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Societal implications of bioinspired technologies: Introduction to the special issue

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ABSTRACT

This Special Issue seeks to introduce a broad range of bioinspired technologies and provides an overview of the challenges regarding sustainability, ethical responsibility and societal acceptance. It adopts both a narrow and broad understanding of bioinspired technology. In a narrower sense, it refers to technologies that mimic natural forms, structures, or functional principles, typically developed within the field of biomimetics. More broadly, bioinspired technologies are defined as those designed with human or non-human nature in mind and adapted to meet the needs of both. The Special Issue addresses five key questions: First, it asks how the broad spectrum of bioinspired technologies can be categorized and classified. Second, it explores the extent to which bioinspired technologies contribute to a sustainable future and in particular to the development of sustainable technologies and what criteria can be used to ensure the sustainability of bioinspired technologies. Third, it presents methods for investigating and fostering societal acceptance of new bioinspired technologies. Fourth, central technical and societal areas are considered in which bioinspiration can contribute to a sustainable future. Lastly, it explores the ontological and ethical challenges associated with bioinspired technologies in so far as they undermine the previous distinction between 'nature' and 'technology'.

1. Introduction to the topic of the Special Issue

The development of bioinspired technologies is an important part of the scientific and technical progress in the context of the challenges discussed under the term "Anthropocene" (Crutzen et al., 2000; Bonneuil & Fressoz, 2015; von et al., 2018; Höfele et al., 2022a). Even though the *International Commission on Stratigraphy* rejected the term "Anthropocene" on March 5, 2024 as a term for a new Earth epoch (in a not uncontroversial vote), the phenomenon of a lasting human influence on the entire biosphere of our planet is still a fact (Zalasiewicz, AdeneyThomas, Waters, Turner, & Head, 2024). This fact is becoming increasingly visible and obvious in the face of the notion "Great Acceleration", that captures exponential increase in many environmentally harmful parameters (Steffen, Broadgate, Deutsch, Gaffney, & Ludwig, 2015). As a consequence, humanity is confronted with immense normative demands that cannot be ignored and which often cannot be tackled without technical innovations.

In view of the ecological challenges of our present age, bioinspired technologies are increasingly important as future technologies (Nachtigal et al., 1994; Benyus, , 2002; Nordmann, 2004; van et al., 2012). In this Special Issue, the term "bioinspired technologies" is understood in two senses. In a narrower sense, it refers to technologies that imitate forms, structures or functional principles of nature, and that are developed within the research field of biomimetics. In a broader sense, this Special Issue also defines bioinspired technologies as those developed with consideration for human or non-human nature and adapted to meet their respective needs.

However, bioinspired technologies, whether understood in the

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narrower or broader sense, are not simply solutions to current challenges. They confront both scientists and society with sustainability issues and certain attitudes and preconceptions (Höfele, Reuter, Estadieu, Livanec, & Kiesel, 2022). The transfer of functions from biological models to technical applications does not guarantee that the applications are good for humans and/or for the environment. Therefore, this transfer is not generally well-suited considering normative aspects. Biomimetic products such as facade paint with Lotus-Effect®, bone-inspired ceiling structures or natural fibre constructions[1] are not *per se* better, more ecological and more trustworthy technical solutions. To determine whether the "biomimetic promise" of better, more ecological and more trustworthy technical solutions is kept, it is necessary to implement a second step of reflection, which considers the products independently of their pure imitation of biological functions (Speck, Speck, Horn, Gantner, & Sedlbauer, 2017; M et al., 2021).

The Special Issue "Societal Implications of Bioinspired Technologies" unites contributions from different disciplines, like engineering, biology, sustainability research, psychology, philosophy and ethics. It aims to discuss in what ways and to what extent bioinspired technologies provide solutions to the societal challenges of the Anthropocene, and in how far the mentioned sciences can and even must contribute to future technical solutions. The challenges discussed under the term Anthropocene always require broad research alliances. These range from Earth System Science to biomimetics, a new approach to creating life-like technical materials systems, from sustainability research to human ecology, cultural ecology and ecocriticism, which seek to open a new space for societal reflection in the context of the current environmental crisis (Ehlers & Krafft, 2006; Höfele et al., 2022a; Müller, 2014; Steffen et al., 2016; Zapf, 2016). As diverse as these perspectives first appear, they all strive towards a new definition of the relationship between the natural and the artificial or between nature and technology in view of the current development and challenges.

The current research approaches characterise the relationship of the individual disciplines to each other in a completely new way, while at the same time resulting in a new definition of society in view of its natural and technical environment (Horn & Bergthaler, 2018; Inkpen et al., 2019; Schellnhuber, 2016). This can be demonstrated in an exemplary way within the Cluster of Excellence "Living, Adaptive and Energy-autonomous Materials Systems (*liv*MatS)" at the University of Freiburg, Germany, in which all guest editors work and have come together. From the very beginning, this research consortium has been confronted with the challenge of reconsidering the coordinate system of nature, life and the living as well as technology and artificial materials with regard to society as they have become dubious in light of the current environmental crisis. This challenge will be met in the Special Issue in view of five questions that the following eleven articles in the Special Issue seek to answer.

- How can the broad spectrum of bioinspired technologies be categorized and classified?
- How and to what extent can bioinspired technologies contribute to a sustainable future and in particular to the development of sustainable technologies? What criteria can be used to ensure their sustainability?
- Which methods are suitable to measure or even ensure the societal acceptance of new bioinspired technologies?
- How can sciences encourage the integration of bioinspired technologies into society?
- What ontological and ethical challenges do bioinspired technologies pose, insofar as they undermine the classical distinctions between nature and technology?

[1] Cf. https://www.livmats.uni-freiburg.de/en/news-press/robotisch-gewickeltes-naturfasergebaude.

The Special Issue seeks to contribute to answers to these five questions and thus provides perspectives for future research on bioinspired technologies that are sustainable, ethically responsible, and socially acceptable. To this end, the Special Issue uses selected examples to provide an overview of the broad concept of bioinspired technologies as defined above. However, the main focus is on bioinspired technologies in the narrower sense, which imitate the forms, structures, properties and functions of living nature.

2. The contributions in detail

The first article by **Andrés Díaz Lantada et al.** (Díaz Lantada, Estadieu, Gorki, Höfele, & Islam, 2024) seeks to explore the "landscape" of artificial materials and systems that mimic the properties of living things, in line with the narrower concept of bioinspired technology. In light of the multitude of quasi-living materials, structures, devices, and systems, it is initially crucial to differentiate and classify them effectively. This "map" offers an important basis for the exploration of the ethical, legal and social implications of bioinspired technologies.

The following four articles take a closer look at the methodological background for the analysis and evaluation of bioinspired technologies. The article by **Marco Tamborini** (Tamborini, 2024) examines the connection between bioinspiration and sustainability. The so-called "biomimetic promise" (von Gleich, Pade, Petschow, & Pissarskoi, 2010) is not an automatism in the transfer of biological forms and functions to technical products. As Tamborini argues, this does not require an ontological analysis of nature, but rather a description of an "epistemic grammar" that plays a role in the transfer from nature to the field of technology. However, this transferred "grammar" only ensures sustainability in the field of technology if, in Wittgenstein's words, the different "language games" and scientific practices are taken into account. The interface between bioinspiration and sustainability is also examined in the article by **Martin Möller et al.** (Möller, Speck, & Speck, 2024) that presents two methodological frameworks for prospective sustainability assessment: the Tiered Approach for Prospective Assessment of Benefits and Challenges (TAPAS) on the one hand and the Bioinspired Sustainability Assessment (BiSA) on the other hand. The sustainability strategies of efficiency, consistency, and sufficiency are provided as examples.

The study by **Asmaeil Ali Mohammed Akhmaaj** and **Mohamed Omar Sharif** (Akhmaaj et al., 2024) focuses on models of technology acceptance by future users. It integrates the Theory of Planned Behavior (TPB) (Ajzen, 1991) with the Technology Acceptance Model (TAM) (Davis, 1989). As an example, the article analyzes the online shopping behavior of residents of the Libyan city of Tripoli, who were surveyed via Google. It looks at the relationship between social influence, perceived behavioral control, perceived usefulness, user-friendliness and purchasing behavior with regard to different age groups. The article thus has important implications for the development of bioinspired technologies, as in addition to the sustainability of bioinspired forms and functions, the end users must always be taken into account to verify acceptance of technology development. This is precisely also the focus of the article by **Wilhelm Johannes Gros et al.** (Gros et al., 2024). The method of Cognitive-Affective Mapping (CAM) presented in the article is a novel mind-mapping technique that enables laypersons to visually represent their belief structure and the associated affective assessment. It can also be used to evaluate the acceptance of new and therefore also bioinspired technologies (Höfele, et al., 2022), as the successful sustainability of technology relies on societal acceptance. The data obtained from the CAMs can be analyzed both quantitatively and qualitatively. The article demonstrates the reliability of this method using the example of Universal Basic Income, even though the method can be used much more broadly and especially with regard to bioinspired technologies.

The following article by **Angela Zhou et al.** (Zhou et al., 2024) provides an example of assessing the acceptance of sustainable

technologies. Using the example of novel, colored photovoltaic systems, it is shown that sustainable technologies can generally be accepted by society. However, concrete acceptance depends on the specific context and the aesthetic embedding of sustainable technologies. For example, photovoltaic systems are generally accepted, but less so on old historic buildings. A similar approach is taken in the article by **Mai Adel Marzouk et al.** (Marzouk, Salheen, & Fischer, 2024). They also look at the implementation of agricultural and solar energy systems in an urban context, albeit in a completely different cultural context, namely in the Cairo region. They take into account different variables such as age, gender, residence type as well as access to shared facilities and identify a knowledge gap regarding the agricultural and solar energy systems.

Sustainable architecture is a key area in addressing the challenges of the 21st century. It faces not only increasing environmental challenges that demand carbon neutrality and resource efficiency, but also the challenges related to a growing global population and rising urbanization (Ott et al., 2018). Bioinspiration is a promising method for building sustainable cities. This is shown in the article by **Siddharth Chaudhary et al.** (Chaudhary et al., 2024). The authors focus on the intersection of biomimicry with sustainable construction technologies, passive cooling strategies, emulation of sustainable ecosystems, net-zero construction techniques, and innovative 3D-printed homes. The focus is on ethical-philosophical and psychological aspects to create a balance between technological progress and a deep respect for nature. The article by **Hamlet Vanderhorst et al.** (Vanderhorst, Heesom, & Yenneti, 2024) can be read as complementary to the previous articles on sustainable urban architecture. This is precisely the aim of the concept of the "digital twin", which stands for a virtual manifestation of the construction process and the associated interactions and processes. It is also about the dimensions of the user's experience. The article paints a picture of future municipalities venturing into the cyber world by embracing digital twins, smart cityscapes, blockchain technologies and other data sets to capture reality, thus arriving at an overarching vision of digital and physical construction domains.

This goes hand in hand with a comprehensive consideration of the dimension of health. Here too, bioinspiration, or at least adaptation to the needs of human nature, plays a decisive role. Think, for example, of innovative health gadgets ranging from wearable fitness trackers to advanced robotic exoskeletons. The article by **Yadong Chen et al.** (Chen, Li, Hussam, Baghaie, & Salahshour, 2024) looks at this in particular in the field of rehabilitation. The study uses machine learning to estimate recovery, performance and well-being by modifying rehabilitation and health criteria.

Finally, the closing article of the Special Issue by **Rangga Kala Mahaswa et al.** (Mahaswa, Gebbyano, & Hardiyanti, 2024) is more of a prospective nature. It deals with the concept of the Anthropocene and reflects on the existing technological paradigms, in particular bioinspired technologies, which arouse both promises and fears. The fact that the naturalization of technology and thus the technologization of nature disrupts our ontological understanding of the human-technology-world mediation is described as "uncanny". Against this background, the article is concerned with a philosophical examination of human existence in the Anthropocene in its relationship to the non-human world, in order to contribute to an ethically conscious and ecologically responsible technological practice.

CRediT authorship contribution statement

Philipp Höfele: Conceptualization, Writing – original draft, Writing – review & editing. **Louisa Estadieu:** Writing – review & editing. **Oliver Müller:** Writing – review & editing. **Lore Hühn:** Writing – review & editing. **Andrea Kiesel:** Writing – review & editing.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.techsoc.2025.102823.

Data availability

No data was used for the research described in the article.

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