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Biodegradation of materials: building bridges between scientific disciplines

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The interactions between water, materials and life belong to the category of fundamental processes that transcend the classical boundaries of traditional science classifications. From an epistemological standpoint, the investigation of *materials biodegradation*, which can be defined as the process leading to the chemical and/or physical breakdown of materials of natural and/or anthropic origin, has long been conducted independently by distinct scientific communities. This has resulted in a terminology specific to each community, although referring to processes that are similar in essence. For instance, the terms *biocorrosion* (or *microbial corrosion*), *bioweathering* and *bioleaching* (or *biomining*) are mostly used by the materials sciences, Earth sciences and engineering sciences communities respectively, whereas they all refer to the chemical breakdown of inorganic phases (mostly metals/alloys, rocks, and ores, respectively). On a similar footing, the physical breakdown and aging of materials may be termed *biofouling* or *bioerosion*, depending on whether the context refers to materials of anthropic[1] or natural[2] origin. As illustrated in Fig. 1, although the topics that mobilize the largest communities have started to spread across various scientific disciplines (see the case of "biofouling", which widely impacts all six disciplines involved in the study of materials biodegradation, except for the Earth sciences), others can still be considered as niches, which hardly spread beyond the frontiers of their very specific communities (e.g., bioerosion and bioweathering are almost exclusively restricted to the fields of Earth and life sciences). Interestingly, the term *biodegradation* itself is now almost exclusively restricted to the breakdown of polymeric substances mediated by living organisms[3,4], a concern of the utmost importance in a world where 79% of plastic ends up in the environment.

With the present collection, it was our aim to gather together state-of-the-art studies covering materials biodegradation in the broadest sense of the term. The motivation was two-fold: on the one hand, to demonstrate that similar issues are addressed separately by (at least, partly) disjointed scientific communities, and on the other hand, to highlight that similar approaches may be used independently by disjointed scientific communities to tackle a wide range of different issues related to materials biodegradation. In both cases, the publication of a single collection of papers focused on materials biodegradation is expected to broaden the spectrum of literature mining for the relevant readers, while potentially representing a supplementary means to build bridges between communities working on materials biodegradation.

As such, a striking common trait of several studies published in the present collection is the use of advanced molecular biology techniques to extract and sequence environmental DNA[5–10] from materials altered in natural and artificial environments to better probe the dominant taxa associated with materials biodegradation, and the changes in microbial community structures as a function of external forcings. In conjunction with classical isolation/cultivation protocols, such an approach has already proven

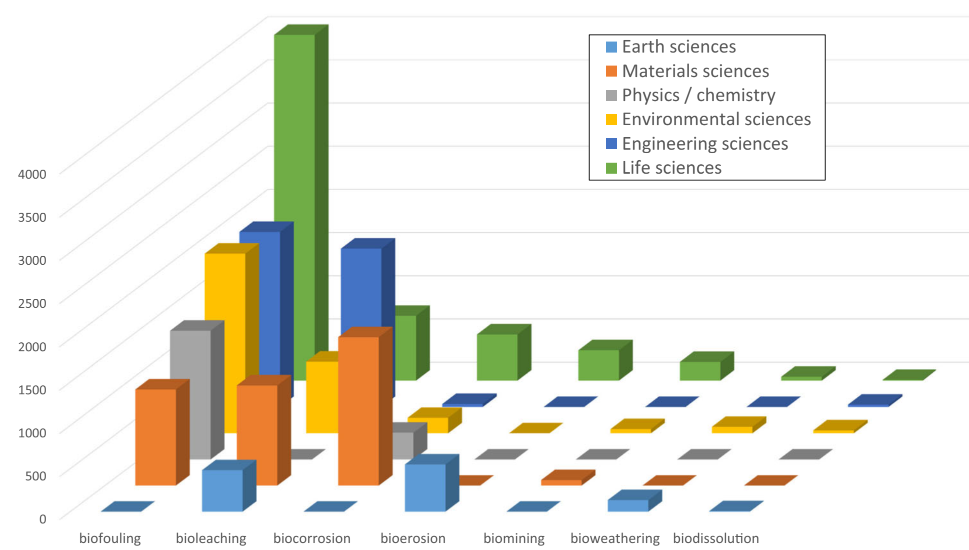

Fig. 1 An overview of the scientific fields impacted by publications dealing with materials biodegradation quantified using the keywords *"biofouling"*, *"bioleaching"*, *"biocorrosion"* (also including: *"microbially induced corrosion"*), *"bioerosion"*, *"biomining"*, *"bioweathering"* (also including *"bioalteration"* and *"microbial weathering"*) and *"biodissolution"* (source: Web of Science, November 2022). The six broad scientific disciplines were defined using Web of Science categories that were grouped as follows: (i) "geology + geosciences + geochemistry/geophysics + mineralogy + paleontology": Earth sciences; (ii) "metallurgy + materials sciences + materials science/biomaterials": Materials sciences; (iii) "physical chemistry + electrochemistry": Physics/chemistry; (iv) "environmental sciences": Environmental sciences; (iv) "environmental engineering + mining/mineral processing + chemical engineering": Engineering sciences; (vi) "microbiology + marine freshwater biology + biotechnology/applied microbiology": Life sciences.

successful to identify microbes associated with the corrosion of steel, and shows promise as a means to ultimately identify the potential actors of rock bioweathering, a question that remains largely open in the field of Earth sciences (see[11] and references therein). After we clearly know who dominates on the surfaces, new strategies for isolating corrosive microbes are still desired to investigate underlying microbial corrosion mechanisms, providing insight into the prevention and detection of microbial corrosion.

A more classical—albeit insightful—approach that is well represented in the present collection consists of incubating materials with relevant bacterial and/or fungal strains to quantify their contribution to material degradation[12–18]. This approach is preferentially used to shed light on the mechanisms and chemical fluxes associated with materials biodegradation, and may open new avenues to develop, in turn, methods that may rely on microbial activity to prevent materials from their (bio)degradation[6,19,20]. Most of these studies emphasize that the potential impact of microorganisms on materials degradation (and/or protection) results mainly from their ability to generate micro-environments within biofilms[11,21–23], where the local chemical conditions may be fully decoupled from those that prevail in the surrounding bulk medium. Upscaling the results from such studies remains a challenge, however, which may be considered as one of the next questions to be solved in the field.

Overall, the increasing number of papers related to materials biodegradation published every year demonstrates that this field of research is constantly expanding. We hope that initiatives such as the present collection may contribute to disseminate the latest findings and ideas in this field and across disciplines, and eventually help tackle some of the most pressing questions associated to the large-scale impact of life on materials degradation, a concern both of fundamental importance and with profound economic consequences.

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AUTHOR CONTRIBUTIONS

D.D. and D.X. contributed equally to this editorial.

COMPETING INTERESTS

The authors declare no competing interests.