The bio-inspired design of novel materials

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Mother Nature has always been a source of inspiration for mankind when designing novel machines and materials, and when overcoming its weaknesses against adversity. However, observation is also necessary for innovation, imagination, design and technological development, as is, to some extent, chance. In the sixteenth century, Leonardo Da Vinci, known for his paintings, was a genius of observation, bringing us the first reasonable proposals for flight with his planes, helicopters and parachutes, as attested by his famous drawings. However, the technology of the time was not yet ready for such revolutionary ideas. In the nineteenth century, it was the observation of the natural phenomenon of tartaric acid crystallisation that put Pasteur on the track of stereochemistry; nevertheless, chiral chemistry was not sufficiently developed at that time. This latter discovery was made by serendipity but, as Pasteur said, "in the field of observation, chance favours only the prepared mind". Becquerel in 1896 and Fleming in 1928 were not only lucky but also clever in their discoveries of radioactivity by observing the natural luminescent minerals of uranium and the penicillin from forgotten cultures of staphylococci, respectively. Many examples of the intelligent exploitation of minerals, plants, animals, earth and stellar systems can be cited, showing that such an approach is still central to scientific advancement. But what is new under the sun?

Firstly, an obvious change comes from the evolution of technology, which allows us to see either further or smaller, using telescopes on one hand and microscopes on the other, and also to characterize materials better at the molecular and atomic levels through the continuous development of spectroscopy of various kinds. On the small length scale, biology and materials are the two fields of science that have largely taken advantage of these changes. Chemists are implied in both fields, from the pure molecular point of view in biochemistry, and from the bottom-up approach of materials design and synthesis. Another change arises from the decompartmentalization of the sciences, bringing physicists, chemists and biologists together to investigate complex systems, such as those observed in nature.

Bio-mimicking nature, as developed through bio-inorganic and bio-organic chemistry, consists of approaching as closely as possible the molecular components of natural systems. Bio-inspiration proceeds from a different conceptual approach, emerging increasingly in the titles of scientific articles since 2000. It is more a conceptual transposition of the important features, properties or functionalities of natural systems than is chemical mimicry, including, without distinction, natural or artificial reagents. Not surprisingly, most of the articles using the terminology *bio-inspiration* are devoted to artificial intelligence and robotics, accounting for more than 90% of such works according to a keyword search on the Web of Science.

Bio-inspiration in chemistry emerged apparently in conjunction with coordination metal chemistry, which was initially confined to the modelling of the metal sites in metalloproteins but later shifted towards a more independent search for artificial analogues.[1] This lead has also been adopted by materials scientists, using soft chemistry to synthesise solids in solution in the presence of organic molecules, shifting from bio-mineralization to bio-inspired mineralization, particularly for silica and calcium carbonate.[2,3] Bio-inspired synthetic routes also apply to nanoparticles.[4] Organic species are selected as directing agents to control the size, shape and porosity of the solid, in the same way that nature does with fascinating success, citing the shells of diatoms and bones as examples.[5] Mixtures of organic and inorganic matter, as well as hierarchical structures,[6] are at stake, thus justifying the denomination of hybrid materials in some of the materials developed according to this concept. The latter are produced on different length scales, implying integrative approaches. Their elaboration or application can make use of natural molecules or even artificial molecules, as far as the latter behave like natural molecules. Their characterisation can also be inspired by biology, using natural chemical probes or classical biology tests. Finally, their properties are the ultimate goal, attempting to perform chemistry as finely as nature does to create new biosensors, highly selective adsorbents, catalysts and even intelligent materials.

The study of bio-inspired materials is quite a new but very promising interdisciplinary field that fits well with the editorial policy of *NJC*. This issue contains selected articles on this theme, including contributions on the biomimetic synthesis of microporous and mesoporous materials, graftable ligands for bio-inspired catalytic materials, polysaccharide aerogels and bio-inspired synthetic pathways. It is not the intention to cover all aspects of this rapidly expanding area, but to present a selection of papers for our readers.

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References

1. P. Gamez, P. G. Aubel, W. L. Dreissen and J. Reedijk, *Chem. Soc. Rev.*, 2001, **30**, 376.
2. E. Dujardin and S. Mann, *Adv. Mater.*, 2002, **14**, 775; S. V. Patwardhan, S. J. Clarson and C. C. Perry, *Chem. Commun.*, 2005, 1113.
3. M. Kuang, D. Wang, M. Gao, J. Hartmann and H. Möhvald, *Chem. Mater.*, 2005, **17**, 656; S.-H. Yu and H. Cölfen, *J. Mater. Chem.*, 2004, **14**, 2124.
4. X. Zhang, P. Yang, W. T. Yang and J. C. Chen, *Mater. Sci. Eng., C*, 2008, **28**, 237.
5. P. Fratzl and R. Weinkamer, *Prog. Mater. Sci.*, 2007, **52**, 1263.
6. J. Currey, *Science*, 2005, **309**, 253.

