

Bio-Inspired Products and Technology Innovation- The Present and Future

Arup Barman¹, and Karan Das²

¹ Professor and Head, Department of Business Administration, Assam University, Silchar, India

² Assistant Manager, APDCL, Rangia, Kamrup, Assam, India

Correspondence should be addressed to Arup Barman; abgeet@gmail.com

Received: 4 May 2024

Revised: 18 May 2024

Accepted: 1 June 2024

Copyright © 2024 made Arup Barman et al. This is an open-access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

ABSTRACT- Businesses throughout the world are looking to nature for ideas when creating new goods; this is a trend that is indicative of the bio-innovation industry's explosive expansion. Product creation has benefited greatly from the so-called "biomimicry," or the mimicking of ancient biological and ecological patterns and principles. In too distant future, technology will not only mimic nature but also stand side by side. 'Bio' in future will serve as an additional descriptor for human creativity. Such creativity has to create more customer-friendly novel products keeping the mind environmentally suitable may be made according to the trend of bio-inspiration. Days are not far to witness the level of creativity beyond our wild imagination. Businesses are learning more about and figuring out how the biological systems operating at the moment may invent the wildest and crazy bio-inspired products.

Nowadays customers are more mindful and conscious of the environment, and paying attention to innovation for sustainability. Growing green customers are forcing companies to put top priority on Bio-Technology as well as on Green Technology a signal for strong customer environmentalism [1]. Businesses are investing an increasing amount of capital in research and development for nature-inspired solutions, and product development synthesizing human ingenuity and biological knowledge. The evolution is not exactly to produce better products, but products fit according to nature for a sustainable world. Given this backdrop of nature-inspired revolution, examination is required especially how industry, technology, and the environment are related to one another. This paper articulates a descriptive picture of Bio-Inspired products, Bio-Inspired Innovation, and Bio-Inspired technology for future businesses that would connect sustainability in future.

KEYWORDS- Bio-Inspired Customer, Bio-Inspired Design, Bio-Inspired Infrastructure, Bio-Inspired Products, Bio-Inspired Services, Innovation, Future Technology

I. INTRODUCTION

The quest for innovation has led us down various paths of inspiration, and one of the most prolific sources has been 'nature' itself. The field of bio-inspired technology draws from the designs and processes of biological entities to create products that solve complex human problems. With an understanding of how nature has refined its mechanisms

over millions of years, engineers and designers are looking to these systems for inspiration, leading to a new era of products that could transform our future.

Bio-inspired customers are a specific group of consumers interested in products or services that are designed based on biological principles. They are driven by a desire for:

A. Sustainability

Bio-inspired products often prioritize eco-friendly materials and processes, which appeals to customers concerned about environmental impact.

B. Performance

Biomimicry can lead to innovative solutions [2] that outperform traditional materials or technologies, attracting customers who value functionality and efficiency.

C. Safety and Health

Bio-inspired designs can be inspired by organisms that have evolved safe and effective solutions, appealing to health-conscious consumers.

D. Uniqueness

Bio-mimicry often leads to unconventional and cutting-edge products, attracting those who appreciate novelty and innovative design.

Here's a breakdown of different types of bio-inspired customers:

- **Eco-conscious Consumers:** These customers prioritize products with minimal environmental impact [2] and appreciate bio-inspired solutions that address sustainability challenges.
- **Tech Enthusiasts:** Early adopters of new technology, they're drawn to bio-inspired products that push the boundaries of innovation and performance.
- **Health and wellness seekers:** This group prioritizes health and well-being, and bio-inspired products that promote natural healing or utilize safe materials resonate with them.
- **Design aficionados:** These customers appreciate aesthetics and functionality, and bio-inspired products that offer unique design elements or mimic natural beauty can be attractive.

By understanding the motivations and preferences of bio-inspired customers, businesses can develop targeted marketing strategies and product features that cater to this growing segment.

Bio-inspired products and technology innovation offer a promising path forward in our pursuit of sustainability and efficient solutions from the perspective of consumers and producers. By looking to nature for inspiration, we can create technologies that are not only effective but also harmonious with the nature around us. As we continue to innovate, we must do it responsibly with an eye toward the preservation of the natural systems that have so much to teach us in future.

II. OBJECTIVES

The author wishes to carry on the literature review to pursue the following objectives-

- Firstly, to collect the evidence of ongoing efforts for producing bio-inspired products;
- Secondly, to describe the bio-inspired technologies and possible innovations for bio-inspired society in future;
- Thirdly, to visualize and predict future challenges for Bio-Inspired products, processes, technologies and businesses in the world.

III. METHODOLOGY

The paper adopts the descriptive content synthesis methods with the help of literature. Descriptive synthesis [3] is more or less like a content analysis method important method of qualitative research [4]. In pursuing the above 3 (three) objectives authors attempted to give an overview of bio-inspired design, and bio-inspired content for future innovation of products and services. The outcome of reviews articulated as the final paper is structured in nine subsections.

IV. THE EVIDENT FUTURE

As we proceed into the future, we will encounter the future. The future is as much an opportunity as it is a journey, and we have the power to take the lead by integrating bio-inspired innovation to help build a more sustainable world. The Bio-inspired design philosophy is a methodology that looks to nature to solve complex problems by observing and studying natural processes and systems and seeks to emulate them. Through millions of years of evolutionary iteration and selection, bio-mimetic designers can create designs and systems that are highly sustainable and efficient. Nature-based design has spawned significantly eco-friendlier products and systems and has revolutionized how we develop new ideas and ways of thinking. It's a wonderful philosophy behind nature, i.e.- "nature may work as a problem but nature can be a great solution". The inherent capacity of nature-nurtured solution engineering is incredible. Plants, animals, and the systems of nature are always curate by the capacity through self-evolving or automatic engineering with their tremendous power(s) for optimization. Considering the characteristics of nature as an engineer, the literature defines 'nature as a network of large numbers of the self-engineered system'. Many of the human inventions that we predict now as the solution future can be looked at as the phenomenon of 'retort of nature'. As an example, we can cite here, the inventions of various wing-shaped aeroplanes, the wings have been engineered by observing the aerodynamics of the wings of natural birds. The flight of birds, alongside the design of jet wings, informs us about contrails-you now know why jets create

contrails and where to place large wind turbines based on this information. Beehive structures are seen everywhere, from architectural overlays to other biological networks. The point is, that nature has solved a lot of problems already, and by following the principles that underlie biological systems and structures, we can begin to apply the natural complexity to human-made systems and products. Models can be found all around us every single day [5]. Consider one: the lotus flower. In nature this plant is extremely hydrophobic, meaning that it involves a process of self-maintenance. While examining the lotus flower a breakthrough in materials science was discovered. A research team found that the micro-scale structure of the leaf creates a physical repulsion for muck and moisture in the form of cells. If rain falls on a lotus flower with any dust on the leaf, the droplets will simply roll off. This study of the simple flower led to the development of a self-cleaning paint and coating.

A. Bio-Inspired Content Design

Bio-inspired content(s) design has not only revolutionized technological advancements but also paved the way for sustainable solutions in various industries. From construction to product design, bio-imitation has been a catalyst for innovation since the beginning of time. Efficiency and environmental awareness are two standards that can be extracted from the method of bio-imitation thinking [6]. For instance, the honeycomb structure's efficiency can be mimicked to create next-generation solutions that outperform anything else while still saving the planet or using spider silk as an inspiration for its strength. This shows human beings' creativity and demonstrates how important studying successful designs in nature is. One type of bio-inspired content design currently driving technological advancements is drones modelled after birds or insects; recently there was much talk about them too. Aeronautical engineers have made these robotic aircraft more agile, efficient and versatile by imitating the flight patterns together with aerodynamics taken from creatures like these also being necessary even alone or with other things could do it alone. They are used in different fields because they can mimic their environments better than any other usual robots which makes them work better for environmental monitoring search-and-rescue missions package delivery etcetera, as a matter of fact – bio-inspired drones succeed where traditional ones fail because they copy some features from living organisms around us. Inspired by biological systems, products can be designed to be not only eco-friendly but also highly functional products. For instance, biomimicry enables engineers to immerse themselves in biological processes and structures to create products that optimize performance and sustainability.

B. Bio-Inspired Products

Biological strategies have gained significant attention in product development due to their sustainability and innovation in nature. By drawing inspiration from biological systems, companies can create products that are not only environmentally friendly but also highly efficient. Biomimicry, for example, allows engineers to mimic natural processes and structures to design products that are optimized for performance and sustainability. This approach will not only benefit the environment but also will

open up new possibilities for cutting-edge solutions in various industries [28].

Table 1: Bio-Inspired Products and Extended Future Use

S. No	Name of Products	Bio Inspirations	Present	Extended Future Uses
1	Self-healing materials	Inspired by the regenerative abilities of organisms like salamanders and starfish	Could automatically repair cracks or tears, reducing maintenance costs	Extending product life-spans.
2	Bio-batteries	Microbial fuel cells found in nature	Could generate electricity from wastewater or organic materials,	Sustainable and renewable power source.
3	Bio-adhesives	Inspired by the powerful glue produced by mussels	Bio-adhesives could bond to wet surfaces and even underwater.	Revolutionizing manufacturing and construction industries.
4	Water-harvesting surfaces	Mimicking the super-hydrophobic surfaces of lotus leaves	Could repel water while collecting it in droplets,	Self-cleaning surfaces or collecting rainwater in arid regions.
5	Bio-filtration systems	Inspired by nature's amazing filtration capabilities, from kidneys to wetlands	These systems could remove pollutants and contaminants from water and air more efficiently.	Pollution Control
6	Bio-inspired robots	Taking after the agility and adaptability of insects and animals.	Could perform tasks in hazardous or delicate environments, or even for medical procedures.	Human Facilitation
7	Bio-luminescent lighting	Inspired by fireflies and other bioluminescent organisms.	This lighting technology could be energy-efficient and aesthetically pleasing,	Potentially illuminating buildings or signage.
8	Microbial enhanced concrete	By incorporating bacteria that can heal cracks and improve the strength of concrete.	bio-inspired material could extend the lifespan of infrastructure and reduce maintenance costs	Low Cost Maintenance
9	Bio-plastic packaging	Biodegradable materials derived from corn starch & cellulose.	Could address the growing problem of plastic pollution.	Plastic Pollution Control
10	Natural insect repellents	Derived from plants or microorganisms.	Could protect from insect bites and for safety.	Safer and more eco-friendly alternative to synthetic chemicals.
11	Biomimetic coatings	Inspired by nature's self-cleaning surfaces like lotus leaves.	Could repel dirt and grime,	Reducing cleaning costs and maintenance needs.
12	Bio-inspired drug delivery systems	Mimicking the way viruses or nanoparticles target specific cells	Could deliver drugs more precisely	Reducing side effects and improving treatment efficacy
13	Algae-based biofuels	Harvested from algae	Could be a sustainable alternative to traditional fossil fuels	Reducing greenhouse gas emissions and reliance on non-renewable resources
14	Bio-inspired sensors	Inspired by the sophisticated sensory organs of animals	Could detect a wider range of stimuli with higher sensitivity	Useful in environmental monitoring or medical applications.
15	Bio-fabrication	Nature's ability to grow complex	Used to create new materials, tissues,	Used for medical purposes

		structures,	organs	
16	Bio-inspired adhesives	Inspired by the strong yet biocompatible adhesives	Used for wound closure or tissue repair in surgeries	Medical and Surgery
17	Bio-inspired water desalination	Mimicking the way mangrove trees filter saltwater	Could provide a more efficient and sustainable way to obtain fresh water in arid regions	Water sustainability
18	Bio-inspired thermal management. [32]	Inspired by the way animals regulate their body temperature	systems could improve energy efficiency in buildings or electronic devices	Energy Sustainability
19	Bio-inspired packaging materials	Nature's strong and lightweight structures like spider silk or seashells	Could be more sustainable and efficient	Sustainable Packaging
20	Microbial-based food production	Utilizing microbes to produce protein or other food components	Could provide a more sustainable and scalable way to meet growing food demands.	The problem of food sustainability
21	Wound healing dressings	Mimicking healing properties of honey or maggot therapy	Could promote faster healing and reduce infection risks	Medical Reason

C. Bio-Inspired Product's Functionality Design

Bio-inspired design can lead to collaboration and new technologies for a better world. Designers can create innovative solutions for performance improvement, sustainability, and resource efficiency. Bio-inspired approaches like replicating honeycomb structures can increase product functionality in creative and sustainable ways. Biomimicry principles can impact energy-efficient, long-lasting, and eco-friendly products.

There are infinite possibilities due to bio-inspired design, that might allow human beings to collaborate with nature and discover new technologies to create a future and a better world. Designers can create innovative solutions assuring performance improvement, besides sustainability and resource efficiency [7]. Bio-inspired approaches were inspired to replicate honeycomb structures to achieve lightweight and strong materials [8]. All these are examples of future potential for increasing the functionality of products in creative and sustainable ways. How living things fit into their environment- can trigger designers to explore and create practical solutions to make the product functional and work efficiently [9]. Better functionality of products can be designed by following the principles of biomimicry may impact energy-efficient, long-lasting and eco-friendly products.

D. Adoption of Bio-Inspired Process Design

In many industries bio-inspired process designs have gained a lot of popularity. Bio-inspired processes are emulating natural systems with the potential to increase efficiency. Bio-inspired process designs are emulated from exploring ideas from biological processes, companies would be able to create many novel solutions by nature-based optimisation for resource utilisation; minimizing wastage, and delivering complete performance. Presently invented swarm intelligence algorithms are based on the behaviour of ant colonies is an example of bio-mimicry. Swarm intelligence algorithms have transformed the modern modus operandi of supply chain management enabling effective route planning

and distribution. Bio-inspiration has brought many positive changes in renewable energy technologies, robotics, and the many wings of material sciences. Many Industrial processes become highly efficient due to mimicry of the principles of bio-systems.

E. Bio-Inspired Structure Design

The way we interact with our surroundings will be transformed by groundbreaking architectural designs. By adhering to conventional practices, architects can create spaces that surpass their intended purpose and evoke feelings of amazement and fascination. The potential is vast, ranging from awe-inspiring, gravity-defying skyscrapers to environmentally friendly structures that seamlessly blend with the natural world. These innovative designs defy our preconceived notions of what is achievable, propelling the industry towards uncharted territories. The influence of bio-inspired advanced structures can be seen across a range of industries, including architecture and aerospace. These innovative designs have resulted in buildings that are not only aesthetically pleasing but also environmentally friendly and energy-efficient.

F. Examples of Bio-Inspired Structured Design

It is not an astonishing fact that bio-inspired advanced structures have been making an important impact throughout various industries, from architecture to aerospace where structural design is required. For example, bio-mimicry in building design has led to buildings that are not only pleasing to look at but also more sustainable and energy-efficient. In aerospace, scientists have looked to nature to improve the design of aircraft wings which is already cited, as leading to more efficient, manoeuvrable aircraft. Such examples prove that looking at the natural world bio-system can result in innovative solutions that can transform industries.

Structural innovation and design can redefine human relationships with the environment. Architects need to manufacture spaces if the same is done following the

tradition of nature, or through inspiration of bio-systems that can make an awe with the wonders through bio-inspired designs and technologies. Nature-based structural innovations offer hope and hope from gravity-defying, futuristic skyscrapers to completely sustainable buildings that harmonise with nature. The possibilities are many but innovative designs challenge our perceptions of the limits of possibility, pushing the industry into areas that have yet to be explored.

G. Bio-Inspired Service Design

The boundaries of tradition can be transcended through innovative architectural designs, revolutionizing our connection with the environment. Architects possess the ability to design environments that surpass their initial function, instilling a feeling of wonder and captivation. The possibilities are immense, spanning from awe-inspiring, gravity-defying skyscrapers to environmentally conscious structures that harmoniously integrate with the natural surroundings. These groundbreaking designs defy our preconceived notions of what is possible, propelling the industry into uncharted territories.

H. Impacts of the Nature-Inspired Service Design

The integration of nature-inspired elements in service design has proven to greatly influence the customer experience, resulting in interactions that are both captivating and unforgettable. Services planning and designs to offer services in conjugation with nature-inspired elements can extract positive emotions, alleviate stress, and enhance overall customer satisfaction. For instance, incorporating natural materials, colours, and textures in a spa setting can promote relaxation and revitalization, ultimately contributing to a more positive customer experience. Moreover, nature-inspired design can also bolster perceptions of a company's dedication to sustainability and environmental stewardship, thereby fostering customer loyalty and enhancing brand reputation. Nature-inspired service design is a great approach. It can leverage the beauty and efficient natural systems to create innovative solutions for customers. By drawing inspiration from nature-based patterns, nature-based processes, and nature-based structures, businesses or organisations in the future can develop services that are not only aesthetically pleasing but also highly functional and sustainable. This design philosophy resonates with customers who are increasingly seeking products and services that align with their values of environmental responsibility and holistic well-being. As businesses continue to prioritize customer-centricity, nature-inspired service design offers a unique opportunity to create meaningful experiences that foster a deep connection between customers and brands.

V. BIO-INSPIRED TECHNOLOGIES

There are proposals for future mobility through the bio-inspired collaborative system. Transport integrating swarm robotics and vehicle platooning models for collaboration [10] is going to become a reality. There is ample evidence of analysis of existing literature on bio-inspired computation and Big Data technologies; Focusing on recent advances, trends, challenges, and future research recommendations [11]. Impact of nanotechnology in biomedical engineering for diagnosis and treatment, development of bio-Nano-tools, nonmaterial, and bio-inspired computing techniques [27]; Noise reduction using GFAC model in medical image processing - PSO algorithm effective for skin cancer detection in images [12]. The paper discusses innovation inspired by Nature in design, Exploring fabrication and technology inspired by biological processes, and the impact of nanotechnology in biomedical engineering for diagnosis and treatment. - Development of bio-nano tools, nanomaterials, and bio-inspired computing techniques [13]. "Biological Transformation" as the next industrial revolution in optics manufacturing, Assessment of innovation potential in glass moulding for optics production [14], [29]. They discussed the development of bio-inspired robots mimicking animal behaviours. Emphasizes the critical role of delicate structures in robot performance [15]. Nature-inspired advancements in additive manufacturing and bio-inspired design (BID) - Covers the history, challenges, capabilities, and future directions of bio-inspired advancements [16]. Bio-inspired nano-level designs in agriculture for increased crop yields. Nanomaterials are used in agriculture for novel pesticides and fertilizers [17]. Utilizes natural insectoid systems for miniaturized drilling solutions. Studies ovipositors of locusts and woodwasps for space applications [18]. Energy efficiency through bi-directional flow for reduced carbon footprint. - Future focus on intelligent energy systems and new liquid fuels [19]. Bio/Nature inspired approaches to network-related problems; Bio-inspired routing algorithms for sensor networks [20]. Bio-inspired technologies, drawing from nature's efficiency and adaptability, offer promising solutions for future applications like swarm robotics and wireless sensor networks, aligning with the paper's focus on pattern recognition [21]. Bio-inspired computing, utilizing genetic algorithms, evolution strategies, and artificial immune systems, shows promise for designing advanced photonic devices, potentially shaping future technological advancements [22].

Table 2: Bio-Inspired Technologies in Future

SL	Author	Technology Visualisation	Bio-Inspiration	Uses in Future
1	Narora, Coretti, & et.al. [10]	Swarm robotics and vehicle platooning models	Mimic natural swarms (Bio-Inspired shared, electric, and autonomous vehicles & collaborative system)	To enhance urban mobility through cooperation and mutuality relationships.
2	Ana, I., & et.al [11]	Bio-Inspired computation for Big Data fusion	Bio-inspired computation for Big Data fusion, storage, processing, learning, and visualization	Identifies trends, challenges, adaptations, and future research recommendations
3	Ajay, Sudhir. & et.al.[12]	Nanomaterials for drug delivery, SBO algorithm for	Enhancing bio-inspired computing for advanced applications.	Bio-medical engineering development of bio-nano-tools,

		skin cancer diagnosis, and integration of nanotechnology with AI,		nanomaterials, and bio-inspired computing
4	S.Lucibello. [13], [30]	Bio-medical engineering, bio-nano-tools	Big Data management, processing, and learning.	Bio-inspired computation enhancement, diagnostics
5	Grunwald & Berg. [14]	Moulded optics and Optical systems	Use of Biological Transformation	Glass Moulding and Optics Manufacturing
6	Ziyu, and Shao [15]	Robots and Robotics Technology	Mimicking animal behaviors	Enhancing Robot Performance
7	Kumar. A & et.al. [16]	Additive manufacturing and bio-inspired design (BID)	Nature Inspired-Advancement	Future directions of bio-inspired advancements
8	Y. Ghidan, A., & M. Al Antary, T. [17]	Nanomaterials used in agriculture	Bio-inspired nano-level designs in agriculture	Novel pesticides and fertilizers
9	Carlo. & et.al.[18]	Utilizes natural insectoid systems for miniaturized drilling solutions	Bio-Inspired Drilling	Locusts and woodwasps for space applications
10	Palit. Shoumen. & et.al.[19]	Efficient Energy System with a focus on multi-directional energy flow	Bio-Inspired Fuel System mimicking mitochondria	Liquid fuels Post-2050; intelligent grids for emphasizing real-time data for decision support tools.
11	Hoon, Yi., & et.al.[23]	Green Manufacturing Technology	Bio-inspired dry adhesives for precise, clean manufacturing technology.	New adhesive systems enable the manipulation of substrates without external force; and routing algorithms for sensor networks.
12	Shibata. T, [20]	Developing VLSI system for human-like intelligent information processing.	Developing brain-mimicking VLSI system for human-like intelligent information processing.	Utilizing state-of-the-art silicon technology and exotic nano-devices
13	Posch. C. [24] [31]	Vision systems with the potential to outperform conventional vision systems	Bio-inspired technologies, like neuro-morphic systems	Potential for advanced vision systems, conventional methods, enhancing redundancy suppression, dynamic range, for power efficiency for future applications.

VI. PREDICTION ON BIO-INSPIRED PRODUCTS AND TECHNOLOGIES

The table-I the column demarcated as “extended future use” indicates on use of bio-inspiration in fields, such as extending product life spans and sustainable and renewable power sources.; Revolutionizing manufacturing and construction industries; self-cleaning surfaces or collecting rainwater in arid regions; pollution control; human Facilitation; Potentially illuminating buildings or signage; low-cost maintenance; plastic pollution control; the safer and more eco-friendly alternative to synthetic chemicals; reducing cleaning costs and maintenance needs; reducing side effects and improving treatment efficacy; reducing greenhouse gas emissions and reliance on non-renewable resources; useful in environmental monitoring or medical applications; used for medical purposes; in the medical and surgery; water sustainability; energy sustainability; sustainable packaging; for the solution of the problem of food sustainability; for the medical reasons. Many products already are in use following bio-inspiration or bio-mimicry. More promising bio-inspired technologies those would bring unsurpassed innovations. We can be visualised from the Table II above. Future innovation would concentrate bio-inspiration based on (i) Enhancing urban mobility through cooperation and mutuality relationships; (ii) Identifying trends, challenges, adaptations, and future research recommendations; (iii) Bio-medical Engineering Development of bio-nano-tools, nano-materials, and bio-inspired computing; (iv) Bio-inspired computation enhancement, diagnostics; (v) Glass Moulding and Optics Manufacturing [14]; (v) Enhancing Robot Performance;

(vii) Future directions of bio-inspired advancements; (viii) Novel pesticides and fertilizers; (ii) Locusts and woodwasps for space applications; (ix) Liquid fuels Post-2050; intelligent grids for emphasizing real-time data for decision support tools. (x) Utilizing state-of-the-art silicon technology and exotic nano-devices; (xi) Potential for advanced vision systems, conventional methods, enhancing redundancy suppression, dynamic range, for power efficiency for future applications.

In the pursuit of groundbreaking products; research and development-based businesses are increasingly gazing inside nature for inspiration, marking a significant shift towards bio-inspired innovations. The concept of biomimicry, where nature's time-tested patterns and strategies are emulated, has already become a goldmine for product ideation and development. This is the trend-“promising a future where technology not only mimics but also collaborates with the biological world”. This approach has the potential to revolutionize how products are designed, making them more sustainable, efficient, and appealing to customers. By studying the intricate details of natural processes, businesses can innovate in ways that were once deemed impossible, which may be possible by creating products that are both revolutionary as well as harmonious with the environment.

VII. CUSTOMER-CENTRIC BIO-INSPIRED TECHS & PRODUCTS

Customers today are more environmentally conscious than ever, seeking products that reflect their values for

sustainability and innovation [25]. They favour businesses that prioritize green technology and bio-inspired designs, showing a clear preference for innovation that benefits the planet [26]. As a result, companies are increasingly investing in R&D that looks to nature for answers, understanding that the future of product development lies in the symbiosis between biological wisdom and human creativity. This shift is not just about creating better products; it's about redefining the relationship between business, technology, and the natural world.

The emergence of bio-inspired innovation and its integrations in business strategies can open new windows for fresh growth and differentiation in any competitive market. Thus, the products with such approaches can have unique selling points—efficiency, consumption of less energy, and bio-mimetic design—with an increase in customer appeal. Moreover, such strategies allow companies to orient their business models toward the principles of circular economy, with less wastage and higher resource regeneration, just like in nature's ecosystems.

Applications of bio-inspired innovations are virtually unconfined, ranging from architectural industries to automobile industries and textiles to information technology. In all instances, every industry can look toward the durability, efficiency, and adaptability found in nature and strive to emulate these features in their products to entice customers. For instance, aerodynamic planes in aerospace technologies have already adopted some bio-inspired designs and are in the beginning of manufacturing more aerodynamic planes, similar to birds, which promise to improve fuel efficiency and effectiveness.

How Businesses Can Target Bio-Inspired Customers

- **Highlight the Bio-mimicry Aspect:** Communicate how your product or service draws inspiration from nature.
- **Focus on Sustainability Benefits:** Emphasize the eco-friendly features and life cycle of your product.
- **Showcase Performance Advantages:** Demonstrate how the bio-inspired design leads to superior performance compared to traditional options.
- **Use Clear Messaging:** Necessary to tailor the marketing message to resonate with the specific values (e.g., sustainability, health, innovation) that appeal to bio-inspired customers.

VIII. CHALLENGES OF BIO-CENTRIC BIO-INSPIRED INNOVATION

Due to the complexity of biological systems- accurately mimicking can be very difficult, especially when it comes to replicating the complex interactions between different biological components. Translating all the complexities to integrate into functional technologies requires significant advancement in various fields.

A. Compatibility to Small Scale:

Many bio-inspired solutions may be compatible only at a small scale rather than at a large scale. Scaling bio-inspired solutions for mass production may act as a challenge as well as a hurdle.

B. Ethical considerations:

Predicting the consequences of applications of bio-inspired solutions are too much difficult. Many a time it was seen

that genetically modified organisms used in the process of bio-remediation efforts showed unintended consequences. Ethical concerns for bio-inspired solutions may discourage businesses and inventors from exploring more.

C. Cost of Concept to Launch:

For the Bio-Inspired innovation, the cost of concept creation to launch requires extensive research and development which consumes huge funds and time [27]. Bio-inspired R&D attracts less numbers of investors due to investment hesitation; finally oscillates back to traditional concepts and ideas rather than crazy bio-inspired ones.

D. Infrastructural Compatibility with Existing Infrastructure:

Bio-inspired solutions do not always impeccably integrate into the existing systems and infrastructure. An example to suffice the justification here is- “a self-healing road might require entirely new construction techniques and machinery”.

E. Unknown Domino Effects:

All technology innovation carries a risk of unforeseen consequences. There is every possibility that bio-inspired solutions could have unintended effects on ecosystems or societal structures if that product is considered for widespread use. Bio-inspiration may create problems one after another or one over the other with chain effects.

F. Breaking down the Public Perception:

The Public are not that easy to embrace any or all of bio-inspired technologies. Gaining public approval for bio-inspired products might require different levels of communication, appropriate education and training on exposing the benefits of the products and the projects.

IX. CONCLUSION

The future of products, customers, business, and innovation is deeply intertwined with bio-inspired strategies. As this trend continues to evolve, it will not only shape the landscape of product development but also redefine what it means to be a sustainable, innovative, and customer-centric business. The embrace of biomimicry signifies a move towards a more thoughtful and creative approach to innovation, one that respects the ingenuity of nature and recognizes its potential to inspire groundbreaking advancements in technology and business. Bio-inspired technologies have innumerable wonder potential to revolutionize various industries in the future. By taking cues from nature, these technologies can develop creative solutions to complex problems. These nature-inspired advancements have already demonstrated sustainability, efficiency, and elegant design in various applications, setting the stage for future bio-inspired innovations. To delve into the applicable bio-inspired products and solutions inventors, businesses and industries need to face multiple challenges.

This paper incorporates enough products, technologies, and innovations for future business and entrepreneurship. Bio-inspired engineers and researchers may get enough input(s) and evidence for the future use of bio-inspired ideas in ensuring a sustainable world. Challenging the challenges for bio-inspired product design, development, invention and innovations may make our path smoother for further

investigation into bio-inspired human welfare and excellence. The study has accomplished three objectives through an overview of collecting evidence of ongoing efforts for producing bio-inspired products. The authors lucidly describe the bio-inspired technologies and possible innovations for bio-inspired society in future. The attempt to visualize and predict the future challenges for bio-inspired products, processes, and technologies for future businesses in the world is also accommodated. Finally, the authors concluded with a comment "The days are not far, the bio-inspiration will soon become a harbour" for human survival on this earth.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest between them and with any third party.

ACKNOWLEDGEMENT

The authors acknowledge **Mr Sourav Acharjee**, Research Scholar, Department of Business Administration, Assam University, Silchar for his valuing time in reading the manuscript as a reviewer while in writing.

REFERENCES

- [1] I. Skačkauskienė and N. Vilkaite-Vaitone, "Green Marketing and Customers' Purchasing Behavior: A Systematic Literature Review for Future Research Agenda," *Energies*, vol. 16, Jan. 2022, Art. no. 456, doi: 10.3390/en16010456.
- [2] B. Forés, "Beyond Gathering the 'Low-Hanging Fruit' of Green Technology for Improved Environmental Performance: an Empirical Examination of the Moderating Effects of Proactive Environmental Management and Business Strategies," *Sustainability*, vol. 11, no. 22, pp. 6299, Nov. 2019, doi: 10.3390/su11226299.
- [3] M. Vanstone et al., "Towards conceptualizing patients as partners in health systems: a systematic review and descriptive synthesis," *Health Research Policy and Systems*, vol. 21, Jan. 2023, Art. no. 10, doi: 10.1186/s12961-022-00954-8.
- [4] T. H. Barker et al., "How should we handle predatory journals in evidence synthesis? A descriptive survey-based cross-sectional study of evidence synthesis experts," *Research Synthesis Methods*, Jan. 2023, doi: 10.1002/jrsm.1613.
- [5] P. Varuneswara and A. Layton, "Bio-Inspired Modeling Approaches for Human Networks With Link Dissipation," 2019, doi: 10.1115/DETC2019-98171.
- [6] L. Ruiz-Pastor et al., "Bio-inspired design as a solution to generate creative and circular product concepts," *International Journal of Design Creativity and Innovation*, Jan. 2022, doi: 10.1080/21650349.2022.2128886.
- [7] R. Fleming and S. H. Roberts, "Bio-inspired design," 2019, doi: 10.4324/9781315159300-7.
- [8] B. Kennedy, "The application of bio-inspiration to human-centred product design," *International Journal of Design & Nature and Ecodynamics*, vol. 9, no. 3, pp. 230–236, Sep. 2014, doi: 10.2495/DNE-V9-N3-230-236.
- [9] A. Weiss, "Bio-inspired product design brief module," 2021, doi: 10.35199/EPDE.2021.2.
- [10] N. C. Sanchez et al., "Future mobility as a bio-inspired collaborative system," *arXiv: Multiagent Systems*, Jan. 2021, doi: 10.36227/TECHRIV.14788074.V1.
- [11] A. I. Torre-Bastida et al., "Bio-inspired computation for big data fusion, storage, processing, learning and visualization: state of the art and future directions," *Neural Computing and Applications*, Jan. 2021, doi: 10.1007/S00521-021-06332-9.
- [12] A. S. Bale et al., "Bio-Inspired Computing Dive into Critical Problems, Potential Architecture and Techniques," *TRENDS IN THE SCIENCES*, Jan. 2021, doi: 10.48048/TIS.2021.703.
- [13] S. Lucibello, "The near (bio) future in design," *AHFE International*, Jan. 2022, doi: 10.54941/ahfe100941.
- [14] T. Grunwald and T. Berg, "Proceedings Volume 12219, Polymer Optics and Molded Glass Optics: Design, Fabrication, and Materials 2022," vol. 1221905, 2022, doi: 10.1117/12.2633562.
- [15] Z. Ren and Y. Shao, "Future bio-inspired robots require delicate structures," *Frontiers in Robotics and AI*, Jan. 2022, doi: 10.3389/frobt.2022.1073329.
- [16] A. Y. Ghidan and T. M. Al Antary, "Applications of Nanotechnology in Agriculture," *IntechOpen*, 2020, doi: 10.5772/intechopen.88390.
- [17] S. P. A. Datta et al., "Bio-Inspired Energy Future: Quest for Efficient Intelligent Mitochondria and New Liquid Fuels," *International Journal of Electronic Business Management*, vol. 9, no. 1, pp. 1–10, 2011.
- [18] C. Menon et al., "Bio-inspired micro-drills for future planetary exploration," 2006, doi: 10.1115/CANEUS2006-11022.
- [19] Y. Shibata et al., "Mechanisms Shaping the Membranes of Cellular Organelles," vol. 25, pp. 329–354, Nov. 2009, doi: 10.1146/annurev.cellbio.042308.113324.
- [20] Y. R. Hettiarachige, "Bio-inspired techniques for pattern recognition," 2019, doi: 10.26180/5DA503AC31CAE.
- [21] C. H. da Silva Santos et al., "Designing Novel Photonic Devices by Bio-Inspired Computing," *IEEE Photonics Technology Letters*, 2010, doi: 10.1109/LPT.2010.2051222.
- [22] H. Yi et al., "Bio-inspired adhesive systems for next-generation green manufacturing," *International Journal of Precision Engineering and Manufacturing-Green Technology*, 2014, doi: 10.1007/S40684-014-0044-X.
- [23] C. Posch, "Bio-inspired Vision and what electronics and computers can learn from nature," *TWEPP 2011*, Austrian Institute of Technology AIT, 2011. [Online]. Available: https://indico.cern.ch/event/120853/contributions/1333939/attachments/66053/94832/Bio-inspired_vision_TWEPP2011_formattest.pdf.
- [24] M. Yea and S.-J. Lee, "Environment-Conscious Consumer: Goodwill and Profit Growth," *Han'gug saengsan gwanli haghoeji*, Jan. 2022, doi: 10.32956/kopoms.2022.33.3.587.
- [25] Z. Ghali-Zinoubi, "Examining Drivers of Environmentally Conscious Consumer Behavior: Theory of Planned Behavior Extended with Cultural Factors," *Sustainability*, Jan. 2022, doi: 10.3390/su14138072.
- [26] S. Suma, "Agricultural Nanotechnologies: Future Perspectives of Bio-inspired Materials," *Bentham Science*, 2023, doi: 10.2174/9789815080179123010010.
- [27] A. G. Khanzode and A. K. Sharma, Eds., "Operations Management on the New Frontier: Bridging Established Norms and Contemporary Innovations," *Imperial Publications*, 2013, ISBN: 978-93-91044-68-8.
- [28] P. K. Asthana and N. Asthana, "Bio-Inspired Nanotechnology," *Bentam Books*, 2023, doi: 10.2174/97898150801791230101.
- [29] T. Grunwald and T. Berg, "Bio-inspired manufacturing of moulded optics and optical systems," 2022, doi: 10.1117/12.2633562.
- [30] T. Shibata, "Bio-inspired devices, circuits and systems," *ESSCIRC*, 2009, doi: 10.1109/ESSCIRC.2009.5325934.
- [31] C. Posch, "Bio-inspired vision," *Journal of Instrumentation*, 2012, doi: 10.1088/1748-0221/7/01/C01054.
- [32] S. Palit et al., "Bio-inspired energy future: the quest for efficient intelligent mitochondria and new liquid fuels," vol. 9, pp. 1–11, 2011.

ABOUT THE AUTHORS



Arup Barman is serving as Professor and Head of, the Department of Business Administration, at Assam University, Silchar (India). He has been serving as a faculty of management since December 1998. He has an M.Com (NET-June 1996 and in 1996), PGDipT&D, PhD (Management), Post-Doctorate (2009-2011), and a D.Litt in Contemporary Management (honoris causa) from IIU, India. In addition, he completed more than 35 numbers of reputed diplomas and certificate programs in the areas of management, technology and innovation. He guided 14 numbers of scholars and was awarded a PhD. Dr. Barman published more than 270 research articles in national and international journals of repute. His main research interest is in interdisciplinary issues of human development, and technology aspects of human resource development. He is a member of numerous professional and academic organisations- such as a Fellow of Scientific Research and Development (FSRD), Fellow of the World Leadership Academy (FWLA) and many Prestigious Awards.



Dr Karan Das is a BE, MBA (HR) and has done his doctoral research on “Acquisition of Workplace Competencies by Management Students- A Study in Select B-Schools in NE India” under the guidance of Professor Arup Barman in 2023. He has published 20 research papers in international and national journals of repute out of which 8 papers are in SCOPUS indexed journals and attended many national and international conferences. Dr Das is serving managers at APDCL, Assam but inner interest in becoming a teacher in the field of management. He authored Strategic Management for CODL, Dibrugarh University, Assam. His research areas are HR & Technology Applications and Skills Acquisition.