TheATLAS

Transdisciplinarity and Biomimicry

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Capitalizing on the emergent movement towards integrating transdisciplinarity with biomimicry, this paper provides an overview of the biomimicry approach, including discussion of its three basic dimensions: (a) nine principles of life; (b) nature as model, measure and mentor; and, (c) the Design Spiral methodology. If the intent of transdisciplinarity is to understand the world in all its complexities, and the world includes humans, non-humans and nature, then it makes sense to gain insights from non-humans (other species) and nature, the intent of biomimicry.
Keywords*:* transdisciplinarity, biomimicry, design spiral, complexity.

1 Introduction

Studying nature to get ideas to solve transdisciplinary problems has recently received new attention from the field of biomimicry [1]. An intriguing discussion has emerged in the literature during the last five years about transdisciplinarity and biomimicry. Those engaged in this intellectual discourse argue that humanity is encountering powerful new insights from the foundations of transdisciplinarity: quantum physics, chaos theory, complexity theory and living systems/ecosystems theory. They further suggest that those engaged in transdisciplinary work can benefit from employing the principles of biomimicry (and vice versa). They maintain that sustainable products, processes, services and institutions are needed as catalysts to the transition towards a sustainable human civilization. They believe that solutions to the world's problems require the transdisciplinary integration of multiple perspectives and knowledge bases, augmented with insights from biomimicry [2, 3, 4, 5].

I find this idea intriguing. If the intent of transdisciplinarity is to understand the world in all its complexities [6, 7], and the world includes humans, non-humans and nature, then it makes sense to gain insights from non-humans (other species) and nature, the intent of biomimicry [8]. Madni [9], when discussing Daimler Chrysler's transdisciplinary application of biomimicry principles to design a Concept Car, observed that "humans have much to learn from Mother Nature"[9:7]. Transdisciplinarity arose from the increasing demand for relevance and applicability of academic research and non-academic knowledge to societal challenges [10]. Biomimicry arose from the increasing demand for deeper innovations and inspirations [8]. It has witnessed explosive growth as a new concept [11]. This paper provides an overview of biomimicry, anticipating insights for future conversations about the synergy between transdisciplinarity as a methodology [12, 13, 14] and biomimicry as an approach to solving problems [8].

Biomimicry claims that the laws of nature can be applied to modeling social systems, that we can adopt natural laws and logics to human needs [15]. Jucevicius [15] observes that analogical thinking (transferring ideas from one context to another) is at the heart of creative solutions to complex human problems. Successful biomimicry thinkers are in-

Figure 1: Nine Life Principles from Nature.

herently transdisciplinary thinkers [16]. The time seems ripe for further discussions around the idea of solving transdisciplinary problems of the world using insights from biomimicry, especially since "[m]any of the currently envisaged solutions to the global challenges facing humanity are in paramount contradiction to the 'approach' of nature" [16: 9].

2 Biomimicry Explained

The term biomimicry is from Greek bios, life and mimesis, imitation. It represents the new focus on mimicking natural processes to find innovative solutions to complex problems; instead of focusing on what can be extracted from nature, biomimics pay attention to what they can learn from nature. Those inspired by biomimicry study nature and then imitate or take inspiration from the designs and processes inherent in nature to solve human problems. Biomimicry occurs at the juncture where ecology meets agriculture, medicine, manufacturing materials science, energy, computing and commerce [8]. It uses an *ecological standard* to judge the rightness of human actions and innovations. The overall approach is grounded in three dimensions, discussed below: (a) nine principles of life; (b) nature as model, measure and mentor; and, (c) the Design Spiral methodology that informs biomimicry-inspired practice [8].

As a caveat, Jane Benyus [8], the founder and genesis of the idea of biomimicry, has deeply and critically engaged with each of these nine principles as a preamble to including them in her biomimicry approach. There is no question that they really work. Indeed, many others are applying this approach to their own work. Also, I purposefully chose to cite her book [8] and the work of the institute she founded, the Biomimicry Institute, as the primary sources for ideas about "what is biomimicry" as a concept and as an approach to design, development, science and research.

2.1 Nine Principles of Life from Nature

Benyus [8] encourages people to engage in behavior that is in harmony with earth processes. To that end, she offers a primer into nature's secrets. Indeed,

many who have analyzed her work conclude that these secrets are hiding in plain sight and have been so hard for us to see because they are so familiar, so obvious [17, 18]. Benyus holds that nature has nine basic operating principles that can be used as a beneficial model for human behavior. She [8] further posits these laws, strategies and principles have been found to be consistent over generations, and over cultures. More importantly, they can be observed by anyone who is interested in perpetuating a high standard of living in harmony with nature. These life principles reflect the inherent characteristics of ecosystems (see Figure 1). In effect, nature:

- **rewards cooperation** and integration and makes symbiotic relationships work because nature is all about connections between relationships. Nature knows that we do not always have to go it alone. In fact, sometimes we cannot do it alone. Moreover, nature allows predation and competition to exist *through* cooperation. Natural ecosystems operate on a symbiotic, complex network of mutually beneficial relationships. Working together is rewarding and necessary.

- **always fits form to function**, efficiently and elegantly - nature builds something that works because it was built within the confines of available resources. Also, the shape that something takes depends upon what it is intended to do. Furthermore, nature's designs are organic and only as big as they need to be to fit their function, rather than being linear (squares and blocks) and oversized, with a focus on form. Nature optimizes rather than maximizes. Organisms in nature co-evolve, adapting to the changes of others (i.e., they fit form to function).

- **depends on and develops diversity** of possibilities to find the best solution(s) (rather than a one-size-fits-all, homogeneous approach). Nature also depends upon randomness, more so than reason, because randomness creates anomalies that open opportunities for diversity. The randomness of entropy (the breakdown of order) allows for flexibility. A wide variety of plants and animals creates the bank of diversity. The entire habitat is used, not just bits and parts of the system. Also, a system must be as diverse as its environment in order to remain viable. Systems respect regional, cultural and material uniqueness of a place. Systems are flexible, allowing for changes in the needs of people and communities - allowing for emergent diversity.

- **recycles and finds uses for everything**. Everything becomes recyclable; everything has a use. Waste should be a good thing because it will be reused again for another purpose. Nature *wants* waste; it *needs* it to sustain itself (waste equals food or sustenance). Nature does not generate waste, per se; it does not foul its own nest because it has to live in it. In closed systems, each co-existing element consumes the waste of another as its lifeline! From this perspective, the word waste goes away because *waste* means to fail to take advantage of something.

- **requires local expertise and resources**. Just as nature requires a rich bio-diversity to adapt to change and to grow, local ecosystems require a rich range of interlocking resources and the involvement of many local species to create a vibrant natural community. Locals are familiar with the boundaries within which they are living and are familiar with other species who share this space and who have developed their own adaptive expertise. Nature does not need to import from outside. If it is not there, it cannot be used. Natural ecosystems are tied to the local land; hence, sustainability requires reliance on local expertise and indigenous knowledge.

- **avoids internal excesses** and "overbuilding" by curbing excesses from within. Nature has no ego to drive it. It remains in balance with the biosphere, that part of the earth and its atmosphere in which living organisms exist, that is capable of supporting life.

- **taps into the power of limits** and manages not to exceed them. Species flourish within the boundaries that surround them. They do not seek elsewhere for resources, and they use existing materials sparingly. Nature depends upon its constant internal feedback mechanisms for information on how to maintain balance. Nature makes the most efficient use of its surrounding resources. Nature uses *limits as a source of power*, a focusing mechanism, always

conscious of maintaining life-friendly temperatures, harvesting within the carrying capacity of the boundaries and maintaining an energy balance that does not borrow against the future. Otherwise, she would perish at her own hand. Learning to live with finite resources is a source of powerful creativity. Limits create power. This idea is the opposite of seeing limits as a dare to overcome the constraints due to scarcity and to continue our expansion. Nature teaches us to flourish within boundaries.

- **runs on the natural sunlight** and other "natural sources" of energy, such as wind. All energy is sunlight. Nature knows how to gather energy efficiently. Leaves follow the sun and photosynthesis is 95% efficient (plants use the sun to turn light into sugar, the natural food that the plant lives on - and then humans eat the plant). The photosynthetic process also uses water and releases the oxygen that everything absolutely must have to stay alive. But, nature does this by using contemporary sunlight rather than heirlooms of sunlight (fossil fuels).

- **uses only the energy and resources that it needs**. Nature draws on the *interest* rather than the entire natural *capital* at its disposal. It does not draw-down resources, meaning it does not deplete resources by consuming them unnecessarily. In order to make optimal and maximum use of the limited habitat, each organism finds a niche, using only what it needs to survive and evolve.

2.2 Nature as Model, Measure and Mentor

Biomimicry is a new way to view and value nature. Benyus [8] posits that if people want to consciously emulate nature's genius, they need to look at nature differently. In biomimicry, people look at nature as model, measure, and mentor. Consulting life's genius brings natures wisdom to bear [8] on todays pressing, messy, wicked problems (see Figure 2).

2.2.1 Nature as model

People would draw on nature to model new forms of behavior. Nature can provide insights into the quest for new ways to frame day-to-day life. In nature, there is no waste, and there are no borders separating things. There are just nested systems wherein each part of the system supports the existence of the other parts. Modeling this interconnectedness and interrelatedness would respect the needs of the other species. As Benyus [8] affirms, humans are one vote in a parliament of 30 million other species. Human being's long standing arrogance (hubris) would no longer be the model for human behavior. Communities modeled on nature learn how to stay put without bankrupting their ecological capital. They learn how to optimize rather than maximize. The latter focuses on increasing measures such as revenue, profits, and margins while optimizing involves making a system or design as effective or functional as possible.

2.2.2 Nature as measure

People would turn to nature for guidance for standards to use to judge the "rightness" of their innovative behaviors and decisions. Are they life promoting? Does the resultant action fit with nature? Will the results or the impact last in a positive way? These questions are judged using an ecological standard, what Benyus [8] refers to as the Nine Laws of Nature, Life's Principles (discussed earlier). When a natural ecosystem reaches maturity, it is populated by *mature living organisms* that act in life affirming ways, grounded in the nine laws of nature. One measure of rightness is *ensemble living*. In nature, an ensemble is a group of complementary parts that contribute to a single effect. Ensemble living means organisms (humans and other species) learn to maintain a dynamic stability, like dancers, continually interacting without harming or compromising each other (stepping on each other's toes in the dance). The parts of the ensemble that manifest (raise up from the whole) are still enfolded in the whole.

2.2.3 Nature as mentor

People's relationship with nature would change from master to teacher and mentor. This new relationship would mean people have to steward nature if they want to continue to have something from which they can learn, a source of ideas, innovation and inspiration. Nature is a source of knowledge fit for imitation. Mentors are trusted friends, counselors or teachers, usually a more experienced person. Nature has had 4.2 billions of years to evolve and gain experience of living systems in evolving complex, efficient, resilient and adaptive systems. Humans would do well to watch and learn rather than exploit

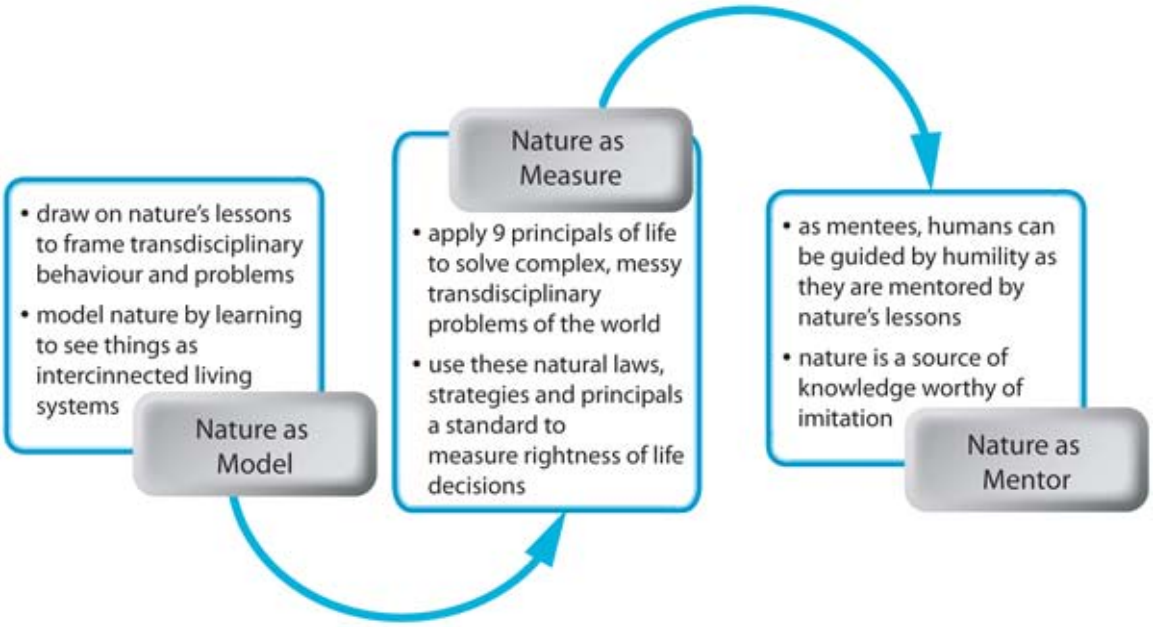

Figure 2: Nature as Model, Measure and Mentor.

and destroy. The answers are there in nature if we take the time to discover and apply innovations. Nature has figured out what works, what is appropriate and what lasts. Nature has a spirit of cooperation, flexibility and diversity that has made her a reliable and long-term survivor. As mentees, humans would be guided by humility (rather than arrogance) as they begin to learn "from" nature so they can learn to fit in alongside the rest of nature.

2.3 Biomimicry Design Spiral

The Biomimicry Institute [19] (founded by Janine Benyus) created a Design Spiral methodology to help people learn and practice biomimicry. It comprises five or six iterative phases (see Figure 3, used with permission) based on the assumption that "after solving one challenge, then evaluating how well it meets life's principles, another challenge often arises, and the design process begins anew" [19: 1]. This section of the paper is shared using second person narrative,*you*, because each reader is presumed to be part of the transdisciplinary narrative.

The spiral process begins with you *identifying* a problem that has to be resolved. Rather than asking "What do I want to design, to come up with?", you would ask "What do I want people to do?" and continue to ask why you want them to do this (distill the problem) until you get to the bottom of the problem. You also have to be concerned with who is involved with the problem, who will be involved in the solution, its consequences, where is the problem and where will the solution be applied.

The second phase involves you *translating* the question so it can be approached from nature's perspective, "What would nature do here? What would nature not do here?" This reframing of the question will yield additional key words and will involve placing the issue in broader contexts and conditions so as to better translate life's principles into problem solving parameters. You need to know the climate, social, temporal and other conditions of the problem. The Biomimicry Institute [19] refers to this as *biologizing the question*.

Now you are ready to look for champions in nature, to observe what is available to answer or resolve the challenge you have identified, distilled and translated into nature's terms. In order to answer "What would nature do here?" you can consider literal examples from nature or you can use a metaphorical approach. The former entails literally going outside and looking at nature to find examples of organisms that offer insights. They are often those aspects of nature that appear unfazed by their milieu, despite its challenges (e.g., tree, stream, field, an ant's nest), and are often on the extremes of the habitat you are observing. You can also open your discussions to other disciplines and specialists, turning the problem inside out

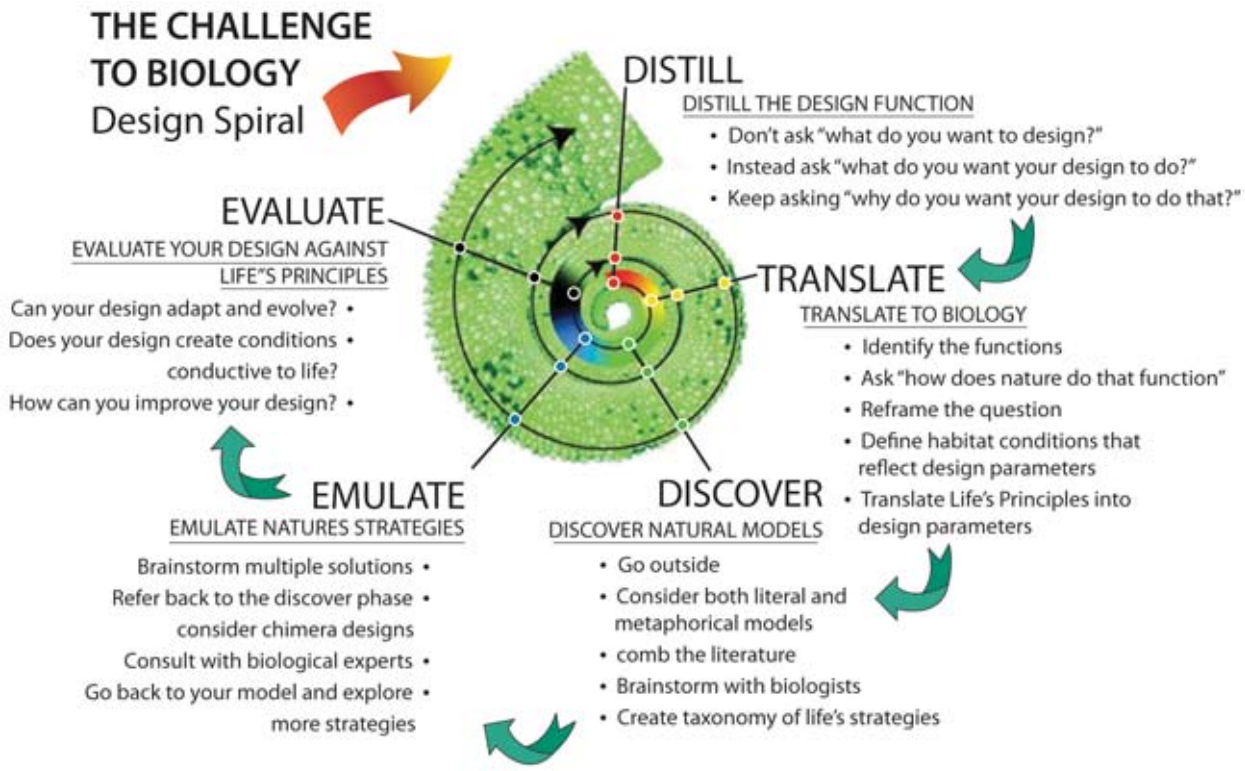

Figure 3: Design Spiral Methodology (used with Permission).

and on its head, the true spirit of transdisciplinarity. Scour the literature and brainstorm solutions.

These third-phase strategies will move you into the fourth phase, wherein you discover and report repeating patterns and processes that nature has used to achieve success. Chronicle these discoveries and create a taxonomy of nature's genius, her life's strategies, selecting those most relevant to your problem or challenge.

The next step is to develop ideas and solutions based on nature's models and apply these solutions to your problem; that is, emulate nature. Your solutions will apply the lessons you have learned from nature, your mentor and teacher (see Figure 2). You may decide to mimic a *form* from nature, one of nature's *functions* or a natural *process* (e.g., an ecosystem). Whatever strategy you settle upon, endeavor to apply the lesson(s) as deeply as possible. Ensuring this depth will likely entail resorting back to the discovery phase so you can find more patterns and processes that repeat in nature, indicating they have worked in the past to ensure survival and evolution. You will also want to consider the merit of chimera designs, those created as a result of purposively integrating two or more things together [19].

In the final phase, you *evaluate* how well your ideas and solutions (i.e., what you designed to address the challenge or problem) reflect the successful principles of nature. Ask yourself, "Does my solution(s) create conditions conducive to life? Are my solutions flexible, and able to adapt and evolve? If not, how must I change my solution(s) so that I can best emulate nature - apply life's principles to solve the problem?" This approach entailed using life's principles to develop these questions that you can now use to question your proposed solutions. As you pose these questions, the design spiral begins to unfold again and the iterative, inclusive process continues. New questions to explore emerge, and these questions tend to refine the concept you initially set out to explore in such a way that life's principles are respected and emulated.

3 The Fit Between Biomimicry and Transdisciplinarity

In summary, transdisciplinary problem solving from a biomimicry perspective means recognizing organic

patterns and natural connections, understanding the causes and effects of competing and interrelated components, and then making appropriate modifications. People intuitively problem solve with deep respect for flexibility, adaptability and universality. They plan space for growth, restructuring and contraction. From a biomimicry perspective, people inherently adapt, deconstruct and recreate as needed, a process that mirrors the actions of living organisms [20].

The nature of problem solving from a biomimicry perspective reflects the very essence of the transdisciplinary methodology used for creating new knowledge. First, transdisciplinary knowledge is complex and emergent, meaning the knowledge is continually changing as it is created, an idea which parallels with biomimicry's assumption that people have to adapt, deconstruct and recreate as needed. Transdisciplinary knowledge is alive because the problems being addressed are alive, emerging from the life world [12, 13, 14]. In the case of biomimicry, the solutions emerge from nature (which is alive as well), as discovered and interpreted by humans.

Second, the creation of transdisciplinary knowledge entails the Logic of the Included Middle wherein as many perspectives as possible are integrated. In the case of biomimicry, there is a special focus on insights gained from nature. Transdisciplinary problem solving happens in the fertile space between things, in this case between people and nature. Finding new knowledge in the fertile middle ground is possible when everyone's ideas are heard. Regarding biomimicry, the agenda is to discover and listen to ideas from nature as well, ideas that present as life principles from which complex human problems can be posed and solved. The fertile middle ground is ripe with possibilities, as is nature. People have permission to wonder, experience awe [13] and seek nature-inspired, far-reaching solutions to the world's pressing problems.

Third, transdisciplinarity assumes that many levels of reality are central to knowledge creation, including the internal mind of humans (their consciousness) and their external world (including nature) (information flows). Just like transdisciplinarity, biomimicry-inspired problem solving, with a deep emphasis on how humans from all walks of life can learn from nature, focuses on the processes and energy flows inherent in deep, complex interactions among people's internal world and their external world, mediated by such factors as culture, art, religion and spirituality. Transdisciplinarians refer to the latter as The Hidden Third, the place full of potential where people's experiences, interpretations, descriptions, representations, images, and formulas meet and new insights, perspectives and indeed, new knowledge, can emerge [12, 13, 14].

The fit between biomimicry and transdisciplinarity is elegant, ripe with hope and potentialities. Within its iterative solution-creation process, biomimicry aims to produce both new knowledge and technical artifacts (innovations) [3]. In concert, transdisciplinarity strives to produce new knowledge that can be used to create innovative solutions to pressing world problems, innovations in thinking as well as in actual artifacts to solve the problems [11]. Transdisciplinarity aims "to make *knowledge products* more pertinent to non-academic actors" [21: 170]. The synergy between these two approaches is encouraging, warranting further reflection and deliberation. Both strive to create new knowledge to inform innovative solutions to human problems.

If transdisciplinary solutions to world problems necessitate a holistic coupling of the human and the natural, as well as the inclusion of many voices and perspectives [12, 22], it makes sense that transdisciplinarity gain inspiration from biomimicry, with its focus on nature. Transdisciplinarity based on the principles of nature (biomimicry) is promising. It supports visionary approaches to solving complex messy problems that require people to "rethink and reorient human's relationship with the planetary environment, leading to *society being able to work together with nature*" [23: 484, emphasis added]. Society *working with and through* nature, in order to solve wicked problems affecting the human condition, is a provocative concept, invoking synergistic, emergent, integral thinking, the hallmark of transdisciplinarity. Readers are encouraged to follow through with any thinking inspired by this paper, especially thoughts about what key research questions can be asked, what problems can be posed, what research designs and methods can be employed, what results can be anticipated, even which disciplines and civil society members could participate in biomimicry-informed, transdisciplinary work.

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