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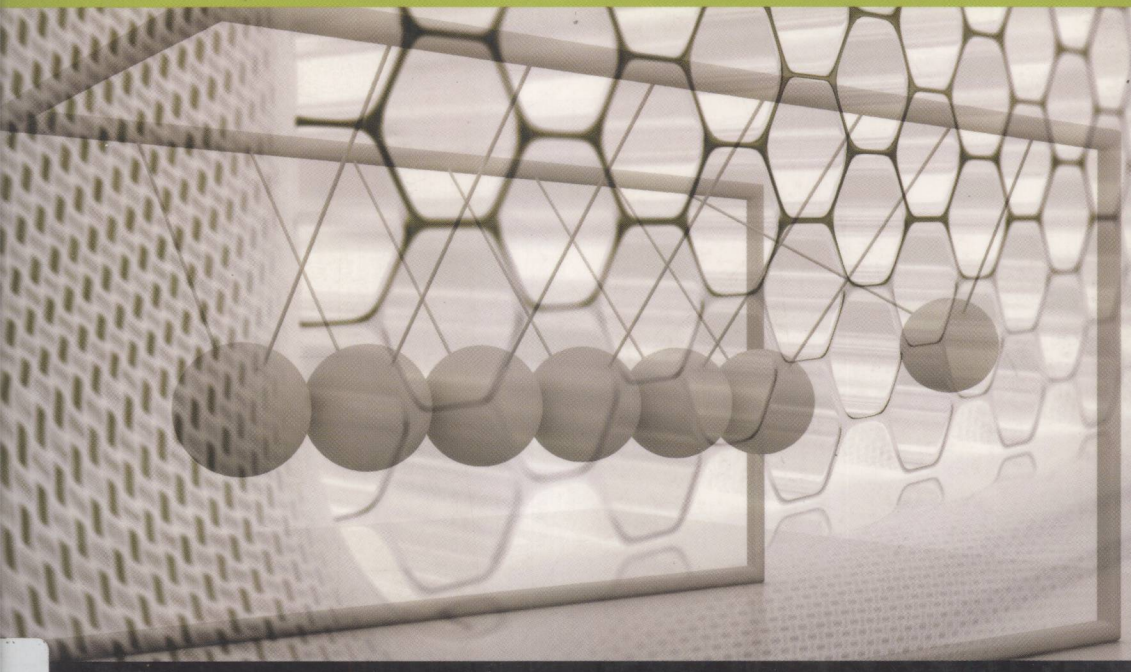
NANOETHICS

THE ETHICAL AND SOCIAL IMPLICATIONS OF NANOTECHNOLOGY



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NANOETHICS

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FOREWORD

Ethical Choices in Nanotechnology Development

Mihail C. Roco

Nanotechnology products are reaching the market with an annual growth rate of over 25 percent, stimulated by a worldwide research investment in 2006 exceeding $10 billion. Both promises and concerns about the societal implications of this new technology are being voiced with increasing frequency. The concerns must be answered to the satisfaction of both the public and experts. Without an attention to ethics, it would not be possible to ensure efficient and harmonious development, to cooperate between people and organizations, to make the best investment choices, to prevent harm to other people, and to diminish undesirable socioeconomic implications.

In a general sense, of course, these concerns are very old. Science and technology have been at the core of human endeavor for as long as we have *been* human. Indeed, human potential and technological development are coevolving, and quality of life has increased tremendously with technological advancements. However, since antiquity, it has been a perception that technological developments are not friendly to human nature—maybe because of its transforming changes. When the Greek god Prometheus taught humans to use fire and other tools, he also told them that this will bring an "*an eternity of torture*."

As old as these concerns are, however, they seem to have particular resonance when it comes to nanotechnology—not least because nanotechnology allows us to work at the very foundation of matter, the first level of organization for both living and man-made systems. At this scale all fundamental structures, properties, and functions of materials and devices are established. This is the lowest scale for transforming capabilities (manufacturing) for practical uses.

Nanotechnology creates a broad technological platform for many fields of application. The potential benefits are large, and so are the potential unexpected consequences. We already know that nanoparticles may penetrate and accumulate in human tissue, designed molecules may self-assemble into artificial tissues, active nanosystems may evolve in time, nanostructured implants may affect the heart and mind, hybrid systems may interface with biological systems, and systematic control of DNA with nanotechnology tools may fundamentally alter genetics. For these and other reasons, societal and in particular the multifaceted ethical aspects need to be fully considered from the beginning to realize the most equitable results among people, organizations, and countries.

The immediate ethical concerns from the first generation of nanoproducts are environmental, health, and safety effects. However, we should also consider issues that

may arise farther in the future, such as implications that nanotechnology might have on information access, privacy, welfare, and human dignity. Also, we need to invest in long-term societal needs for basic resources (such as water, energy, and food) and maintaining a clean, shared environment. Responding and interacting with the public and civil organizations on all these aspects may be the ultimate test for the successful introduction of nanotechnology. After all, political leaders, not academic leaders, will ultimately craft the laws governing nanotechnology's future, though this is not to say that the latter should not inform the former.

Ethical concerns in the development of nanotechnology should be a priority in *governance.* The governance of nanotechnology needs to be transformative, responsible (including professional ethics), visionary, and inclusive. All indications are that the future needs us. Novel, converging technologies are key drivers for change in industry, medicine, and society and such changes require specific policies and governance. One should consider long-term anticipatory scenarios and multistakeholder engagement. Until very recently, broad nanoscale investigations such as understanding biological systems, connecting the brain and mind, and simulating and controlling large nanosystems have been beyond the reach of human action. Now a variety of new discoveries and tools allow scientists, engineers, doctors, philosophers, and economists to study and even to transform those systems. Such transformations are expected to fundamentally affect human progress. As science and technology advance, new ethical issues are raised. The approach for risk governance suggested by the International Risk Governance Council (www.irgc.org) considers two reference frameworks for nanotechnology: one for passive nanostructures and a second for active nanoscale devices and systems. Ethical issues are relevant to both frameworks, and their relevance only increases over time. This volume is a step in that direction.

There is a *dilemma of choices* in the complex societal system where nanotechnology and social interactions develop. First, beyond a few very simple principles, the rules of ethical behavior are not universally accepted. They are functions of group interests, ideologies, and religions. Also, this is a decision to be made not necessarily by scientists using a systematic approach, but by elected leaders and civil and many other organizations tasked to make decisions about governance in a complex, evolving society. Should we give priority to societal benefits or else to individual rights? For example, it would be unethical to limit the development of basic needs of a large cross section of population for the interest of smaller groups. However, it is unethical to affect others without consent. Democratic principles for equal opportunity, access to information, knowledge, and development are other challenges. Experts, the public, and others need information and must participate in order to make best choices. Progress in the long term cannot be derailed even if the road is not straight. Progress is faster with proper vision and choices guided by moral values, transformative goals, collective benefits, and professional ethics.

The promise of nanotechnology, however, will not be realized by simply supporting research. Just as nanotechnology is changing how we think about unity of matter at the nanoscale and manufacturing, it is also changing how we think about the management of the research enterprise. Quite simply, it is changing some of our long-held and often-cherished methods of governing science and engineering. The ideas advanced in this volume may help foster new approaches.

Nanotechnology is entering new science and engineering challenges such as building nanomachines and nanosystems, designing new molecules, developing nanobiotechnology and nanobiomedicine, agricultural products, energy conversion, and environment. All trends for published papers, patents, and worldwide investments experience exponential growth, with potential inflexion points in several years. We have to make deliberate choices for future developments. Ethical aspects are increasing in relative importance, and their upstream consideration may be a key for the successful and sustained application of nanotechnology.

This volume includes essays from an outstanding group of distinguished contributors in key aspects of "nanoethics," from large intellectual strokes on major trends made by Ray Kurzweil and Bill Joy to basic concepts on complexity and precautionary principle, health and environmental concerns, democracy and policy, society, economics and equity, and visionary ideas. This is a rich material and not surprisingly with many opinions. The reader is exposed to the basic definitions on ethics, research issues, philosophical dimensions, and economical and political implications of this emerging field. The entire collection of contributions stimulates thinking about what is specific for nanotechnology and why ethics is important in the context of the new technology development. It provides intellectual and practical guidance on addressing ethical concerns and what research is needed and what directions may take. This is a timely publication that is prepared to become a reference in the field of societal dimensions of nanotechnology.

PREFACE

In the last several months and as recently as this morning, nanotechnology has made the news in such a way that immediately triggers ethical and social questions—or "nanoethics" questions. For instance, invisibility cloaks that can hide objects or people seem to raise serious privacy and national security issues. "Bionic hornets" that are designed to track and hunt down military insurgents resurrect worries about another arms race and misuse by terrorists.

Granted, it may take years to perfect such fantastic innovations—though it is not too early to begin thinking through their implications—but nanoethics is also highly relevant today. For instance, nanotechnology has already made its way into ordinary products, from clothing to sports equipment to cosmetics and much more, raising concerns about both consumer and manufacturing worker health risks. The environment and animals are similarly at potential risk from such products as a "nanotechnology washing machine" that releases over 100 quadrillion silver ions into the water to better sanitize clothes.

Nanoethics, then, poses such broad questions as: Are companies morally required to address or otherwise mitigate these risks before such products reach the marketplace? How will our expectations or conception of privacy change in the face of virtually invisible surveillance devices? If we can embed ever-shrinking devices into our bodies to enhance physical and mental performance, what are the implications for personal identity as well as society at large?

But it is far from being all bad news with nanotechnology. Billed as the "Next Industrial Revolution," it is predicted to provide profound benefits to the world, such as cleaner air and water, affordable energy, more effective medical treatments, much greater computing power, and more—benefits that perhaps will ultimately overshadow any harms (though that does not relieve us of the obligation to prevent such harms).

However, nanoethics even has a role in these positive areas in asking, for instance: What is our moral obligation to help developing countries with these advances? How might radical medical advances change our notion of disease as well as the doctor–patient relationship? If nanotechnology might help extend our life span by 20, 50, 100, or even 1000 years and more, as some predict, is cheating death to that extent necessarily a "good" thing, and how disruptive would that be to society, for example, with respect to overpopulation and pensions?

This anthology was conceived to help spark a thoughtful discussion on the full range of issues in nanoethics, which we found missing in the literary marketplace. It is not enough to focus on just near-term questions, such as related to regulation and risks with respect to the environment, health, and safety; nanoethics is far richer than that, as the reader might already see from just the preceding discussion. In this volume, we also tackle other important and far-reaching issues, from the need for educational reform to the ethics of nano-enabled space exploration and everything in between.

Further, we designed this anthology to be accessible to a broad audience with little familiarity with either nanotechnology or ethics, particularly since it is the general public who may be the largest beneficiary—or victim—of nanotechnology, and so the everyday person needs to understand its possible impact. At the same time, this collection of essays is valuable for students as well as industry stakeholders, policymakers, and others to better understand the issues and debate.

Finally, we need to thank many individuals for enabling us to create such an ambitious volume, the first of its kind. Our contributors truly represent the "A-list" in nanotechnology and nanoethics, hailing from leading universities such as Oxford, Cambridge, Stanford, Berkeley, Dartmouth, and other top organizations. We are indebted to the editors and staff at Wiley, who include Amy Byers, Darla Henderson, Becky Amos, Lisa Van Horn, and others. Special thanks are also owed to those who have supported our efforts and provided guidance: Jeff Dean, Priscilla Regan, Alison Niedbalski, Burleigh Wilkins, Brenna Robertson, and undoubtedly others. And we thank the U.S. National Science Foundation for providing support for our investigations, under Grant numbers 0620694 (to Western Michigan University) and 0621021 (to Dartmouth College).

Most of all, we thank you—the reader—for your interest in nanotechnology and its ethics. By engaging the issues as early as possible, we can together clear a responsible path for emerging sciences, such as nanotechnology, to help humanity realize its great potential.

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