Article

Biomimetic Buildings: The Emerging Future of Architecture

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Abstract

Biomimicry is sustainable innovation inspired by Earth's diverse lifeforms which, thanks to billions of years of evolutionary refinement, embody high-performance, resource-efficient design solutions. Dismissing large potential ecological and economic returns associated with biomimicry, critics argue the approach 1) diminishes the role of the human designer; 2) relies on suboptimal models due to evolutionary incrementalism; 3) demands humans repress their impulse to build; and 4) depletes architecture of human meaning. The purpose of this article is to defend the merits of biomimicry by revealing how poorly founded these assertions are. Each is based on an outdated paradigm that we must shed in order to nurture a new era of architecture.

Keywords: biomimicry; bioinspiration; environmental sustainability; sustainable design

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Introduction

The ancient Greek philosopher, Aristotle, said 'man, when perfected, is the best of animals' (Aristotle, Pol. 1.1253a). This laid the foundation for the 'Great Chain of Being' [Figure 1], a medieval cultural conception which alleges a linear ranking of life forms from lowest, simplest, and least like humans, up through humans, considered the best, most complex, and most intelligent (Marks 2008).

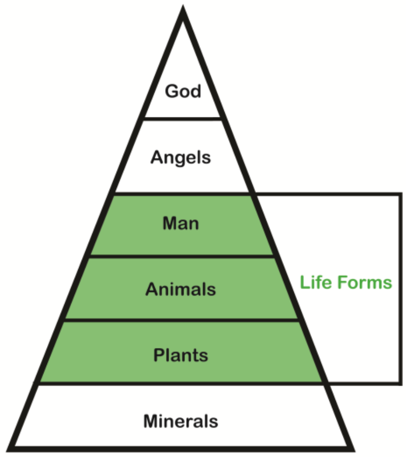

Figure 1. The Great Chain of Being. Illustration by Laura Kennedy. Reproduced with permission.

The 'Great Chain of Being' reflected the dominant Western interpretation of natural order until the eighteenth century, when Carl Linnaeus, a Swedish botanist-physician, introduced a disruptive biological classification system based on a nested, rather than linear hierarchy, with life forms grouped according to similar features. Linnaeus recognized three 'kingdoms' of equal rank – animals, plants, and minerals. Within each kingdom were classes; within each class, orders; within each order, genera; and within each genus, species (Marks 2008). Humans were situated in the animal kingdom, mammal class, primate order, and in the same genus as apes (Corbey 2005). Charles Darwin took another damaging swing at the 'Great Chain of Being' with his theory of evolution. In his books *On the Origin of Species by Means of Natural Selection*, published in 1859, and *The Descent of Man, and Selection in Relation to Sex*, published in 1871, Darwin provided robust scientific evidence that humans evolved from an apelike ancestor. Scientific advances spearheaded by Linnaeus and Darwin, repositioned the human as but one twig on an evolutionary tree; a modest figure in an expansive natural history. However, the ghost of the 'Great Chain of Being' continues to haunt Western culture. It has proven difficult to relinquish the longstanding belief that humans are superior in value, capacity, and worth relative to other species; a belief that permits us to ravage our environment without concern for the consequences.

Biomimicry – from *bios*, meaning life, and *mimesis*, meaning to imitate – is a sustainable design philosophy that jettisons the 'Great Chain of Being' in favor of a modern interpretation of humans as a young species among an astounding 30 to 100 million. Since life first emerged on our planet 3.8 billion years ago, biological systems have been evolving high performance, resource-efficient strategies that can be translated to address many of the technical challenges designers face (Benyus 2002). The term "biomimetics" was coined by

Otto Schmitt in the 1960s (Harkness 2002) and popularized by Janine Benyus and her critically acclaimed 1997 book, Biomimicry: Innovation Inspired by Nature (Benyus 2002). Deep practice of biomimicry requires a fundamentally different perspective of the relationship between humankind, the built environment, and the rest of nature than what was endorsed by the 'Great Chain of Being.'

Biomimicry has inspired innovation in diverse fields and is projected to account for $1.6 trillion global output, as well as $0.5 trillion savings associated with reduced resource depletion and pollution, by 2030 (Fermanian Business & Economic Institute 2013). It has had a particularly significant impact in the architectural field, where it has led to innovations in climate control, ventilation, and structural integrity, among other features. Melbourne's Council House 2 was inspired by gas and heat exchange in termite mounds [Figure 2]; and London's 30 St. Mary Axe building, affectionately called 'The Gherkin,' by structural reinforcement in sea sponges [Figure 3]. For many centuries, we were blind to the possibility that animals and plants, seen as lower life forms, had anything to teach us, but these examples show how much we have to learn.

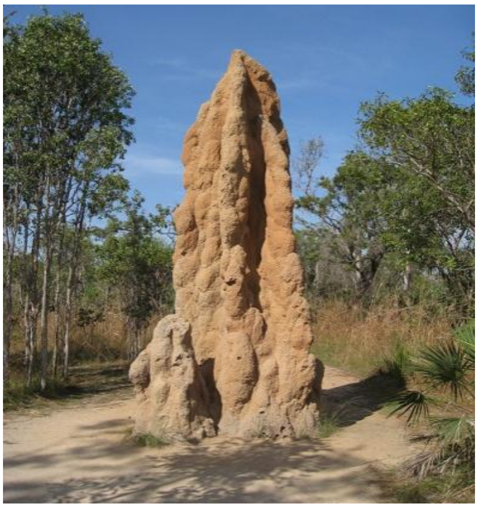

Figure 2. Melbourne's Council House 2 (Left, Photo by Nick Carson, CC BY-SA 3.0) inspired by termite mounds (Right, Photo by Brewbooks / Flickr, CC BY-SA 2.0)

Figure 3. London's 30 St. Mary Axe building (Left, Photo by Aurelien Guichard, CC BY-SA 2.0) inspired by sea sponges (Right, public domain).

The building sector offers more opportunities for cost-effective greenhouse gas mitigation than any other (Intergovernmental Panel on Climate Change 2007) and biomimicry case studies demonstrate the approach's ability to guide eco-integration. As such, architects are uniquely positioned to embrace biomimicry and become leaders of a sustainability transition. Biomimicry has proven ecologically and economically viable in the face of critics who cling to an antiquated view of humans as the champion life form. Criticisms leveled against biomimicry as an approach to design include: 1) biomimicry diminishes the role of the human designer, 2) design inspired by biological models is too tightly bound by evolutionary incrementalism; and 3) eco-conscious approaches like biomimicry urge humans to repress their impulse to build. Some critics even go so far as to argue that 4) biomimetic architecture reflects an impoverishment of human meaning (Kaplinsky 2006). In this article, I defend the merits of biomimicry by revealing how poorly founded these assertions are. Each is based on an outdated paradigm, which 'must be destroyed in order to build new knowledge of a type that is more socially robust, more scientifically reliable, stable, and above all able to better express our needs, values, and dreams' (Gebeshuber, Gruber, and Drack 2009). We have to create space, especially in the architectural world, for approaches such as biomimicry, which provides an environmentally ethical framework for architectural design, urban planning, and economic development in general.

In Defense of Biomimicry

Biomimicry encourages humility, not diminished self-confidence: The biomimicry philosophy encourages humility in the face of our natural limits. Humans are not a rank above other species with regard to eco-dependencies. We cannot absolve ourselves of our reliance on nature. However, humility is not self-deprecating. A humble person is honest about who he is and does not act as if he is more (Cloud 2007); he is not arrogant, but this does not mean he cannot be self-assured. Humans can step down from the pedestal once provided by the 'Great Chain of Being' and still stand tall. In fact, humility can be a source of confidence. In biomimicry, humility is seen as a 'source of power, a focusing mechanism'(Benyus 2002). If we admit that all problems are not solvable by our own genius, we are empowered to look for alternative solutions (Orr 1995).

Architect William McDonough is an example of a humble yet confident biomimicry practitioner. McDonough has accepted that the continued prosperity of humankind is dependent on the health of the biosphere (McDonough 2005; Braungart and McDonough 2008). McDonough rejects the traditional 'cradle-to-grave' manufacturing model, in which up to 90 percent of materials used in production are cast off as industrial waste. Instead, McDonough advocates a 'cradle-to-cradle' model. 'Cradle-to-cradle' manufacture emulates nature's closed loop use of materials (McDonough 2005). In nature, an organism's waste is cycled through the ecosystem and becomes nutrient for other living things. In 'cradle-to-cradle' manufacture, waste from one production line becomes feedstock for another. Products at the end of their lifecycle safely re-enter the environment and decompose into biological nutrient, or are disassembled into 'technical nutrient' and up-cycled – which means they are recycled to form higher-grade product (Braungart and McDonough 2008) [Figure 4]. McDonough has designed 'cradle-to-cradle' cities for the Chinese government that could house more than a hundred million people. His blueprints are respectful of each site's hydrology, biota, wind, and solar income. In each city all sewage is up-cycled, water waste is converted into natural gas via constructive wetlands, and solid waste is used as farming compost (McDonough 2005).

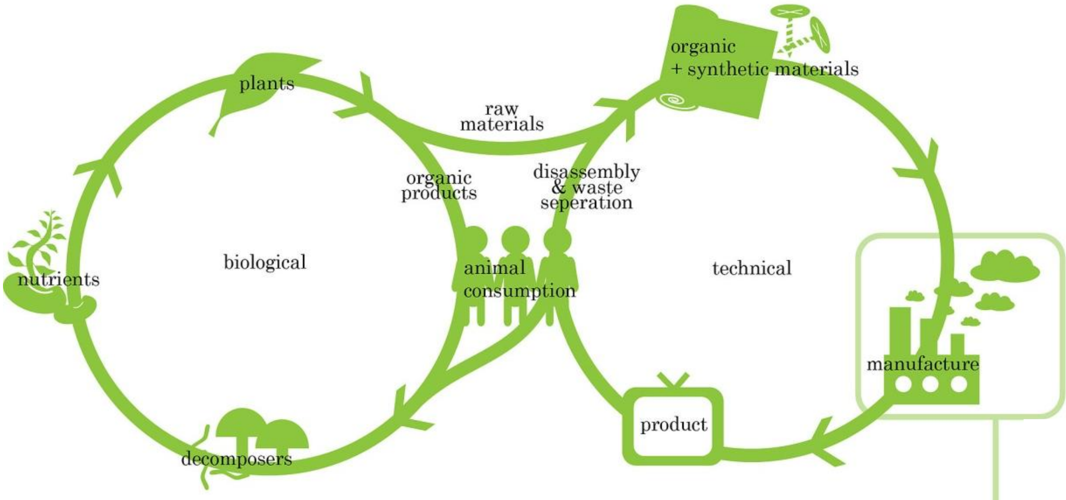

Figure 4. Diagram of biological and technical nutrient cycles in William McDonough's 'cradle-to-cradle' model. Illustration by Zhying.lim / Wikimedia Commons. Reproduced under CC BY-SA 3.0.

Biomimicry does not encourage diminished self-confidence. In fact, biomimicry places great faith in a designer's creative capacity, which allows him to apply biological insights in a manner suited to human application. The measure of a good idea cannot be found in nature alone, but only in how the human adapts it to his ends. Mercedes-Benz engineers turned to nature for advice in their quest to design a car with ample interior space, high stability, high maneuverability, and low drag. When the boxfish (*Ostracion meleagris*) emerged as a potential natural model, the engineers were not deterred by its bulky, counterintuitive appearance; they remained open-minded, and were able to translate the boxfish form into an aerodynamic concept car, boasting 20 percent less fuel consumption compared to similar-sized models (Bartol et al. 2008) [Figure 5].

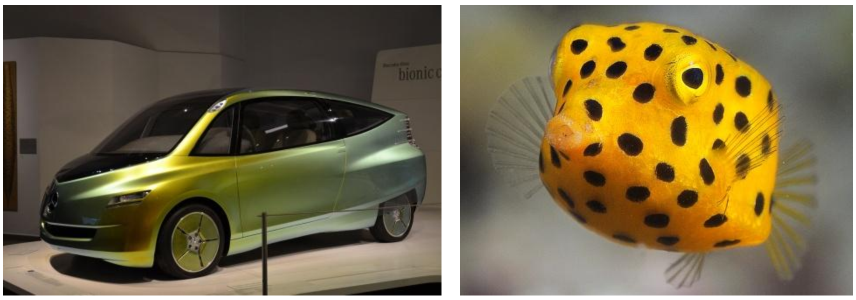

Figure 5. Mercedes-Benz concept car (Left, Photo by NatiSythen / Wikimedia Commons, CC BY-SA 3.0) inspired by the boxfish (Right, Photo by Zsispeo / Flickr, CC BY-SA 2.0).

This process of translation resulted in a design that is not a replica of the organism that inspired it, but utilizes the same functional concepts (Zari 2010). Humans' unique ability to bring into mind things that are not present (Robinson 2014) and formulate strategies (Capra and Luisi 2014) enables creative abstraction, and abstraction of biological principles is a critical step in biomimicry.

Biomimicry is not constrained by evolutionary incrementalism: Nature's designs are developed through natural selection, which proceeds incrementally. The evolving anatomy of an organism is constrained by the anatomy and genetic makeup of its evolutionary ancestors. While nature cannot elect to wipe the slate clean and redesign an organism from scratch, the human designer can scrap existing design concepts and choose to start over (Kaplinsky 2006). The giraffe's neck might be considered an example of a suboptimal result of nature's incremental design. 'No [human] designer would make the nerve connection between the brain and larynx of a giraffe by looping it all the way down the neck and back up to the throat'(Kaplinsky 2006). Nature had limited options due to the anatomy of the giraffe ancestor, in which the nerve looped around a blood vessel at the base of the neck (Kaplinsky 2006).

Nature is not a designer, so the comparison between nature and a designer is *a priori* false. We may speak of the "design" of a biological system, but in doing so we use metaphorical language. Design requires reflective consciousness, and this ability, as far as we know, is limited to humans and the great apes. As such, there is no *design* in nature at large, only selective processes that respond to immediate environmental cues (Capra and Luisi 2014). Instead of comparing human design processes to natural selection, one should consider whether the outcomes of natural selection – thriving biological models – have anything to offer. Biological analogies can stimulate human creativity in new ways, enhancing our own problem-solving ability (Wilson et al. 2010). Besides, it is a mistake to cast off the design of the giraffe's neck as an evolutionary blunder. As the giraffe's neck elongated, it evolved a unique mechanism for preventing lethally high blood pressure to the head when it bows to drink. The arteries in its neck automatically constrict to prevent blood from pooling with gravitational force. This mechanism inspired the biomimetic 'G-raffe' fighter pilot acceleration suit. The fabric of the suit tenses with air pressure, compressing the body in strategic areas to maintain even blood circulation. Wearing this biomimetic suit, a jet pilot can withstand up to nine G force without losing sensory control. Without the suit the average human would lose consciousness at four to five G (Booth 2012). Giraffe anatomy may be odd, but close study showed its potential for informing human design.

Biomimicry does not urge humans to repress their impulse to build: According to Biomimicry 3.8, an organization founded by biomimicry thought leaders Janine Benyus and Dayna Baumeister, the goal of biomimicry is to create more sustainable designs (Benyus 2013). The likelihood of sustainable outcomes increases when practitioners consider the form, process, and ecosystem levels of biomimetic design (Kennedy et al. 2015). Those who still correlate low impact design with the extent of untouched nature presume the biomimicry ideal is to not build at all. That is not the case. Biomimicry encourages humans to keep building, but to render construction consistent with life on earth over the long haul (Mathews 2011). Right now, human production and post-production maintenance often have a negative impact on the environment. For example, constructing a large dam requires concrete. The production of concrete results in excessive CO2 emissions. Post-production effects of a concrete dam can include soil erosion; species endangerment if dam bypass routes are not constructed for migrating species; spread of disease since water flow decreases and the river turns into a breeding ground for parasites; etc. Nature holds lessons for life-friendly manufacture and maintenance. Consider the fact that the total biomass of ants on earth is greater than the total biomass of humans, yet the ants do not pollute or otherwise degrade their environment (Braungart and McDonough, W. 2008). A tool called Life's Principles [Figure 6], developed by Biomimicry 3.8, summarizes six major principles and 20 sub-principles embodied by the vast majority of organisms and ecosystems on earth. If we use Life's Principles as a benchmark for good design, we may achieve the same neutrality possessed by the ants. Our socioeconomic processes will no longer create friction with the ecological processes on which we depend (Mathews 2011).

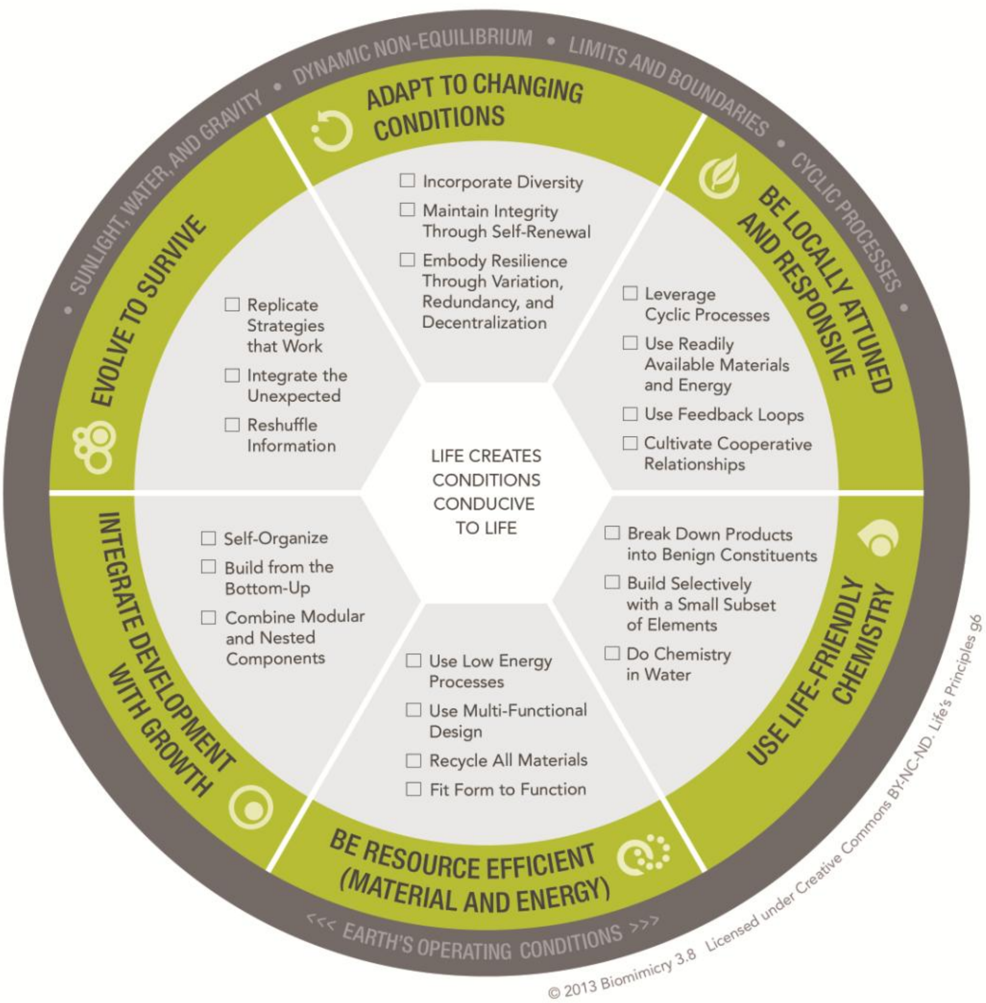

Figure 6. Life's Principles, a benchmarking tool for biomimetic design that identifies principles embodied by most species on Earth. Its purpose is to help practitioners create designs that fit

seamlessly within the larger natural system. Illustration by Biomimicry 3.8. Reproduced under CC BY-NC-ND.

Biomimetic architecture does not reflect an impoverishment of human meaning: At least one critic of biomimicry has contended that biomimetic architecture which references animal or plant forms reflects an 'impoverishment of human meaning' (Kaplinsky 2006). Yet humans derive meaning from non-human form. The biophilia hypothesis suggests all humans have an innate, positive emotional response to architectural form that mimics any naturally occurring geometry (Wilson 1984). This includes geometries embodied by plants and animals. Many people are enamored by the columns in Gaudi's Sagrada Família, which mirror branching trees (Armengol 2001), and the scallop-shaped motifs used extensively in cathedrals (Goss 1975) [Figure 7].

Figure 7. Tree-like columns in Gaudi's Sagrada Família (Left, Photo by Enric / Wikimedia Commons, CC BY-SA 3.0) and a scallop-shaped niche in the façade of the Cathedral of Girona (Right, Photo by Georges Jansoone, CC BY-SA 3.0).

This assertion also presumes biomimetic architecture is exclusively modeled after non-human animals and plants. Humans are biological beings, and biomimicry does not exclude humans from study. TECTONICA Architecture, a Puerto Rican firm, designed reinforced concrete building frames with reduced seismic vulnerability inspired by the human femur's structural strength. The frame technology, called STICK.S, emulates the human femur's hollow cylinder design to provide maximum strength with minimum material. STICK.S exhibits 35 percent less base shear under lateral loads, and uses a remarkable 30 percent less material compared to conventional building frames (EHSAAN 2011) [Figure 8].

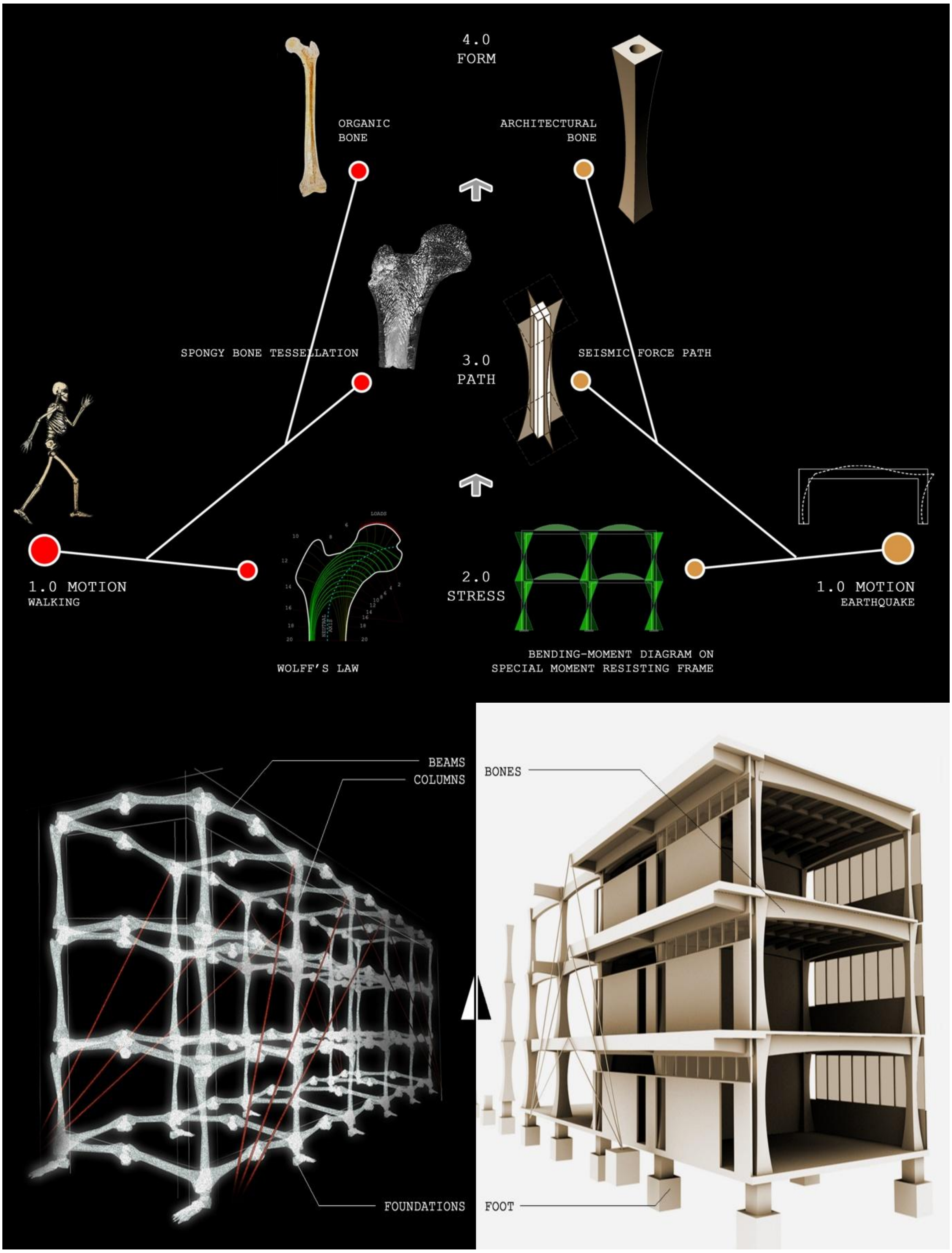

Figure 8. STICK.S building frames inspired by the human femur. Illustrated by Wilfredo Mendez. Reproduced with permission.

Conclusion

Our understanding of humans is transitioning from nature's *best* animal, as the 'Great Chain of Being' purported for centuries, to one of nature's *youngest* animals. If Earth's history were compressed into one calendar year, beginning one minute past midnight on the 1st of January, life appeared on the 25th of February, and humans on the 31st of December, at 11:49 PM. Civilization has existed for only one minute, and modern industrial society, only two seconds (Milbrath 2002). Biomimicry is a design ethic that has emerged from this shift in understanding. Biomimetic design emulates biological systems refined over 3.8 billion years of evolution (Benyus 2002).

Critics of biomimicry cling to a dangerous, dated cultural conception of humans as the ultimate life form. They argue that biomimicry diminishes the role of the human designer. It does not. We can step down from the pedestal once provided by the 'Great Chain of Being' and still retain our confidence as designers. The human is of central importance in biomimicry, since the approach depends on the designer's ability to distill what he learns about biology into a set of abstract design principles which can be implemented to solve a human design problem. Critics also argue that we should not seek Nature's advice when it comes to design, since Nature designs incrementally. Species are built from a binding template provided by their evolutionary ancestors. This fact does not mean the outcomes of natural selection have nothing to offer us. We can learn from a leaf how to harness energy without creating toxic byproducts; from a diatom, how to effectively absorb mechanical stresses. Critics also assert that biomimicry's mission of sustainability forces humans to repress their impulse to build. This cause-and-effect relationship is unfounded. Biomimicry recognizes that humans, and human developments, are in no way separate from the ecosystems in which they exist. Humans are part of nature. As biotic citizens, our handiwork is as much an expression of nature as is the 'handiwork of the spider or the bee' (Mathews 2011). We should continue to build, but our designs should support rather than stifle life on earth. Finally, some critics contend biomimetic architecture that references animal and plant forms reflects an impoverishment of human meaning (Kaplinsky 2006). This neglects a large body of evidence suggesting humans have a positive emotional response when their built environment contains naturally occurring geometries of any kind, including those of plants and animals (Wilson 1984).

Architects who adopt biomimicry as an approach to sustainable building will incite small shifts in thinking with their biomimetic designs, which in turn may lead to striking, positive changes in the broader material world (Meadows 2009) and in turn our culture. To quote Pedersen Zari, 'Incorporation of a thorough understanding of biology and ecology in architectural design will be significant in the creation of a built environment that contributes to the health of human communities, while increasing positive integration with natural carbon cycles' (Zari 2010).

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