

## FROM THE EDITOR

### Innovating Nanoethics

Linda Jiang and Kim A. Carmichael, MD

In the past decade, innovation in nanotechnology has led to rapid advances in the development of novel pharmaceuticals and imaging and diagnostic devices. Nanomedicine, a rapidly advancing subfield of nanotechnology that combines the basic and medical sciences, involves the use of nanoscale materials for the diagnosis, monitoring, prevention, and treatment of disease.<sup>1</sup> Indeed, nanomedicine has revolutionized how we think about diagnosis and treatment of disease at the atomic, molecular, and macromolecular level. Advances in nanodrugs, nanoimaging, theranostics, and other nanoproducts are expected to transform the practice of medicine.<sup>2</sup>

Nanotechnology has received significant attention and funding in recent years. Global funding for emerging nanotechnology reached \$18.5 billion in 2012, with US corporations investing \$4 billion in research and development.<sup>3</sup> The National Institutes of Health also spent more than \$350 million annually between 2014 and 2018 on nanotechnology research.<sup>4</sup> Global sales of nanomedicine products were estimated at \$138.8 billion in 2016,<sup>5</sup> and the value of nanodrugs expected to be developed by 2019 is estimated at \$178 billion.<sup>6</sup>

The particular properties of nanomedicines make them superior to their traditional counterparts. Due to their size, composition, and design, nanodrugs have advantages over conventional medicines such as improved pharmacokinetics, increased tissue selectivity, and enhanced efficacy. However, despite these benefits, nanomedicine faces numerous developmental challenges due to high costs, indeterminate standards and regulations, and unknown biological interactions, effects, and toxicities.<sup>7,8</sup>

This special issue of the *AMA Journal of Ethics* explores potential ethical, legal, regulatory, and policy challenges in the United States inherent in the development, regulation, and clinical application of nanomedicine.

Nanomedicine raises particular ethical challenges regarding respect for patient autonomy and beneficence. In her commentary on a case of 16-year-old with schizophrenia who resists use of a digital pill to track his compliance, Constance E. George explores the interests of the patient and parents and the benefits and risks of prescribing the medication. She argues that the adolescent's assent to the digital pill can best be gained through [shared decision making](#). Similarly examining the ethical dilemmas

of prescribing digital pills for patients with psychoses, Tahir Rahman argues that such medications can exacerbate delusional symptoms and [erode the therapeutic trust](#) between the physician and the patient. In addition, Nancy M. P. King and Christine E. Bishop examine the role of the physician in helping patients understand the unknowns of [nanomedicine-based clinical trials](#), arguing that physicians should draw upon their knowledge of the disease's typical progression, the patient's unique clinical situation, the clinical trial, and the characteristics of nanomedicines to promote reasonable expectations about the risks and benefits of trial enrollment and to facilitate discussions about goals of care. The striving of both patients and physicians toward a [common goal](#) is represented in an abstract painting by Madeleine Schachter.

In recent years, leaders in medical education have called for widespread reform in medical education to prepare students to practice medicine—with all its anticipated technological advances—in the 21st century. Given the enormous research support for and vast potential of nanotechnology, how should nanomedicine content (eg, the size and scale of nanotechnology, mechanisms of nanodrug delivery, interactions of nanomaterials with biological systems, nanodiagnosics, and nanoethics) be integrated into the medical school curricula? Should nanomedicine be a stand-alone course or part of other courses? What pedagogical approaches should be used in teaching this content? Joel C. Sunshine and Amy S. Paller review the importance of nanotechnology in medicine and discuss ways that medical educators can introduce concepts of nanotechnology, nanotoxicology, and nanoethics into the [medical school curriculum](#).

Regulation of nanotechnology remains controversial, as we lack clear frameworks for the use, disposal, and recycling of nanomaterials. Certain nanomaterials are known to cause harm to humans and the environment.<sup>9-11</sup> Although the Food and Drug Administration (FDA) has been regulating products containing nanotechnology for years, nanoscale products challenge existing [regulatory frameworks](#) and legal paradigms, as examined by Jordan Paradise. The regulation of nanowaste is difficult to address for several reasons. First, nanowaste is not visible to the naked eye, so it is difficult to track and monitor. Nanoparticles—and, by extension, nanowaste—do not behave like their bulk materials counterparts: nanomaterials are generally more chemically reactive due to their larger surface area-to-mass ratio. Predicting how nanoparticles would react under different environmental conditions has remained difficult. In addition, risks of toxicity and other hazards of nanowaste are not well understood.<sup>12</sup> David B. Resnik argues that, in order to minimize risks, policymakers should take [reasonable precautions](#) by using the best available evidence and existing laws to regulate engineered nanomaterials and by supporting additional research to assess their risks. These and other precautions can help to mitigate and manage the potential public health and environmental risks of nanomaterials without sacrificing their medical, social, and economic benefits.

Health monitoring has become ever more ubiquitous with the advent of the smart watches, activity trackers, and health monitoring mobile apps. An increasing number of

employers have implemented corporate wellness programs that provide workers with wearables or health apps to monitor their health, productivity, and well-being. Nanotechnology enables the development of more powerful monitoring devices with improved functional monitoring. Although such wellness programs provide potential win-win benefits to both employers and employees by promoting better employee health, they raise ethical and legal concerns. Gary E. Marchant argues that [workplace monitoring programs](#) can only succeed and be sustained when workers find them to be acceptable and transparent, and he discusses 5 best practices to ensure nano-enabled worker monitoring programs are acceptable and effective.

This special issue of the *AMA Journal of Ethics* aims to foster discussion among members of the medical community on the ethical complexities inherent in the development, disposal, regulation, and clinical application of nanomedicines. Physicians have a key role to play in such discussions, which will shape future legislation, national health policy, and their patients' health care.

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