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Citation	Aizenberg, Joanna, and Peter Fratzl. 2013. "New Materials through Bioinspiration and Nanoscience." <i>Advanced Functional Materials</i> 23 (36) (September 23): 4398–4399. doi:10.1002/adfm.201302690.
Published Version	10.1002/adfm.201302690
Citable link	http://nrs.harvard.edu/urn-3:HUL.InstRepos:37255519
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New Materials through Bioinspiration and Nanoscience

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It was recognized a long time ago that new material functionalities emerge from the assembly of nanoscale objects. Indeed, optical or mechanical properties are largely determined at this length scale. The last decades have brought many new approaches to manipulate objects at this fine, earlier unapproachable, size. This length scale is also the one that living cells—themselves spanning the microscale—control in an exquisite way, giving rise to elaborate materials with optimized designs, architectures, properties and functionalities. It is, therefore, not surprising that nanoscience is increasingly turning to natural materials for inspiration. This has led to a very logical convergence of the nanosciences with bioinspired materials sciences.

While natural materials are based on a rather small selection of basic constituents—proteins, polysaccharides and a few minerals—it is their precise assembly in space that provides the function. Spider silk is a good example, where the properties required to build a web are not just due to the amino acid sequence of the protein but to its microstructure fabricated by processing the raw material in the silk gland of the spider during excretion. The same is true for other strong fibrous proteins, and one of the feature articles in this issue reviews this aspect [see Scheibel et al.]. Chitin is the second most abundant polysaccharide (after cellulose), and another article reviews its structure and potential for new materials [see Fernandez et al.]. More generally, natural materials are graded composites made of harder and softer components with a well-organized arrangement that is crucial for mechanical function. The appropriate use of (hierarchical) structuring and grading is described in a feature article by Studart et al.

The biggest stumbling block in bioinspired materials research is the difficulties associated with the fabrication of complex structures similar to the elaborate designs of their biological analogs. The approach of 3D printing is one of the strategies that may enable us to overcome this hurdle. One of the feature articles in this issue focusses on 3D printing (biocompatible) hydrogels [see Torgesen et al.] and another article puts hierarchical organization into use through 3D printing [see Buehler et al.]. A second promising fabrication strategy is to directly copy naturally available structures into useful materials. The method of biotemplating is reviewed in one of the feature articles [see Paris et al.], while another paper describes a new approach by which carbon replicas of diatom frustules can be turned into supports for catalysis [see Sandhage et al.]. Other approaches to fabricate highly porous catalysis supports are also reported [see Kong et al.].

The “arms race” between insects and plants has been teaching us that the micro- and nanostructuring of surfaces is crucial to provide or forbid adhesion or to control interactions with water. Several strategies for fabricating microstructured surfaces with various functions are described, including those based on particle assembly [see Fery et al.], on surfaces with drag-reducing riblet surfaces inspired by shark skin [see Bhushan et al.], on selectively functionalized post

arrays [see Hatton et al.] and on the use of wax crystals deposited on surfaces, as most plants would do [see Pokroy et al.].

One of the most promising applications of bioinspired nanostructured materials is, of course, for programming and guiding interactions with cells, in controlling biofouling or in tissue engineering in general, as reviewed in one of the feature articles [see Skorb et al.]. Newly developed specific applications are described in three full papers, including polymeric shells for cell encapsulation and protection [see Tsukruk et al.], polymer matrices mimicking inflammatory environments to recruit dendritic cells [see Ali et al.] and self-repairing polymer-based surfaces preventing the adhesion of bacteria [see Minko et al.].

Finally, a very exciting development which will impact the community working in (soft) robotics is related to the creation of bioinspired actuating materials. In this way, fairly complex movements can be encoded into the structure of a material without the need of external control. Several articles in this issue relate to this topic, including self-folding origami [see Okuzaki et al.], self-actuated gel-based materials [see Ionov et al.] and materials that enable directed motion in non-uniform illumination [see Balazs et al.].

We hope that the reader will enjoy these exciting developments at the interface of materials, nanoscience and biology. Some of the papers were presented at the first Potsdam Conference on Bioinspired Materials: a second edition of this meeting is planned for March 18–21, 2014, again in Potsdam, Germany (<http://www.dgm.de/dgm/bio-inspired/>).

((short bios of about 100 words, and photographs))