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Developing a Common Ground for Learning from Nature

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Background, Motivation and Goals

The potential for tapping nature's storehouse of solutions, solution pathways and systems' principles has captured the world's imagination, especially after the publication of Benyus' *Biomimicry, Innovation Inspired by Nature* (1997). A growing number of proponents have been using biomimicry, biomimetics and biologically inspired design (B^3D for short, pronounced "B-cubed-D") in diverse contexts and employing a wide range of approaches. The language and cultural issues that challenge effective communication in the practice of B^3D among experts in the biological and technological domains are well known. There are also communication issues within the B^3D community itself, exemplified by the proliferation of terms used to describe what we do: *biomimicry, biomimetics, bioinspiration, biologically inspired design, biologically inspired engineering, bionics, biognosis, bioreplication, biomorphosis,* and so on. B^3D is intended to represent the common elements underlying these diverse terms.

Proponents of B^3D often adopt very different stances. Some are motivated by *biophilia*, a term coined by E. O. Wilson (1984) that refers to humankind's "innate tendency to focus on life and lifelike processes". Some are keenly interested in sustainability, repairing society's fractious relationship with nature and enabling "the possibility that human and other life will flourish on the planet forever" (Ehrenfeld, 2008). Others are seeking creative solutions for complex problems, with sustainability being one among multiple goals. While nature as the source of inspiration is common to all, B^3D would benefit from a consensus on what B^3D encompasses and what constitutes its 'best practices' in terms of methods and outcomes.

Perhaps the diversity of the B^3D community is a consequence of its ambitious goals and rapid growth. Nevertheless, it is clear that this diversity has a cost. Gleich et al. (2010) identified four recognized biomimetic networks with academic roots in Europe (two in Germany and two in the UK) but found evidence for only low levels of collaboration within and amongst these networks. A search on keywords associated with the broader concept of "learning from nature" identified extensive B^3D activities in Britain, China, France, Germany, Japan and the USA. These activities were often not associated with the official biomimetic networks but instead were aligned with traditional disciplines such as biology, chemistry, engineering, and material sciences. Again, these groups were largely working independently. B^3D initiatives were often tied to specific institutions or even to specific individuals within those institutions. Furthermore, limited collaboration was found between B^3D practitioners in industry or business and researchers in academia.

Building a consensus on the essence of what B^{3}D means could encourage a productive dialogue across disciplinary boundaries, increase collaboration and lay the foundation of a B^{3}D community. It could also help integrate the perceptual, analytical, cognitive and affective aspects of B^{3}D. Fragmentation impedes the effectiveness of B^{3}D practice by inhibiting the free exchange and discussion of approaches, methods and tools. Sharing and evaluating a broad range of approaches to practicing B^{3}D would help improve scalability, repeatability and predictability, essential for defining the best models, methods and tools necessary to establish B^{3}D as a credible community of practice and a recognized discipline.

The lack of a generally accepted standard for research and evaluation can lead to claims of uncertain authenticity that challenge the credibility of B^{3}D. A web search of "biomimicry", "biomimetics", "biologically inspired design" or similar terms yields a large number of articles and images including the Mercedes-Benz concept car mimicking the aerodynamics of the boxfish and the Eastgate building in Harare (Zimbabwe) imitating ventilation in termite mounds. Questions have been repeatedly raised as to the depth of the biological research involved in these cases (Gebeshuber, Gruber & Drack, 2009), the completeness of the biological model and accuracy of its transfer to design (Turner & Soar, 2008) and whether nature was used to primarily explain, justify and communicate the designs after the fact.

In spite of the many genuine examples of B^{3}D and the rapidly growing number of B^{3}D papers, patents and products (Bonser & Vincent, 2007), dubious claims often found in parts of the popular media can damage the reputation of B^{3}D in the eyes of pragmatic members of industry and business or researchers in academia. Working towards a common ground based on shared goals, values and practices would help increase the credibility of B^{3}D by framing the development of a research-based body of B^{3}D trans-disciplinary work that continues to promote innovation supporting social, economic, and environmental values.

Characteristics of a Common Ground for B^{3}D

It is important to recognize the diversity of views in B^{3}D. However, it is equally important to identify and build on the underlying unity of methods and outcomes of learning from nature. We propose the following main characteristics of a common ground for B^{3}D.

Inclusive: At this early stage of development of B^{3}D when there are many possible paths forward, a wide diversity of B^{3}D perspectives and approaches need to be embraced.

Nurturing collaboration among scientists (such as biologists, physicists and chemists), designers (such as architects, engineers, industrial and organizational designers), entrepreneurs and innovators (business and social) is fundamental to B^{3}D. Creating conditions that encourage boundary or edge effects similar to an ecotone (http://www.britannica.com/EBchecked/topic/178617/ecotone) can generate unexpected encounters leading to novel ideas and new perspectives on existing concepts. Julian Vincent et al. (2006), among others, emphasized the importance of convergence, not only in generating new concepts but also in identifying opportunities where B^{3}D can demonstrate its unique value.

Embedded: For B^{3}D to be effective, proponents must actively engage supporters and critics in institutional, industrial, regulatory, legislative and commercial settings. Effective internal and external feedback loops enmeshed within the complex networks of research, education and practice should be established. B^{3}D needs to actively explore and strengthen its relationships to the other systems on which its success depends.

Flexible: In its current stage of development, rapid advances in different aspects of B^{3}D can be expected. Instead of following a pre-determined path forward, B^{3}D should adapt and take advantage of advances within its own and related fields.

One example is the recent interest in additive manufacturing and 3D printing to imitate some of the assembly operations in nature. Another involves fast-paced advances in nanotechnology that may solve current limitations in developing hierarchically structured and adaptive materials. Green chemistry is yet another promising area for rapid growth.

Trans-disciplinary: B^{3}D practitioners have traditionally focused on transferring or translating knowledge between the natural and technological domains. For example, B^{3}D is sometimes understood in terms of "challenge-to-biology" or "biology-to-design" pathways (http://biomimicry.net/about/biomimicry/biomimicry-designlens/biomimicry-thinking/). While these pathways are useful, a complementary approach involves identifying or creating shared spaces between domains that integrate knowledge across disciplines and inform both domains. In general, B^{3}D enables innovation by engaging practices that span both biology and design, are distinct from methods used in either domain and encourage a deeper form of collaboration.

Annick Bay et al. (2012) explored the optical properties of the *Photuris* firefly's abdomen which led to ways of improving the efficiency of LEDs. Although Bay et al. collaborated with domain experts in biology and LED manufacturing, her team's unique knowledge of optics contributed new insights to both domains by applying practices that are distinct from those used in either domain.

Linked to Related Research: The development of B^{3}D could be accelerated by building two-way linkages between B^{3}D and other fields of research. This includes not only research in the natural sciences (such as physics, chemistry, biology and ecology) but also research in social, cognitive, design, systems, organizational and management sciences (including systems thinking, analogical reasoning, self-organization of complex systems, as well as cultural diffusion and economic impact of innovations). In addition to bringing an established and recognized body of knowledge to B^{3}D, this collaboration could create opportunities for both pure and applied/action research in these related fields.

Situated: The practice of B^{3}D should be deeply situated in nature and grounded in the study of dynamic, living systems. Nature is living: life in nature is not only situated in a context, but also evolves alongside the context. The products of B^{3}D should connect with and live in their natural and technological contexts. B^{3}D encourages looking beyond the artifact being designed to explore its dynamic "relationship to place" (http://www.regenesisgroup.com/Services/UnderstandingRelationshiptoPlace), not just in the present but over its entire lifecycle.

It is important to recognize that humans are an integral part of nature. Urbanization and industrialization have separated significant populations from nature; B^{3}D can reconnect us with nature in ways that can help address the far-reaching social, economic and environmental challenges we face individually and collectively.

Results-oriented: Emphasizing results encourages the mobilization of knowledge to solve real problems. B^{3}D programs should reflect the needs of B^{3}D practitioners by organizing resources around design practices. This in turn requires a deeper understanding of B^{3}D practice that is not only descriptive but also explanatory. Practitioners must be empowered to act, recognizing that the promise of success never comes without the risk of failure and that results have value, whatever the outcome.

Evidence-based: A commitment to building a body of verifiable evidence relating to the process (the 'how') and the outcomes or functions (the 'why') of B^{3}D will enhance its credibility. As described previously, some case studies often cited as examples of B^{3}D do not bear close scrutiny. In others, nature is used to explain or justify a design solution, rather than generate one. A deliberate effort at documenting, reviewing and re-evaluating the processes and results in the practice of B^{3}D is critical. Developing metrics relevant to the practice discipline would appropriately recognize prevailing practice and encourage practitioners to exceed current levels of achievement.

For example, it is often claimed that nature is sustainable, in the sense that natural systems appear to be more sustainable than technological systems. Aside from issues of scale, this first claim is sometimes extrapolated to assert that therefore all B^{3}D products, processes and systems are more sustainable than traditional designs. While the latter claim is intuitively appealing, supporting evidence is at present unclear. While it is important to embrace sustainability as an aspirational goal, it is also important to quantitatively demonstrate the sustainability of B^{3}D systems in practice.

Transformative: B^{3}D has the potential to drive significant, multi-faceted innovation, encouraging new ways of thinking about humankind's relationship with the natural world (which includes humans) and new approaches to driving change in society. Gleich et al. (2010) suggest that B^{3}D is particularly well suited for dealing with complex challenges where existing approaches are no longer adequate. The practice of B^{3}D will benefit from research into how complex natural systems develop and adapt while remaining resilient. B^{3}D can deliver not just a novel building inspired by nature but also shape the building's relationships to the community and habitat such that the building plays a positive, multi-faceted role over its lifespan.

Interface, a carpet manufacturing company, is an example of how B^{3}D can deliver both environmental and economic benefits (Anderson & White, 2009). The PAX Streamlining Principle (http://paxscientific.com/flow/) demonstrates that it is possible to leap-frog the small improvements in efficiency often associated with mature technologies. William McDonough and Michael Braungart's (2002) idea of creating a technical metabolic stream has transformed the way products are designed in those countries that have adopted 'manufacturer take-back' legislation. John Todd's (1984) Living Machines have helped break down the 'just move the waste elsewhere' mentality. Odum (1969) advocated the use of ecological succession in natural ecosystems as a principle for designing industrial ecosystems. Namibia Breweries, in which the waste of one industrial ecosystem is food for a related ecosystem, could be an application of this principle (http://www.sdearthtimes.com/et0101/et0101s7.html). Whenever possible, B^3D practices that are similarly transformative should be promoted.

Table 1 summarizes the set of characteristics that could become the basis of a common ground among B^3D proponents for learning from nature.

Characteristic	**Benefits**
Inclusive	Provides a common ground for discussion, research and action to create opportunities for rapid learning and growth
Embedded	Identifies and engages partners, builds strong feedback loops and seeks constructive discourse in diverse settings to firmly ground B^3D within its broader context
Flexible	Adapts to and leverages rapid advances in B^3D and related fields, encouraging a spirit of discovery and exploration
Trans-disciplinary	Transcends the exchange of knowledge between disciplines towards a true integration of methods and knowledge across disciplines that spurs advances in both disciplines
Linked to related research	Accelerates progress through engagement in ongoing work of related research disciplines, creating mutually beneficial opportunities for advancement
Situated	Grounds B^3D through observing, understanding and responding to the natural world, encourages recognizing and strengthening the relationship of design solutions to the natural ecosystems and human communities in which they are embedded
Results-oriented	Encourages addressing real problems, focuses on practitioner needs and reinforces the relevance of B^3D in a broad range of contexts
Evidence-based	Requires documentation to support claims and replication of results, increasing the credibility and relevance of B^3D
Transformative	Encourages innovative ways of thinking about humankind’s relationship with nature and new approaches to driving changes in society that support growth, renewal and regeneration

Table 1. Characteristics of a Common Ground for B^3D

Next Steps

Thomas Kuhn (1962) famously described different stages in the development of a science: pre-scientific (no agreement on a paradigm or commonly accepted methods), normal (a single paradigm and related methods characterizing the discipline), and revolutionary (accumulation of data conflicting with the current paradigm leads to the emergence of a new paradigm). B^3D as an emerging field of inquiry and practice is in the early, pre-scientific stage of development. The ultimate goal is to become a credible and recognized discipline supported by a network of trans-disciplinary research and practice. Yet, it is also important that as a new discipline B^3D has room - and plenty of it - for exploration, experimentation, serendipity, risk-taking, and failure. Transformative work emerges through challenging limits and reframing the inevitable failures into opportunities. Computer science is an example of a modern discipline with a sound theory and well-established communities of practice that has also supported almost continuous discoveries, innovations and revolutions.

This preliminary proposal seeks to create a network by engaging a broad spectrum of B^3D proponents, identifying areas of common interest, fostering a discussion of core principles and values, agree on an over-arching name and laying the groundwork for developing a set of best practices through applied research. It also suggests questions for further discussion and exploration through projects, studies, experiments and results which might demonstrate that B^3D leads to solutions that are more likely to be sustainable. Stimulating discussions and encouraging broad-based research in the field can help build a stronger and closer B^3D community that not only promotes sustainability, but is itself more sustainable.

Discussions are underway to plan for a face-to-face workshop that will attract a cross-section of the B^3D community. The workshop will leverage the diverse perspectives and expertise of the participants to identify key initiatives that will further the goals outlined in this article. If you are passionate about building a B^3D discipline, please see http://bioinspired.sinet.ca/content/b3d-workshop-initiative for the current status and ways to get involved.

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Author Bio

The authors are members of a Think Tank supporting the BID Community (http://bioinspired.sinet.ca) that was launched in 2010 to serve a growing community of practice. The BID Community is currently working towards a consensus on the core elements of B^3D including an unambiguous way to investigate, define and organize its practice and knowledge. The Think Tank represents a wide range of perspectives and views through our backgrounds in science, engineering, architecture, computing and design as well as our roles as active B^3D practitioners, educators and researchers.