The Living Building: Biomimicry in Architecture, Integrating Technology with Nature

by Bob Berkebile and Jason McLennan

"The best way to predict the future is to design it"

—Buckminister Fuller

In the future, the houses we live in and the offices we work in will be designed to function like living organisms, specifically adapted to place and able to draw all of their requirements for energy and water from the surrounding sun, wind and rain. The architecture of the future will draw inspiration, not from the machines of the 20th century, but from the beautiful flowers that grow in the landscape that surrounds them.

The Evolution of Architecture

Architecture of the 20th Century and the Environmental Backdrop

The history of architecture in the 20th century can be looked upon as a history of buildings emulating machines and technology. The machine, such as the internal combustion engine has been the symbol of progress and mankind's mastery over nature for the last hundred years. The machine has allowed us to achieve comfort in any climate, to traverse long distances in short amounts of time and has revolutionized everything from food production to the manufacture of clothing. It is not surprising that machines are the ultimate metaphor for the buildings of today. Le Corbusier, one of the 20th century's greatest architects even went so far as to say that, "houses were machines for living in."

As machines, our buildings also began to look more and more similar, regardless of culture or climate. With machines as metaphors our buildings took on the characteristics of clinical assembly line productions. An office building in Singapore now looks the same as an office building in Manhattan and both share the same "perfect" climate controlled indoor environment. At the same time, the loss of regional difference began to undermine the uniqueness of place, removing us from understanding what local culture and climate have to offer. The architecture of the 20th century has seen the diminishment of the importance of art and "artfulness" in building and seen the emergence of engineering and technological solutions as the dominant factor in building design, fitting for "machines for living in."

Unfortunately, like the machines of our age, our buildings use energy and materials wantonly, depleting resources and using energy in ways that is beginning to alter the very climate that we all depend on. According to the US Green Building Council buildings in the United States consume 30% of our total energy and 60% of our electricity while generating 2.5 pounds of solid waste per square foot of floor space for construction alone. 5 billion gallons of water are used per day in buildings just to flush toilets! The root of the problem was our shortsighted belief that technology combined with a great deal of energy was the answer to any design problem.

And yet, not too long ago we had a different model for our buildings and a different relationship with nature. Until modern times, buildings could be compared to living organisms in that they evolved in response to climate and topography, changing form and composition as necessary to protect what was inside from the elements, while regulating temperature and humidity to the greatest extent possible. This evolution produced vernacular forms that differed from locale to locale in a similar way that plants and animals differ from biome to biome. One need only compare the igloos of the Inuit with the adobe structures of the southwest to understand that climate and culture shaped architecture. Both the igloo and the adobe house were built to temper the harsh extremes of climate using only the materials at hand. Neither building type significantly impacted the environment and both helped define the culture of the people that built it.

But Western society was never completely satisfied with a close relationship to nature and were quick to follow the ideas of individuals like Francis Bacon who sought “dominion over nature” using the scientific method. As early as the 17th century we began to look for ways to put distance between the elements on the outside and activities held indoors, in other words to be warm no matter how cold it was outside and cool no matter how hot. With new design freedoms made possible by technologies such as insulated glass, air conditioning and central heating systems architecture moved quickly away from living organisms as a model towards a model based on the machines that were making these changes possible.

Unfortunately, In our haste to surge ahead with "progress" we lost the ability to discern between practices that were damaging to environmental health and those that were not. We forgot the hard learned lesson that how you get someplace is as important as getting there. Amory Lovins, founder of the Rocky Mountain Institute reminds us that what we want is comfort not higher energy bills and oil spills. It isn't our intentions that are wrong but rather the path we chose to get there. What is needed is a return to the old metaphor, one that respected regional differences and environmental health while embracing appropriate technologies than can give us the comfort, service and security we now expect.

Changing the Metaphor

"To emulate nature, our first challenge is to describe her in her terms. The day the metaphors start flowing the right way, I think the machine-based models will begin to lose their grip"

- Biomimicry pg. 237

Describing things as metaphors can provide clarity and allow us to understand complex systems quickly, but it can also lock us into a set way of thinking. For too long now the machine has been the metaphor for our buildings which implies a relationship with nature that is exploitative, solving problems with brute force and the addition of great amounts of energy. It is a nineteenth century model that has been carried forth into the 21th century.

Architecture has often been described using metaphors, drawing comparisons to things in the world that evoke similar emotional responses and can quickly sum up the intent of the architects expression. In contrast to "machines for living in," Goethe once said that "architecture is music etched in stone." What is interesting with architecture, is that when the metaphor

changes, new sets of rules of emerge that can guide the design process. To us the most compelling model for the buildings of the future can be found growing almost everywhere on the planet—Flowers.

Flowers are marvels of adaptation, growing in various shapes, sizes and forms. Some that lie dormant through the harshest of winters only to emerge each spring once the ground has thawed and others that stay rooted all year round -opening and closing as necessary to respond to changing conditions in the environment such as the availability of sunlight. They are the perfect metaphor for buildings in the future because, like buildings they are literally and figuratively rooted to place, able to draw resources only from the square inches of earth, and sky that they inhabit. The flower, must receive all of its energy from the sun, all of its water needs from the sky, and all of the nutrients necessary for survival from the soil. Flowers are also ecosystems, supporting and sheltering microorganisms and insects like our buildings do for us. Equally important is that flowers are beautiful and can provide the inspiration needed for architecture to truly be successful.

Changing the Approach

“The significant problems we face today cannot be solved by the same level of consciousness that created them.”

—Albert Einstein

Prior to the 1990's we believed that technology was the primary barrier to creating building designs that were resource efficient, healthy and less polluting. We had seen significant advances in glazing, lighting, carpeting and adhesives and Amory Lovins was working with Ford, Chrysler, and GM on a “Hyper Car” that would travel across the United States on one tank of fuel (not necessarily gasoline) without creating pollution. We were convinced that similar advances in building materials and systems would facilitate dramatic advances in the quality of building designs and the performance of the built environment.

In this decade we have begun to realize that technology is not the limitation. In fact technology has given us access to critical information (locally and globally) and the tools to develop and analyze more options efficiently. Breakthroughs on our projects and a series of national demonstration projects from Greening the Whitehouse to Antarctica have usually been born in the synergy resulting from the brilliance and diversity of team members working in a collaborative process. It has become increasingly clear that it is time to move beyond Francis Bacon's view of the future which set our western culture on a shortsighted but enthusiastic journey utilizing his scientific outlook and technology to establish "dominion over nature." Bacon's recommendations came three hundred years ago, and we should have been more wary knowing that he had rejected the Copernican Theory.

The quantity and quality of the synergistic breakthroughs we have experienced on projects seem to increase with the quality and diversity of the team members and the quality of their relationship. The collaborative team's ability to create a strong sense of community, clear goals, and their interest in searching for integrated designs that are inspired by nature dramatically improve the results. Establishing and maintaining this forum for discovery requires

more preparation, research and participation by more people (users and designers). More participation means more time and money. Fortunately there is a growing body of evidence that the additional investment delivers long term benefits including increases in flexibility, durability, and human health and productivity, with decreases in energy consumption, pollution and operating costs.

We are finding it useful to measure our designs and innovations against a test set forth in Benyus' Biomimicry, "Is there a precedent for this in nature?" If so the answers to the following questions will be yes:

- Does it run on sunlight?
- Does it use only the energy it needs?
- Does it fit form to function?
- Does it recycle everything?
- Does it reward cooperation?
- Does it bank on diversity?
- Does it utilize local expertise?
- Does it curb excess from within?
- Does it tap the power of limits?
- Is it Beautiful?

-p 291

Emerging Bio-mimetic Technologies

Many technologies are currently in use or being developed that are bio-mimetic in nature and will contribute to making the living building possible.

Perhaps the oldest of the bio-mimetic technologies are photovoltaics, otherwise known as PV. Photovoltaics are a solid state technology that directly converts solar radiation into electricity that can be stored or used on demand while producing no pollution. While many people might remember the technology as clunky, expensive panels that gained prominence in the seventies, the technology has advanced considerably in recent years becoming more efficient and able to integrate seamlessly into architecture. Where before solar panels were placed on top of roofs they can now serve as the roof membrane themselves, replacing conventional metal roofs or shingles. Transparent PV panels are also being developed that can be used as windows and skylights allowing daylight to enter a building while still generating electricity. This technological "multi-tasking" is integral to bio-mimetic technologies that often do more than one job at a time. Photovoltaics will play an increasingly important role in buildings of the future.

Another electricity producing technology that has started to generate considerable attention in recent years are fuel cells, a technology that is poised to change the way we power

our automobiles, computers, cell phones and buildings. All the major automobile manufacturers in the world, including Chrysler, Ford, General Motors and Honda are racing to produce the first commercially viable fuel cell cars, which are expected to be released as early as 2004. Prototype vehicles already exist today, that release drinkable water from the tail pipe instead of carbon dioxide, carbon monoxide and ozone. When used in buildings, fuel cells can provide steady, uninteruptable power with minimal to zero environmental impact. Fuel cells operate similar to a battery but never run down provided that some type of fuel containing hydrogen is supplied to the system.

As hydrogen runs through a fuel cell it encounters a semi-permeable membrane that is designed to permit the flow of protons while inhibiting electrons. The electrons must flow around the membrane to rejoin the protons, thereby generating an electric current. Fuel cells that run off of fossil fuels such as gasoline or methane will still generate pollution, but in the future, they will run entirely off of hydrogen generated by renewable resources such as wind and solar power "creating a zero polluting source of energy."

Cleaning wastes in a building using bio-mimetic principles is also becoming more common. Ecological waste treatment systems are available that recreate wetland ecosystems using microorganisms and plants to purify wastewater from toilets or other industrial uses. These systems, first developed by a biologist named John Todd and originally called "living machines"(an interesting twist on the metaphor) rely on the power of living systems that view our waste products as "food." In nature, it is important to remember that there is no such thing as waste. Only mankind creates things useless to all other forms of life. In the ecological waste treatment system, the effluent is moved by gravity from tank to tank, each a complete and increasingly complex ecosystem, where it is attacked and consumed by microorganisms. Unlike conventional waste treatment systems, which use great amounts of energy and harsh chemicals, ecological waste treatment systems use only sunlight, bacteria and plants to clean water.

A whole host of other bio-mimetic technologies are being developed for all areas of building construction including insulation, windows, electric lighting, controls and mechanical systems. These technologies are also being designed to be integrated with one other for greater efficiency and comfort. Models are now emerging that showcase the use of bio-mimetic technologies and the integration that make them so successful.

A Living Laboratory for the Year 2000

Many of the principles of the living building will be tested at a benchmark project called the EpiCenter in Bozeman, Montana, being designed by an international team of innovators, architects, scientists, engineers, and stakeholders under the leadership of BNIM Architects. The EpiCenter, funded by the National Institute of Standards and Technology (NIST) and the students of Montana State University (MSU) seeks to redefine resource efficiency, including human resources. The facility will house new centers for integrated, collaborative research including the Center for Computational Biology, the Center for the Discovery of Bio-Active Compounds and the National Resource Center a research laboratory for sustainable building systems.

This building is part of a larger movement occurring in the architectural community that is known as sustainable design- buildings that are designed to minimize energy and resource

demands. What is unique about the EpiCenter project is the level of integration and unique combination of state of the art "green technologies."

The building was envisioned to operate as much as possible like a living organism, with all systems interconnected for maximum efficiency and minimum environmental impact. The building was designed to generate a significant portion of its power without pollution, clean all its own wastes on site, and respond actively to temperature changes to maintain a comfortable indoor environment. New standards and advances would be created in the areas of energy generation, waste treatment, human health and productivity and resource conservation.

In order to test some of the concepts developed for the EpiCenter, and to generate interest and enthusiasm for the larger building project, MSU and the design team began work earlier this spring on a $7 million "pilot project." Like the main EpiCenter concept, the pilot will contain research and teaching laboratories for science and a mix of informal student space. Construction will begin on the pilot facility in early 2000, and will demonstrate many of the emerging bio-mimetic technologies.

Perhaps the most compelling example of the living building approach being demonstrated at the EpiCenter is what is what is being called the Integrated Waste Treatment System that combines ecological waste treatment with photovoltaics and fuel cells. The system works in the following way: Rainwater is collected from the roof of the building and stored in a large cistern located in the basement of the building. This water is then used for non-potable uses such as flushing toilets or cleaning lab equipment (water for drinking fountains still comes from the municipal supply). After the water is used it travels through the building to the ecological waste treatment system located in a greenhouse on the south side of the building. The water is then cleaned through the use of microorganisms and plant life and returned to the original cistern for re-use.

A portion of this water is diverted from this path and fed through an electrolyzer. The electrolyzer, that is powered by the photovoltaic array -cracks- the incoming water into its constituent components "hydrogen and oxygen, storing them in tanks in the basement of the building. The photovoltaics are also used to power the pumps, lights and aerators of the ecological waste treatment system. When there is inadequate solar radiation from the sun (such as at night or extended cloudy periods) a switch is flipped and the waste treatment process is powered by the fuel cells located within the building.

The fuel cells run off of the pure hydrogen that was stored in compressed form and the pure oxygen is fed into the aerobic digesting stage of the waste treatment system making it more efficient. In this way, several systems are linked and feeding off of each other while producing no pollution at any stage. The system uses only sunlight, water and other living organisms and provides clean water and power for the building.

The Montana project is important because it is a step towards the ultimate goal, a future where our buildings are produced and operated sustainably.

Communities of the Next Millennium

We see the world piece by piece,

as the sun, the moon,

the animal, the tree; but the

whole, of which these

are the shinning parts, is the soul.

—Ralph Waldo Emerson

Ironically, most of the world's growing population is rushing to imitate our building and community patterns just as we are discovering them to hold all the records for consumption, waste and pollution. As we seek to understand more of Emerson's "whole" it seems bizarre that our cities are crowded with buildings that struggle to separate us from nature and community. The buildings of the future may not look like flowers but they certainly will not resemble the buildings of today. A new architecture is emerging as an expression of climate and culture while being shaped by technologies that are bio-mimetic in nature. As Bucky Fuller once said "we do not seek to imitate nature, but rather to find the principles she uses." We can imagine whole cities operating like complex ecosystems, processing water and waste while generating energy. Communities in desert regions will be designed to maximize the ability to collect water, and like the plants of the desert retain and conserve that water. In colder climates the focus will shift to retaining heat and capturing the available sunlight. From region to region the focus will change but environmental performance will be constant.

Institutional facilities will be flexible and durable enough for more than 500 years use, while some facilities for short term use such as exhibitions and public celebrations will be designed for adaptive use, recycling or composting. Building codes and contracts for professional services will become more performance based. The public of the next millennium will require that all buildings have zero environmental impact and maximum comfort. Exemplary buildings and communities will be restorative, pedagogical and inspirational Living Buildings.

The Living Building will

- Harvest all its own water and energy needs on site
- Be adapted specifically to site, and climate and built primarily will local materials
- Operate pollution free and generate no wastes that aren’t useful for some other process in the building or immediate environment
- Promote the health and well being of all inhabitants–consistent with being an ecosystem
- Be comprised of integrated systems that maximize efficiency and comfort
- Be beautiful and inspire us to dream.

Biomimicry

[From the Greek bios, life, and mimesis, imitation]

1. Nature as Model. Biomimicry is a new science that studies nature's models and then imitates or takes inspiration from these designs and processes to solve human problems, e.g., a solar cell inspired by a leaf

2. Nature as Measure. Biomimicry uses an ecological standard to judge the "rightness" of our innovations. After 3.8 million years of evolution, nature has learned: what works. What is appropriate? What lasts?

3. Nature as Mentor. Biomimicry is a new way of viewing and valuing nature. It introduces an era based not on what we can extract from the natural world, but on what we can learn from it.

-Janine Benyus – Biomimicry Innovation Inspired by Nature

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