, The Genome, and The Internet*. New York: Oxford University Press, 1999.

McDonough, William and Michael Braungart. *Cradle to Cradle*. New York: North Point Press, 2002.

Benyus, Janine. *Biomimicry*. New York: HarperCollins, 1997.

Carlson, Rob. *Biology Is Technology: The Promise, Peril, and New Business of Engineering Life*. Cambridge: Harvard University Press, 2011.

Designer and architects to watch:

Mitchell Joachim

Maria Aiolova

Marin Sawa

Mike Thompson

Eduardo Mayoral Gonzalez

Susana Camara Leret

Alexandra Daisy Ginsberg

Sean Quinn of HOK

Kate Orff

Alberto T. Estévez

Ginger Krieg Dosier

Damian Palin

David Benjamin

Suzanne Lee

Organizations to follow:

Wyss Institute at Harvard University

One Lab: New York School for Design and Science

Genspace

Royal College of Art, Department of Design Interactions

Wellcome Trust

The Arts Catalyst

IGEM

Le Laboratoire

SymbioticA

Biology and The Built Environment Center (BioBE)