TYPE Editorial
PUBLISHED 08 November 2023
DOI 10.3389/fevo.2023.1325315

OPEN ACCESS

EDITED AND REVIEWED BY
Jordi Figuerola,
Spanish National Research Council (CSIC), Spain

*CORRESPONDENCE
Dakota Piorkowski
dakota.sportsfan@gmail.com

RECEIVED 21 October 2023
ACCEPTED 26 October 2023
PUBLISHED 08 November 2023

CITATION
Blamires SJ, Joel A-C and Piorkowski D (2023) Editorial: Advances in soft matter biological adhesives. *Front. Ecol. Evol.* 11:1325315. doi: 10.3389/fevo.2023.1325315

Editorial: Advances in soft matter biological adhesives

Sean J. Blamires[1,2,3], Anna-Christin Joel[2,4] and Dakota Piorkowski[5]*

[1]School of Biological, Earth and Environmental Sciences, University of New South Wales, Sydney, NSW, Australia, [2]Mark Wainwright Analytical Centre, University of New South Wales, Sydney, NSW, Australia, [3]School of Mechanical and Mechatronic Engineering, University of Technology, Sydney, NSW, Australia, [4]Institute of Zoology, Rheinisch-Westfälische Technische Hochschule (RWTH), Aachen University, Aachen, Germany, [5]Schmid College of Science and Technology, Chapman University, Orange, CA, United States

KEYWORDS

biomimetics, arthropod, anti adhesion, nano, biomolecules

Editorial on the Research Topic
Advances in soft matter biological adhesives

Background of Research Topic

Nature used millions of years of evolution to produce its material designs – a length of time that is not available to scientists and engineers searching for novel solutions to complex materials challenges (Cohen and Reich, 2016; Wolff et al., 2017; Wang and Lee, 2019; Xue et al., 2019; Melrose, 2022; Cerullo et al., 2023; Stuart-Fox et al., 2023).

Attaining a deep knowledge of the ecology and evolution of biological soft matter adhesives is critical for the successful engineering of novel synthetic adhesives with adaptable properties for a range of applications (Wolff et al., 2017; Lim et al., 2020; Meyer et al., 2021; Lutz et al., 2022; Joel et al., 2023). An inspiring example of this is how studying the adhesive mechanisms of gecko toe pads led to the development of products such as the "gecko tape" adhesive (Raut et al., 2017). Similarly, a multi-scaled understanding of spider viscous silk functionality has inspired the development of novel water-resistant adhesives (Sahni et al., 2012; Bré et al., 2013; Sahni et al., 2014; Amarpuri et al., 2017; Lutz et al., 2022).

Summary of articles

Multiple hierarchical structuring reduces spider silk adhesion

Lifka et al. examined the processes acting when spiders produce nano-cribellate silks. They obsevered micro- and nanostructures along a grooved structure on their forelegs, the so-called calamistrum, used to brush out the nanofibers. Theoretical modeling as well as use of a technical replicate indicate that both, micro- and nanostructures decrease adhesion to nanofibers. This finding offers an intriguing solution to the challenge of producing and processing technical nano fibers including synthetic antiadhesive multi hierarchical combs.

Surface nanoripples promote anti-adhesion

Buchberger et al. focused on how surface nanoripples function as a mechanism of anti-adhesion for cribellate nanofibers. The surface of the calamistrum features a rippled nanotopography (periodicity: 200–300 nm) that does not adhere to the adhesive nanofibers. Similar structures can be found covering the complete body of the spider. The researchers accordingly demonstrated how manufactured surfaces with laser-etched nanoripples of varying geometry decrease the silk's adhesion. Potential applications of Buchberger et al.'s anti-adhesion technology includes artificial nanofiber spooling, which could be adapted for prevention of biofilm formation.

Translation and processing drive gluey silk property variability

Ayoub et al. characterized the physical properties and molecular components of gluey spider silks and explored the influence of the environment on silk adhesiveness. Their findings revealed differences in glue properties between species, which were driven by protein composition variation. This highlighted the potential for glue properties to vary by a combination of: (i) differential translation of silk glue proteins, along with post-translational modifications, and (ii) variability in the extrusion rate of the silk throughout the glands. This offers an explanation to the rapid evolutionary change in structure and property of different species' glues, which could pave the way for the creation of bio-inspired adhesives.

Common design features of a diverse pressure sensitive adhesive

Wolff et al. compared the relative chemical compositions of orb weaving and cobweb weaving spiders' pressure sensitive adhesives (PSAs). Despite the broad phylogenetic differences between the spiders sampled and corresponding differences in overall mix of organic compounds of their glues, there were common principles in functionality. Primarily, the PSAs relied on an organic salt plasticizer to promote adhesion. Which organic salt acted as the plasticizer, however, varied across the PSAs but roles for gamma aminobutyric acid (GABA), GABA-amide and betaine were implicated. By exploiting these commonalities in functional principles of these PSAs, researchers might be able to design environmentally-friendly and sustainable adhesives for a range of applications.

Gastropod glue chemistry links to properties

Barajas-Ledesma and Holland investigated the chemistry, production mechanism, and mechanics of six phylogenetically different snail and slug mucuses. They revealed a commonality between mucus chemistry and material properties across species, most notably, at the family level, suggesting some kind of, yet to be delineated, evolutionary role. This study runs parallel and complementary to work on spider silk glues and represents an important step toward developing diverse biomimetic glues.

Conclusions

The articles within this Research Topic delve into the remarkable multi-scalar properties of several intriguing soft matter adhesive systems, including those of spider silk and gastropod mucus. Collectively, these articles underscore the incredible potential for biomimetic research to provide inspiration for innovation in materials technologies with applications in fields of medicine, cosmetics, biotechnology, and green technologies.

Author contributions

SB: Writing – review & editing, Writing – original draft. A-CJ: Writing – review & editing. DP: Conceptualization, Writing – review & editing.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

Amarpuri, G., Zhang, C., Blackledge, T. A., and Dhinojwala, A. (2017). Adhesion modulation using glue droplet spreading in spider capture silk. *J. R. Soc Interf.* 14, 20170228. doi: 10.1098/rsif.2017.0228

Bré, L. P., Zheng, Y., Pêgo, A. P., and Wang, W. (2013). Taking tissue adhesives to the future: from traditional synthetic to new biomimetic approaches. *Biomater. Sci.* 1, 239–253. doi: 10.1039/C2BM00121G

Cerullo, A. R., McDermott, M. B., Pepi, L. E., Liu, Z. L., Barry, D., Zhang, S., et al. (2023). Comparative mucomic analysis of three functionally distinct *Cornu aspersum* secretions. *Nat. Comms* 14, 5361. doi: 10.1038/s41467-023-41094-z

Cohen, Y. H., and Reich, Y. (2016). *Biomimetic design methods for innovation and sustainability* (Tel Aviv: Springer).

Joel, A. C., Rawal, A., Yao, Y., Jenner, A., Ariotte, N., Weissbach, M., et al. (2023). Physico-chemical properties of functionally adhesive spider silk nanofibers. *Biomat. Sci.* 11, 2139–2150. doi: 10.1039/D2BM01599D

Lim, H. R., Kim, H. S., Qazi, R., Kwon, Y. T., Jeong, J. W., and Yeo, W. H. (2020). Advanced soft materials, sensor integrations, and applications of wearable flexible hybrid electronics in healthcare, energy, and environment. *Adv. Mater.* 32, 1901924. doi: 10.1002/adma.201901924

Lutz, T. M., Kimna, C., Casini, A., and Lieleg, O. (2022). Bio-based and bio-inspired adhesives from animals and plants for biomedical applications. *Mater. Today Bio* 13, 100203. doi: 10.1016/j.mtbio.2022.100203

Melrose, J. (2022). High performance marine and terrestrial bioadhesives and the biomedical applications they have inspired. *Molecules* 27, 8982. doi: 10.3390/molecules27248982

Meyer, M., Buchberger, G., Heitz, J., Baiko, D., and Joel, A. C. (2021). Ambient climate influences anti-adhesion between biomimetic structures foil nanofibers. *Nanomaterials* 11, 3222. doi: 10.3390/nano11123222

Raut, H. K., Baji, A., Hariri, H. H., Parveen, H., Soh, G. S., Low, H. Y., et al. (2017). Gecko-inspired dry adhesive based on micro-nanoscale hierarchical arrays for application in climbing devices. *ACS Appl. Mater. Interf.* 10, 1288–1296. doi: 10.1021/acsami.7b09526

Sahni, V., Labhsetwar, D. V., and Dhinojwala, A. (2012). Spider silk inspired functional microthreads. *Langmuir* 28, 2206–2210. doi: 10.1021/la203275x

Sahni, V., Miyoshi, T., Chen, K., Jain, D., Blamires, S. J., Blackledge, T. A., et al. (2014). Direct solvation of glycoproteins by salts in spider silk glues enhances adhesion and helps to explain the evolution of modern spider orb webs. *Biomacromolecules* 15, 1225–1232. doi: 10.1021/bm401800y

Stuart-Fox, D., Ng, L., Barner, L., Bennet, A. T. D., Blamires, S. J., Elgar, M. A., et al. (2023). Bio-informed advanced materials: current challenges and opportunities. *Commun. Mater.* 4, 80. doi: 10.1038/s43246-023-00405-z

Wang, X., and Lee, H. (2019). *Novel nanomaterials for biomedical, environmental and energy applications* (Cambridge MA: Elsevier).

Wolff, J. O., Wells, D., Reid, C., and Blamires, S. J. (2017). Clarity of objectives and working principles enhances the success of biomimetic programs. *Bioinspiration Biomim.* 12, 051001.

Xue, J., Wu, T., Dai, Y., and Xia, D. (2019). Electrospinning and electrospun nanofibers: methods, materials and applications. *Chem. Rev.* 119, 5298–5415. doi: 10.1021/acs.chemrev.8b00593