ADVANCED MATERIALS
www.advmat.de



# Materializing Personalized Medicine

*Natalie Artzi*

There is plenty to read on materials science for biomedical applications, yet an up-to-date topical compilation focused on methods and knowhow most relevant to personalized medicine, highlighting promising opportunities, is hard to come by. This is the aim of the *Reviews* and *Progress Reports* included in the collection that accompanies this editorial. I hope that this broad update of (nano)biomaterials for the delivery of therapies and for diagnostics, and of the development and manufacturing of biomaterials for medicine, will stimulate your interest and help advance your research program, and also inspire many to push personalized medicine forward.

For those working in nanomaterials for diagnostics, the collection features three of the most up-and-coming topics: the possibilities of nucleic acids as molecular probes of the biochemical processes that occur in live cells (Mirkin an co-workers, article number 1901743); the unique properties of two-dimensional nanostructures (sheets of graphene and of a range of crystalline heterostructures with tunable electronic and optical properties as well as modifiable surface chemistry) (Liu and co-workers, article number 1902333), and the development of machine-learning algorithms for discovering and optimizing nanomaterials for diagnostic applications, and for classifying the measured outcomes (Schroeder and co-workers, article number 1901989).

The community working on materials for delivery is big and broad. To make justice to the recent developments in this area, the collection highlights the most promising range of strategies for improving the effectiveness of the delivery of conventional and new therapies. For delivering drugs and biologics to particular cell types, two progress reports (Tzeng and co-workers (article number 1901081) and (Kataoka and co-workers (article number 1902604)) describe the most promising avenues in the engineering of nanomaterials with optimal presentation and type of targeting ligands. Biologics are typically delivered by injection, though some require a release profile that is responsive to dynamic disease traits, as in glucose-responsive insulin delivery systems. Molecular approaches for the design of glucose-responsive insulin delivery systems and their translational challenges are summarized (Gu and co-workers, article number 1902004). Yet, for gastrointestinal diseases, new formulations of oral-delivery nanomaterials enhance their resistance to the gut's harsh environment and allow for site-specific delivery (Alonso and co-workers, article number 1901935). More recently, the promise of immunotherapy—as evident by the recent approvals by the U.S. Food and Drug Administration (FDA), of checkpoint blockade therapy and of CAR-T cells (where CAR = chimeric antigen receptor)—as well as identification of promising vaccine adjuvants, opens up further prospects for long-lived and personalized therapeutic strategies. Macrophages also shape the immune microenvironment, and strategies to polarize them in situ (as well as the mode of delivery) may help improve therapeutic outcomes (Pun and co-workers, article number 1902007). The delivery of cells (and in particular of patient-specific cells), rather than specific molecular factors, can also shape the immune system. Precision materials can deliver these cells or create niches that can be personalized to guide cellular activity in situ (Anderson and co-workers, article number 1902005). Moreover, materials can be designed for effective immunotherapy and to account for the type of immunomodulators that are delivered, or on the basis of their intrinsic ability to activate or suppress the immune system (Mitragotri and co-workers, article number 1901633). Yet, to generate immune memory, personalized vaccines can be construed by using biomimetic nanosystems for both antibacterial and anticancer therapies (Zhang and co-workers (article number 1901255), Jewell and co-workers (article number 1903367)).

**Natalie Artzi** is an assistant professor at Brigham and Women's Hospital, Harvard Medical School. She is a principal research scientist at the Institute for Medical Engineering and Science at MIT and is an associate member of the Broad Institute of Harvard and MIT. The research in her laboratory for tissue-responsive (nano)biomaterials is dedicated to leveraging materials science and engineering, biology and medicine to improve human health.

Dr. N. Artzi
Department of Medicine
Engineering in Medicine Division
Brigham and Women's Hospital
Harvard Medical School
Boston, MA 02139, USA
E-mail: nartzi@bwh.harvard.edu

Dr. N. Artzi
Institute for Medical Engineering and Science
Massachusetts Institute of Technology
Cambridge, MA 02139, USA
E-mail: nartzi@mit.edu

Dr. N. Artzi
Broad Institute of Harvard and MIT
Cambridge, MA 02139, USA

Dr. N. Artzi
State Key Laboratory of Molecular Engineering of Polymers
Fudan University
Shanghai, China

**DOI: 10.1002/adma.201908065**

 

However, the most common vaccination routes—subcutaneous and intramuscular—induce marginal immune protection in mucosal cancers in the absence of tissue-specific imprinting molecules. Key considerations in biomaterial design, administration routes, and antigen–adjuvant identification in the context of mucosal immunity are discussed (Artzi and co-workers, article number 1903847).

In order to translate these technologies, scale-up manufacturing is crucial. Three articles in the collection convey the most promising approaches for personalizing manufacturing on the basis of the complexities of individual patients. 3D printing enables the design of precision implants serving as in vitro models to screen for patient-specific therapeutics, and ultimately for designing materials with specific shapes and compositions for each patient (Burdick and co-workers, article number 1902516). Most intriguing is the ability to design and manufacture biohybrid materials that can mimic the responsiveness and dynamic behavior of natural biological systems (Langer and co-workers, article number 1901969). Additive manufacturing may thus help realize many precision biomaterials, by accounting for the complexity of the different building blocks that must be integrated. Also, it enables freedom of design, mass customization, multimaterial fabrication, and the ability to produce parts with complex geometries (Tibbitt and co-workers, article number 1901994).

Designing optimal personalized combination therapies requires knowledge beyond the patient-specific genetic and molecular information, the basic understanding of the structure and function of bio(nano)material building blocks, and of the biological barriers and changes in the biological milieu most immediate to the therapeutic site. Rather, toward making new personalized therapies a reality, the systematic examination of the role of the route of administration, the sequence and duration of each therapy, and the resulting local and systemic immune responses, become paramount.

The prospects of developing new devices, better therapeutics, and diagnostic tests, that can eventually help better the lives of patients, and deciphering the relevant underlying biological mechanisms, keeps biomedical engineers like myself excited about our contributions to medicine. More bioengineers should take up opportunities of collaboration with clinicians and scientists working across materials science, chemistry, and biology that cross-disciplinary institutions such as my own offer. In fact, research programs in hospital environments such as that at the Brigham and Women's hospital makes their researchers particularly cognizant of the struggles and needs of the so many patients that we are passionate to help. The bulk of progress made in the past few years and highlighted in the collection raises the hopes and expectations that today's prospects for precision medicine will materialize.