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SPECIAL ISSUE PROSPECTIVES: SYNTHETIC BIOLOGY

Towards the directed evolution of protein materials

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Protein materials have emerged as a powerful instrument for a new generation of biological materials, with many chemical and mechanical capabilities. Through the manipulation of DNA, researchers can design proteins at the molecular level, engineering a vast array of protein materials. However, the capability to rationally design and predict the properties of such materials is limited. Directed evolution has emerged as a powerful tool to improve biological systems through mutation and selection, presenting another avenue to produce novel protein materials. In this prospective review, the authors discuss the application of directed evolution for protein materials, reviewing current examples and developments that could facilitate the evolution of protein for material applications. DOI.org/10.1557/mrc.2019.28

Synthetic biology for the development of bio-based binders for greener construction materials

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The development of more sustainable construction materials is a crucial step toward the reduction of CO_2 emissions to mitigate climate change issues and minimize environmental impacts of the associated industries. Therefore, there is growing demand for bio-based binders, which are not only safer toward human and environmental health but also facilitate cleaner disposal of the construction materials and enable their compostability. Here, the authors summarize the most relevant bio-based polymers and molecules with applications in the construction sector, and include an evaluation of existing biotechnological processes and potential synthetic biology advances that may impact future development and production. DOI.org/10.1557/mrc.2019.39

Synthetic biology for fibers, adhesives and active camouflage materials in protection and aerospace

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Synthetic biology has huge potential to produce the next generation of advanced materials by accessing previously unreachable (bio)chemical space. In this prospective review, we take a snapshot of current activity in this rapidly developing area, focusing on prominent examples for high-performance applications such as those required for protective materials and the aerospace sector. The continued growth of this emerging field will be facilitated by the convergence of expertise from a range of diverse disciplines, including molecular biology, polymer chemistry, materials science, and process engineering. This review highlights the most significant recent advances and addresses the cross-disciplinary challenges currently being faced. DOI.org/10.1557/mrc.2019.35

Bioderived protoporphyrin IX incorporation into a metal–organic framework for enhanced photocatalytic degradation of chemical warfare agents

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Porphyrins absorb light to initiate photocatalytic activity. The complex, asymmetric structures of natural porphyrins such as heme, chlorophyll, and their derivatives hold unique interest. A platform for biosynthesis of porphyrins in *E. coli* is developed with the aim of producing a variety of porphyrins for examining their photocatalytic properties within a porous material. Bioderived protoporphyrin IX is tethered inside the highly porous metal–organic framework NU-1000 via solvent-assisted ligand incorporation. This MOF catalyzes the photocatalytic oxidation of 2-chloroethyl ethyl sulfide with improved performance over an expanded range of the visible spectrum when compared to unmodified NU-1000. DOI.org/10.1557/mrc.2019.22

Engineered living conductive biofilms as functional materials

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Natural living conductive biofilms transport electrons between electrodes and cells, as well as among cells fixed within the film, catalyzing an array of reactions from acetate oxidation to CO_2 reduction. Synthetic biology offers tools to modify or improve electron transport through biofilms, creating a new class of engineered living conductive materials. Engineered living conductive materials could be used in a range of applications for which traditional conducting polymers are not appropriate, including improved catalytic coatings for microbial fuel cell electrodes, self-powered sensors for austere environments, and next-generation living components of bioelectronic devices that interact with the human microbiome. DOI.org/10.1557/mrc.2019.27

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SPECIAL ISSUE RESEARCH LETTERS: SYNTHETIC BIOLOGY

Engineering CAR-Expressing Natural Killer Cells with Cytokine Signaling and Synthetic Switch for an Off-the-Shelf Cell-Based Cancer Immunotherapy

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Immune cells can be genetically engineered with a synthetic chimeric antigen receptor (CAR) to eliminate cancer cells, but clinical efficacy in solid tumors has been disappointing due in part to the immunosuppressive tumor microenvironment (TME). Additionally, the cost and logistical issues of personalized medicine necessitate the creation of an off-the-shelf CAR therapy. Synthetic biology tools were implemented in addressing these problems: an anti-mesothelin CAR, membrane-bound IL-15/IL-15Rα complex, and inducible caspase 9 "kill switch" were expressed in natural killer cells for tumor-targeting capabilities, immunostimulatory effects, and safety in treating a preclinical model of ovarian cancer with a renewable, allogenic cell therapy. DOI.org/10.1557/mrc.2019.31

Identification of Proteins for Controlled Nucleation of Metal–Organic Crystals for Nanoenergetics

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Here, the authors report that a marine sandworm *Nereis virens'* jaw protein, Nvjp-1, nucleates hemozoin with similar activity as the native parasite hemozoin protein, HisRPII. X-ray diffraction and scanning electron microscopy confirm the identity of the hemozoin produced from Nvjp-1-containing reactions. Finally, they observed that nAl assembled with hemozoin from Nvjp-1 reactions has a substantially higher energetic output when compared to analogous thermite from the synthetic standard or HisRPII-nucleated hemozoin. Results demonstrate that a marine sandworm protein can nucleate malaria pigment and set the stage for engineering recombinant hemozoin production for nanoenergetic applications. DOI.org/10.1557/mrc.2019.46

Coupling synthetic biology and programmable materials to construct complex tissue ecosystems

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Synthetic biology combines engineering and biology to produce artificial systems with programmable features. Specifically, engineered microenvironments have advanced immensely over the past few decades, owing in part to the merging of materials with biologic mimetic structures. In this review, the authors adapt a traditional definition of community ecology to describe "cellular ecology," or the study of the distribution of cell populations and interactions within their microenvironment. The authors discuss two exemplar hydrogel platforms: (1) self-assembling peptide hydrogels and (2) poly(ethylene) glycol hydrogels, and describe future opportunities for merging smart material design and synthetic biology within the scope of multicellular platforms. DOI.org/10.1557/mrc.2019.69

SPECIAL ISSUE PROSPECTIVES: ARTIFICIAL INTELLIGENCE

Automating material image analysis for material discovery

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Advancements in temporal and spatial resolutions of microscopes promise to expand the frontiers of understanding in materials science. Imaging techniques produce images at a high-frame rate, streaming out a tremendous amount of data. Analysis of all these images is time-consuming and labor-intensive, creating a bottleneck in material discovery that needs to be overcome. This paper summarizes recent progress in machine learning and data science for expediting and automating material image analysis. The discussion covers both static image and dynamic image analyses, followed by remarks concerning ongoing efforts and future needs in automated image analysis that accelerates material discovery. DOI.org/10.1557/mrc.2019.48

Machine learning for composite materials

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Machine learning has been perceived as a promising tool for the design and discovery of novel materials for a broad range of applications. In this prospective article, we summarize recent progress on the applications of machine learning to composite materials modeling and design. An overview of how different types of machine learning algorithms can be applied to accelerate composite research is presented. This framework is envisioned to revolutionize approaches to design and optimize composites for the next generation of materials with unprecedented properties. DOI.org/10.1557/mrc.2019.32

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