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Editorial: Biologically-informed approaches to design processes and applications

Alberto Pugnale[1], Devi Stuart-Fox[2]*, Mark A. Elgar[2], Cecilia Laschi[3] and Ahu Gumrah Dumanli[4]

[1]Faculty of Architecture, Building and Planning, The University of Melbourne, Melbourne, VIC, Australia, [2]School of BioSciences, The University of Melbourne, Melbourne, VIC, Australia, [3]Department of Mechanical Engineering, National University of Singapore, Singapore, Singapore, [4]Department of Materials, The University of Manchester, Manchester, United Kingdom

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EDITED AND REVIEWED BY
Elise Huchard,
UMR5554 Institut des Sciences de l'Evolution de Montpellier (ISEM), France

*CORRESPONDENCE
Devi Stuart-Fox
d.stuart-fox@unimelb.edu.au

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Editorial on the Research Topic
Biologically-informed approaches to design processes and applications

Practitioners across domains—from architectural design (Zari, 2010; Ha and Lu, 2020), medical interventions (Chen et al., 2021), and robotics (Coyle et al., 2018; Ahmed et al., 2022) to materials science (Wegst et al., 2015)—are increasingly drawing inspiration from biology to address a wide range of challenges. This is perhaps unsurprising because life on earth represents over 3.8 billion years of evolution, whereby natural selection ruthlessly purges design failures. Despite the growth and promise of biomimetic and bioinspired approaches, the analogy to biological form or function is often superficial or largely figurative. This Research Topic was born from the topic editors' shared belief that to capitalize on insights from biology, we need to move beyond figurative referencing toward functional analogy informed by accurate biological knowledge. For this reason, we advocate a biologically-informed (or bio-informed) approach that captures key properties of living organisms and systems, such as sustainability, multifunctionality and self-assembly.

The articles collected in this interdisciplinary Research Topic illustrate the strengths of a bio-informed approach to design processes and applications. Ultimately, the goal is to demonstrate how simple concepts can be abstracted from highly complex and inter-connected biological materials, structures and processes to be applied or manufactured at scale.

A bio-informed approach requires deep collaboration between biologists and practitioners in other fields. To gauge the current extent of engagement with biologists in biomimetic and bioinspired research, Ng et al. surveyed the literature over 30 years (1990–2020) to reveal that only 41% of research papers published in the field included an author affiliated to a biology-related department, and most of them focus on a limited range of popular model species. The authors show the value of capitalizing on biological diversity and understanding the ecological and evolutionary context of the biological models. They also highlight that interdisciplinary engagement is a two-way street—for example, application of engineering approaches can improve biological understanding just as biology can offer new engineering solutions.

Several of the articles in this Research Topic focused on expanding biological knowledge for bio-informed applications. Ensikat and Weigend explored the diversity and distribution of biominerals (organic/inorganic composite materials) that comprise the "hairs" (trichomes) on leaf surfaces of many plants. Biomineralization is an area of considerable interest for biomedical applications and plant trichomes provide a more tractable model to enable *in-vivo* study of complex composite materials comprising different minerals and organic compounds.

Turning from plants to animals, Freyer et al. compared the structures responsible for different types of iridescent plumage in two bird species. Their study shows how adjusting the thickness of one layer in the complex feather microstructure can tune the iridescence from blue-purple in the European starling to blue-green in the Cape starling. This discovery has potential applications in bioinspired materials that tune color through a single sensing layer.

Two studies in this Research Topic provided elegant demonstrations of how complex biological processes can be simulated, simultaneously enhancing biological understanding and paving the way for future applications. Howard et al. showed that honeybees are able to process and categorize odd and even numbers of elements and that this learning task can be simulated with a simple neural network comprising 5 neurons. On one hand, this study suggests that complex cognitive-like behaviors can be seen in honeybees and other assumed simple biological systems. On the other hand, it demonstrates that it is possible to design computing solutions with very simplified mechanisms that resemble simple animal brains.

Sellers et al. also simulated a biological process, namely locomotion, borrowing from robotics to improve our understanding of animal biomechanics. Rather than typical steady state locomotion such as walking or running at constant speed, the study focused on non-steady-state movements such as starting, stopping and turning. The study shows how gait controllers used in robotics can be used to realistically simulate non-steady-state gaits of a chimpanzee.

Turning to applications, Salami et al. used a bio-informed approach to design a novel tandem flapping wing mechanism based on dragonflies, which achieve remarkable flying agility with four wings arranged in a tandem configuration. The tandem flapping mechanism enabled the team to study the aerodynamic forces and demonstrate how tandem wings can generate higher lift and improve stability compared with a single pair of wings. The mechanism could be used for the design of a future biomimetic micro air vehicle.

A bio-informed approach to the design process is exemplified by the article by Mirra et al. The authors implement a novel artificial intelligence (AI) agent to design 3D tree forms with complexity and features that are attractive to arboreal wildlife. Although the generated artificial designs deviate from natural structural forms, they are easy to build, and their form preserves those visual features that are meaningful to birds and other wildlife.

Finally, a bio-informed approach encompasses not only artificial materials and technologies, but also natural materials. Mycelium—the vegetative body of a mushroom or fungus—is one of the most promising natural materials for a wide range of applications. Like polystyrene, it is light weight with excellent thermal insulation and fire retardance, but unlike polystyrene, it is sustainable and biodegradable. McGaw et al. argue that the slow uptake of mycelium-based materials is due to psychological, aesthetic and economic barriers, rather than technical challenges. McGaw et al. show the importance of considering social, cultural and economic factors in the design of bioinspired sustainable materials, and identify opportunities for future zero-waste mycelium-based products.

Concluding remarks

The articles in this Research Topic span an extraordinary breadth of biological systems and disciplines. They showcase the utility of a biologically informed approach to enhance not only design processes and applications, but also biological understanding and sustainability. The focus of the articles ranges from expanding biological knowledge and simulating complex biological processes for bioinspired applications, designing new technologies and human-made habitat structures, to exploring the social and economic context for the uptake of products based on novel biomaterials. We hope that this collection of articles inspires new ideas and helps to foster deeper collaboration between biologists, physical and social scientists, engineers and designers to solve the significant challenges of our time.

Author contributions

AP and DS-F wrote the first draft. All authors edited and contributed intellectually to the work and approved it for publication.

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References

Ahmed, F., Waqas, M., Jawed, B., Soomro, A. M., Kumar, S., Hina, A., et al. (2022). Decade of bio-inspired soft robots: a review. *Smart Mater. Struct.* 31, 073002. doi: 10.1088/1361-665X/ac6e15

Chen, H., Zhang, Y., Zhang, L., Ding, X., and Zhang, D. (2021). Applications of bioinspired approaches and challenges in medical devices. *Bio-Design Manuf.* 4, 146–148. doi: 10.1007/s42242-020-00103-6

Coyle, S., Majidi, C., LeDuc, P., and Hsia, K. J. (2018). Bio-inspired soft robotics: material selection, actuation, and design. *Extreme Mech. Lett.* 22, 51–59. doi: 10.1016/j.eml.2018.05.003

Ha, N. S., and Lu, G. (2020). A review of recent research on bio-inspired structures and materials for energy absorption applications. *Compos. Part B: Eng.* 181, 107496. doi: 10.1016/j.compositesb.2019.107496

Wegst, U. G. K., Bai, H., Saiz, E., Tomsia, A. P., and Ritchie, R. O. (2015). Bioinspired structural materials. *Nat. Mater.* 14, 23–36. doi: 10.1038/nmat4089

Zari, M. P. (2010). Biomimetic design for climate change adaptation and mitigation. *Architect. Sci. Rev.* 53, 172–183. doi: 10.3763/asre.2008.0065