Sustainability in the Biom*

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Abstract Bioinspired innovation is a growing field and is often attributed to sustainable design outcomes. After reviewing existing literature in bionics, biomimetics, and biomimicry, a comparative analysis was used to compare and contrast these subdisciplines. This theoretical analysis aims to reveal differences between bioinspired design approaches to show that each is distinct and to position bioinspired design approaches along the sustainability spectrum. This research contributes to the conceptualization of sustainability within bioinspired innovation and advances nuanced perspectives for scholars and practitioners in this field.

Keywords Biomimicry · Biomimetics · Bionics · Bioinspired design · Sustainable design · Eco-design · Responsible design · Strong sustainability

1 Introduction

Early design work encouraged consumption which contributed to environmental degradation through the extraction of raw materials and accumulation of waste [11, 29, 44]. It was the critical work of Papanek [44] that called for improvements in the design profession. Early responses to this call focused on reducing the environmental impact of products but each approach, such as green design and ecodesign, had shortcomings [8]. A later wave of design approaches for sustainability turned to nature-inspired design [8].

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Nature-inspired or biologically inspired designs are now present in many fields, including architecture, industrial design, engineering, medicine, urban planning, materials science, management, agriculture, and more. Research has shown that exposure to biological examples increased novelty in design ideas while exposure to human-engineered examples decreased variety in design ideas [64]. Nonetheless, it has also been shown that designers do not always make analogous use of biological phenomena [9] and that a better understanding of biological phenomena could help designers improve the application of biologically inspired, or bioinspired, design.

There are three bioinspired design approaches that are commonly referenced interchangeably: bionics, biomimetics, and biomimicry. Researchers and practitioners alike have called for research that offers a clearer delineation between these approaches based on factors such as methodology, origins, and connections to sustainability [24, 25, 36, 53]. Using comparative analysis of the existing literature, the aim of this chapter is to reveal differences and similarities between these three bioinspired design approaches to illustrate the ways in which each is distinct and represents varying degrees of sustainability, thus responding to the call of Papanek [44] to make design more responsible. While it is widely recognized that the aforementioned terms are used interchangeably in many contexts, we believe that additional analysis is necessary to develop and define the unique, nuanced trajectory of each discipline in its respective field and toward sustainability. We propose to advance the relationship between bioinspired disciplines and sustainability and further differentiate between the dichotomous categorization of "weak vs. strong" biomimicry categorization [7] by applying a phased model of sustainability. The rest of this chapter is organized as follows. In Sect. 2, we review the three bioinspired design approaches of bionics, biomimetics, and biomimicry. A brief history of each design approach is presented and practical examples are offered. In Sect. 3, we introduce strong sustainability theory, the sustainability spectrum, and a corresponding five-stage model of sustainability. In Sect. 4, we place each of the design approaches along the sustainability spectrum and explain how these design approaches can be positioned from less sustainable to more sustainable and showing that, ultimately, only one of these design approaches is sustainable. Section 5 discusses the practical value of this comparative analysis for the field of design studies. Section 6 suggests the limitations of our work and future directions for sustainable design research. Finally, Sect. 7 offers our conclusion.

2 Bioinspired Design

Bionics, biomimetics, and biomimicry are biologically informed disciplines that lead to bioinspired design solutions [24]. All three share a common approach toward design: (1) observation of biological models, (2) translation of biological principles or strategies, and (3) application of biological principles or strategies to design [19, 63]. Despite their similarities, we will demonstrate that each term has unique aspects.

2.1 Bionics

Jack Steele, formally trained as a medical doctor, is credited with coining the term bionics in 1958, a combination of biology and technics. His work on bionics and cybernetics was the inspiration for science fiction books and television shows of the 1970s. Werner [41] and others further advanced bionics into a field of study. It is also noteworthy that the term "bionik" is the German language interpretation of the concept overall, with Nachtigall relying on this as his first language.

Experts place bionics within the fields of biology, medicine, and engineering, viewing bionics as a sub-field of engineering that is focused on robotics and mechanics [24]. Bionics is the Anglo-Saxon term used in medicine, however, it is also the term used for the overall discipline in German-speaking countries [54]. Bionics employs the principles of physics for creative problem-solving, is practiced by functional biologists and engineers in the fields of medicine and cybernetics, specializes in technical complexity and innovation, and seeks mechanically innovative solutions [24]. Practitioners study mechanics and processes in nature and replicate those processes in engineering and computing design. Bionics focuses on nature's mechanical abilities or technology without regard for ecology [24] and is a "prediction and control approach to learning from nature" ([61], p. 292). The practice of bionics fails to consider sustainability, ecology, or society and can ultimately lead to unsustainable solutions [24, 61]. The intent of bionics is to extract physics principles found in nature and apply them to solutions [24] by using nature only for the inspiration it can provide in developing technical design [41]. Thus, bionics extracts physics principles to create technical solutions that perform the same function as nature but does not imitate those principles in the same way as found in nature. The innovation culture and narrative of those who adopt bionics don't have a clear motivation for sustainability beyond learning from nature [34]. Rather, the emphasis in developing the innovation is on immediate return on investment and taking advantage of strategic business opportunities [34].

Examples of bionics include researchers who are studying the echolocation of bats to integrate similar mechanical functions into drones for improved navigation [15, 39]. Popular applications of bionics are those in which robotic movements mimic those of humans, such as the prosthetic arm and hand system developed for veterans [47]. Another bionics example might be a building developed by architects and designers that is inspired by the form of termite mounds [54].

2.2 Biomimetics

Otto Schmitt, a biophysicist formally trained as an engineer, is largely credited with launching this field of study in the 1950s; in 1969, he coined the term biomimetics from the roots bios (life) and mimesis (imitate) [59]. Schmitt (founder of biomimetics) and Steele (founder of bionics) were colleagues in the 1960s at

Wright-Patterson Air Force Base, but each took his work in a different direction, thus separating biomimetics from bionics.

Experts place biomimetics within the discipline of engineering [24]. Practitioners study and imitate nature in design [8] and engineering [20], the focus is predominantly on the mechanical capabilities of the structure–function relationship [2, 24]. Biomimetics employs principles of biology [2], is practiced by biologists, engineers, and designers in the fields of medicine, information technology, economics, and systems science; specializes in mechanical abilities, technical complexity, and innovation; and seeks to imitate nature without a focus on sustainability [24]. Biomimetics not only draws inspiration from nature's designs, like bionics, but focuses on the application or replication of nature's design, unlike bionics. Research into the process of biomimetic innovation frequently focuses on the analogical transfer of biological strategies (e.g., [9, 21, 55]), rather than broader reaching metaphorical inspirations that are frequently applied in biomimicry. And while there is great "promise" that biomimetics will produce more sustainable results, these results are frequently called into question [17].

Examples of biomimetics can be found in stronger fibers modeled after spider webs, multifunctional materials modeled after nature's efficient creation of materials that form multiple functions, and superior robots that mimic both shape and performance of biological creatures [2]. Continuing with our earlier bionics example of a building with constant temperature, while bionics would mimic the structure, biomimetics would mimic the structure and the function of the termite mound chimneys to help vent hot air out and keep the interior temperature constant. This design was mimicked in the Eastgate Centre shopping mall in Harare, Zimbabwe, and maintains a comfortable inside temperature year-round without the use of traditional heating and cooling systems [16].

2.3 Biomimicry

The term biomimicry is generally acknowledged to have first appeared in a doctoral thesis in 1982 [38] but was conceived in its modern interpretation by Janine Benyus in 1997. Benyus [3] defines biomimicry as "the conscious emulation of life's genius" (p. 2) and a science that imitates nature's models, uses an ecological standard to measure what is sustainable, and values nature as a mentor for learning. Though biomimicry was likely practiced throughout history prior to the industrial revolution [8], Benyus was the first to connect bioinspired solutions to the evolutionary sustainability of the human species.

The terms biomimetics and biomimicry are often used interchangeably [3, 7, 31, 57, 58]. In fact, some refer to biomimetics as "reductive biomimicry" [3, 49]. However, biomimicry goes one step further than biomimetics in that biomimicry uses nature as a model and mentor but adds the dimension of "measure" to determine what is sustainable [3, 12, 13]. Biomimicry doesn't focus only on the mechanics or process but also includes mimicking form or shape and as well as interactions within and between systems. Therefore, not only do we learn from and imitate nature, but biomimicry designs create conditions that are conducive to life. This means pursuing efficiency in using benign materials and renewable energy in a closed-loop system without producing waste [3, 42] and also designing with regeneration in mind [61]. The nature-focused ethos and the realization that humans are part of nature is what separates biomimicry from the other terms [24]. The intent of biomimicry is not to just extract biology principles found in nature but to learn from nature and develop solutions that are life-sustaining [3, 13, 24, 50]. Biomimicry has been described as an approach for more holistic systems design [1, 6], suggesting a more encompassing perspective than the simple analogical translation of biological functions.

It is for these reasons that some refer to biomimicry as "sustainable biomimetics" [25] and "holistic biomimicry" [3] although much of what passes for biomimicry today would more accurately be defined as biomimetics. Wahl [61] argues that biomimicry is ecologically informed, more holistic, and simultaneously considers humans, ecosystems, social systems, and economic systems, this would be described as a co-evolutionary level of sustainability [28]. That is, modern interpretation and practice of biomimicry have co-evolved with our sustainability challenges and the ongoing adaptation of the concept of sustainability in ever-changing global realities [14, 30, 48].

Experts place biomimicry within the fields of design, business, architecture, and philosophy [24], though there are exceptions, e.g., in engineering [49] and chemistry [59]. Practitioners mimic complex living systems which are supportive of life on earth to solve design challenges. Biomimicry employs biological and life-sustaining principles, is practiced by ecologists, environmental scientists, designers, architects, economists, and biologists; incorporates a nature-focused ethos with minimal technical complexity; and designs solutions focused on life-sustaining principles, but which might lack real-world applicability [24]. Biomimicry draws inspiration from nature's designs (like bionics and biomimetics), focuses on the application or replication of nature's design (like biomimetics), but unlike either bionics or biomimetics, biomimicry incorporates sustainability into the design as an explicit component of the methodology [5]. Those who adopt biomimicry have innovation cultures and narratives that can be described as "aspirational" in that they are ambitious and seek to "be like nature," sustainability is the purpose and is intrinsically motivated, and it is setting a model for others in its sustainability orientation [34].

An example of biomimicry is the "Factory as Forest" initiative [18]. This work began as a project between consultancy Biomimicry 3.8 and carpet manufacturer Interface and continues with other companies through Project Positive [4]. The goal is to mimic interactions between systems with the explicit goal of achieving sustainability. This work focuses on transforming the built environment to become an active participant in its surrounding ecosystem. Continuing with our example of a building that is self-regulating in temperature, biomimicry designers would ensure the building and its materials are life-sustaining in a way that allows self-sufficiency, self-regulation, zero waste, and participation in its surrounding ecosystem, such as the Factory as Forest concept at Interface.

It is precisely because these three terms are often confused and used interchangeably that we focus on revealing differences between these three bioinspired design approaches. We summarize these differences in Table 1.

Equipped with this knowledge, we can now offer a simplified yet more nuanced definition of the three bioinspired design approaches showing how each adds a progressive layer toward achieving sustainability (Table 2). Bionics gains design inspiration from nature through the utilization of physics principles in technological design but does not mimic nature. Biomimetics gains inspiration from nature and mimics natural design through increased control of mechanics and structure in technical design. Biomimicry gains inspiration from nature, mimics natural design, and uses nature as a measurement against which to define sustainability through a nature-based ethos applied to design.

Table 1 Differences between bioinspired design approaches

	Bionics	Biomimetics	Biomimicry
Intent	Employs principles of physics [24], inspiration from nature to develop technical design [41]	Employs principles of biology [2] for increased prediction, manipulation, and control [61]	Employs biological principles and life-sustaining principles [24] for human adaptation [3]
Disciplines and practitioners	Functional biologists, engineers, medicine, cybernetics [24]	Biologists, engineers, designers, medicine, information technology, economics, systems science [24]	Ecologists, environmental scientists, designers, architects, economists, biologists [24]
Specialization	Technical complexity & innovation [24]	Mechanical abilities with technical complexity & innovation [24]	Nature-focused ethos with minimal technical complexity [24]
Solution	Creates mechanically innovative solutions that lack sustainability [24]	Solutions that imitate nature but lack sustainability [24], though with the aforementioned exceptions	Solutions that adhere to life-sustaining principles but may lack real-world applicability [24]

Adapted from Bar-Cohen [2], Iouguina et al. [24], Nachtigall [41], Wahl [61]

Table 2 Defining characteristics of bioinspired design approaches

	Bionics	Biomimetics	Biomimicry
Gains design inspiration from nature	x	x	x
Nature serves as a model of design		x	x
Nature serves as a mentor for learning and a measure of sustainability			x

3 Bioinspired Design and Sustainability

While intentionality can be a useful indicator of sustainability-oriented innovation, it provides little indication of the systemic impacts of any innovation, bioinspired or otherwise. Some methodologies specifically indicate steps and criteria for sustainable design (e.g., Biomimicry 3.8's Design Toolbox), but this is not a guarantee of better performance when the innovation outcomes are scrutinized in a social and ecological life-cycle analysis. Despite the "Biomimetic Promise" of superior innovation performance [17], assumptions that innovations are inherently sustainable because they somehow emulate a biological strategy result in a naturalistic fallacy that because something is "natural," it is inherently better [7]. It has been shown that bioinspired approaches can generate both positive and negative impacts [40], therefore, these assumptions about sustainability are worthy of further analysis and consideration [8]. Given this wide array of approaches and perspectives [35, 36], proposed that rather than viewing bioinspired approaches in a dichotomous frame of an innovation being *unsustainable* or *sustainable,* it is more useful to gauge the sustainability of a bioinspired innovation along a gradient of *less* to *more sustainable* [33] as shown in Fig. 1.

3.1 Sustainability Spectrum

Sustainability can best be understood as a gradient ranging from less sustainable to more sustainable which leads us to understand that each gradient holds different meanings for different people. As such, the sustainability spectrum proposes a continuum of worldviews within environmentalism to help us understand the varying positions along the gradient. The original spectrum of sustainability included four worldviews: very weak, weak, strong, and very strong [43, 45, 46, 56]. Landrum [28] expanded the model to include an intermediate position.

DICHOTOMOUS (OR BINARY) ORIENTATION OF SUSTAINABILITY IN BIOM*

Unsustainable Innovation ----------------|--------------- Sustainable Innovation

GRADIENT (OR RELATIVE) ORIENTATION OF SUSTAINABILITY IN BIOM*

Less Sustainable Innovation <---------------------------> More Sustainable Innovation

Fig. 1 Dichotomous versus gradient orientation. Adapted from Mead et al. [35]

Very weak sustainability. Very weak sustainability is a worldview that sees the natural environment for its instrumental value to humans. The focus is on human-made technocentric solutions to our sustainability challenges that have been extracted from nature (a more exploitative orientation) and a belief in the ability of humans to develop technological solutions that are superior to nature, and which will improve life [43, 45, 46]. In corporate contexts, this is defined by compliance-based decision-making and strongly influenced by external factors that force change [28]. Examples may include using bioinspiration to innovate new materials to replace previously used materials that have been banned.

Weak sustainability. Weak sustainability is a worldview that is less exploitative and has taken a more accommodative orientation. This worldview sees more value, albeit self-serving, in adopting solutions from nature, such as reduced costs, new markets, or improved reputation. However, this stage is still a "manipulative and technocentric position" ([43], p. 88) in that it uses natural resources to develop solutions based upon human ingenuity and technology. Also called business-centered sustainability in relation to corporate environments, this position views sustainability as internally driven by the reduction of costs and eco-efficiency [28]. An example of bioinspiration applied through a weak sustainability lens might be a structural color coating that mimics the Morpho butterfly wing but relies on toxic materials to produce the effect.

Both very weak and weak sustainability worldviews are technocentric in that they view humans as dominant over nature and seek technological solutions to environmental problems. These positions view nature for its instrumental value and allow for human-made solutions that can improve upon nature.

Intermediate sustainability. Landrum [28] posits that there exists an intermediate worldview between weak and strong sustainability that has characteristics of both strong and weak sustainability but is not clearly situated on either side of the spectrum. In this worldview, there is an emphasis on systems-level sustainability that goes beyond a single organization or product. Also referred to as systemic sustainability in a business context, this position looks outside the company and works with others to improve conditions within its sphere of influence [28].

One example of intermediate sustainability can be found in global efforts to reduce single-use plastics. This movement has led designers to create many plastic alternatives. Biobased plastics attempt to create systemic change away from fossil fuels but they also have negative environmental impacts. Eating utensils made from sugar cane, for example, are chemically identical to polyethylene terephthalate (PET) plastic, do not biodegrade, and create the same long-term waste as plastic from fossil fuels [27]. Polylactic acid (PLA) biobased plastic is recyclable, biodegradable, and compostable *if commercially composted* [27]. However, if they are discarded in the conventional waste stream, they produce the same environmental problems as traditional plastic [27].

Strong sustainability. Strong sustainability is a worldview that is more radical and considers self-sufficiency and cooperation [44]. Landrum [28] describes further, equating strong sustainability with regenerative approaches to innovation, design, and operations. A regenerative approach is characterized by the goal of repairing and restoring human and natural systems. This might be exemplified by Interface's "Net-Works" program which collects, cleans, and upcycles discarded fishing nets from beaches and oceans and remanufactures them into bioinspired carpet tiles [23].

Very strong sustainability. Very strong sustainability sees the intrinsic value of nature and believes in the need for humans to co-evolve alongside nature. This position supports "obedience to natural laws" ([43], p. 91) and the maintenance of life-sustaining conditions. Landrum [28] also refers to this as the co-evolutionary phase of sustainability within corporate contexts where companies view themselves as reintegrating with natural systems using science-based approaches and steady-state economics. An example of this is Biomimicry 3.8's application of Ecological Performance Standards that redesign operations of factories and cities to use "nature as measure" and systematize integration with ecological systems [18, 62].

Both strong sustainability and very strong sustainability worldviews are ecocentric in that they view humans and nature as co-existing and seek solutions that allow humans and nature to flourish together. These worldviews believe nature has intrinsic value and that man-made solutions are not superior to nature's solutions.

4 Positioning Bioinspired Design Approaches

Drawing from prior work on the sustainability spectrum [43, 45, 46, 56] and the stages of corporate sustainability [28], the concept of "weak" versus "strong" biomimicry has also been proposed as a way to differentiate between those innovations that aim to make some gains in sustainability versus those innovations that have no such intention [7]. When we view nature simply as a source of inspiration for human design, we develop solutions that are technocentric rather than ecocentric [7]. These designs are anthropocentric and focus only on humanity's needs and nature's instrumental value to humans [32]. This "weak" biomimicry allows us to design solutions that serve human needs and continues to advance the notions of human separation from nature and human control over nature, in fact viewing nature's designs as deficient and our technological designs as supplementary [7]. "Strong" biomimicry, on the other hand, enables us to design solutions that are situated within nature and in harmony with ecosystems [7], an approach that positions humans and nonhumans in a bioinclusive relationship where our focus is not to reduce human impact but to have a generative impact on nature recognizing our interconnected life system needs and the intrinsic value of nature [32]. For example, the natural world has been the inspiration and model for military technologies, spacecraft, nanomachines, and even surveillance cameras [31] and has been interpreted as merely another methodology for the enslavement of nature [26]. But replacing a conventional climbing robot with a gecko-inspired climbing robot [37, 51] or developing a painless needle that imitates a mosquito's stinger [10] does little to advance sustainability and may, in fact, create a rebound effect that drives more consumption.

Table 3 Bioinspired approaches and sustainability

	Bionics		Biomimetics	Biomimicry	
Gradient	Less sustainable		Mixed	More sustainable	
Sustainability spectrum	Very weak	Weak	Intermediate	Strong	Very strong
Stage of corporate sustainability	Compliance	Business centered	Systemic	Regenerative	Co-evolutionary
Worldview	Technocentric		Mixed	Ecocentric	

Based upon our analysis, we can position the three bioinspired design approaches along the sustainability continuum (Table 3). Bionics solves human-defined problems by looking to nature for solutions. It is an anthropocentric and technocentric approach that extracts design ideas from nature and applies them to design solutions without necessarily replicating the mechanics of nature. For this reason, we classify bionics within the very weak and weak sustainability worldviews.

Biomimetics extracts design ideas from nature but without consideration of the sustainability of the design. However, biomimetics focuses more on the adoption of nature's mechanics and, for this reason, we classify biomimetics as an intermediate sustainability worldview.

Biomimicry seeks nature-defined solutions to apply to human problems. Biomimicry is ecocentric and is not focused on extraction but rather on learning from nature in terms of form, process, and system and ensuring the sustainability of the design. Therefore, we classify biomimicry within the strong and very strong worldviews.

5 Discussion and Implications

There is growing interest in sustainable design. Bioinspired approaches for sustainable design include bionics, biomimetics, and biomimicry but the terms are often confused and erroneously used interchangeably. Although [62] believes it is of limited use to distinguish between these various approaches because they all contribute a degree of sustainability, experts agree that clearer distinction is needed between these concepts [24, 25].

Contrary to [62], our comparative study shows that these three bioinspired sustainable design approaches do not each contribute a degree of sustainability. Our analysis shows that bionics, biomimetics, and biomimicry are distinct terms regarding intent, disciplines and practitioners, specialization, and solutions. This allows us to identify more nuanced differences and to develop more precise descriptors for each bioinspired approach toward design. Given that sustainability is a much-contested concept [22], we show how [28] five-stage model can be used as a framework to illuminate a path toward sustainable bioinspired design. Using this framework, we can order these three bioinspired design approaches along a gradient of less sustainable to more sustainable following the sustainability spectrum [43, 45, 46, 56]. On the left side of the spectrum, bionics is classified within very weak sustainability and weak sustainability and do not contribute to sustainability. Therefore, this design approach is appropriate when designers are not seeking sustainability but, nonetheless, want a design inspired by nature. Biomimetics is an intermediate position between weak and strong sustainability. This design approach is appropriate when designers create a design inspired by nature and which uses models found in nature but is not made with sustainable materials or in a sustainable way. On the right side of the spectrum, biomimicry is classified within strong sustainability and very strong sustainability and does contribute to sustainability. This design approach is appropriate when designers are seeking a design that is inspired by nature, follows models found in nature, and uses nature's measure of sustainability in methods and materials.

For design and innovation practitioners seeking sustainable solutions, the nuanced distinction of the different phases of sustainability is a necessary inclusion in the design process. Understanding the differences between bionics, biomimetics, and biomimicry approaches can be useful to designers and to the field of design in determining which approach to use depending upon the desired outcome. Designers can choose bionics for novel designs inspired by nature, or they can choose biomimicry for a sustainable design inspired by nature.

Cooper ([11], p. 15) posits that the future of design "offers the significant potential of design to change the world at all levels and to do so in an ethical, trustworthy and collaborative manner." To do this, design must be sustainable. Of all the bioinspired approaches, only biomimicry will lead to sustainable design and only with intention and accountability toward sustainability.

6 Limitations and Future Directions

The authors recognize that several attempts have been made to classify and distinguish between the bioinspired disciplines as they relate to sustainability. While we have attempted to be inclusive in our selection of literature reviewed, we recognize this is a vast and evolving conversation, with both memes and specific words quickly evolving.

Further research is needed to aid in delineating the variety of bioinspiration terms that are often misunderstood or used interchangeably, such as those highlighted here. In addition, future research would benefit from the application of [28] staged sustainability framework to new and existing case studies of bioinspired design to better exemplify how it can be relevant for designers. Finally, the staged sustainability framework [28] can be applied to other sustainable design approaches beyond bioinspired design methods to assess their contribution toward sustainability.

7 Conclusion

Victor Papanek proclaimed that few professions are more harmful than industrial design while simultaneously advocating that design is the most powerful tool for shaping our environment [44]. Papanek called for responsible design that had purpose, served humanity, and protected the environment; design that could change the world [44]. Since that time, numerous sustainability elements have entered the design profession. Of interest here are the bioinspired approaches of bionics, biomimetics, and biomimicry. These concepts are related and often used interchangeably, leading to confusion. Designers have called for better clarity between these terms [24, 25]. This is the goal of the current chapter: to provide clarity.

Our comparative analysis of the terms bionics, biomimetics, and biomimicry uses sustainability theories and frameworks to provide clarity. We define bionics as a design method that gains design inspiration from nature, biomimetics goes one step further to use nature as the design model, while biomimicry extends both concepts and exclusively uses nature as a mentor and measure of sustainability (Table 2). We also show that it can be useful to think of sustainability as being along a gradient of less to more sustainable [35], as shown in Table 3. Using the sustainability spectrum [43, 45, 46, 56], we applied [28] framework of five stages of corporate sustainability to define a placement for each of the three terms, bionics, biomimetics, and biomimicry. From this exercise, we show that bionics is less sustainable, adopts a technocentric worldview, represents weak or very weak sustainability, and is aligned with compliance and business-centered stages of sustainability. Biomimetics represents intermediate sustainability with mixed technocentric and ecocentric worldviews that are somewhere between less and more sustainable, and is aligned with systemic sustainability. Biomimicry is most sustainable, adopts an ecocentric worldview, represents strong or very strong sustainability, and is aligned with regenerative and co-evolutionary stages of sustainability. Improved understanding of these terms reveals that they are distinct concepts with each subsequent approach building upon the other. This understanding can help designers choose appropriate methods suitable to their intended purpose. It is clear that if the design intends to be sustainable, biomimicry is the only solution.

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