D. Baird, A. Nordmann & J. Schummer (eds.), *Discovering the Nanoscale*, Amsterdam: IOS Press, 2004.

Introduction

Science and engineering, industry and politics, environmentalists and transhumanists are *Discovering the Nanoscale*. Public debate is widening, policy makers are demanding explicit consideration of ethical, legal, and social aspects, and popular books are explaining the achievements and promises of nanoscience. It may therefore seem surprising that this is the first collection of studies that considers nanoscience and nanotechnologies from the critical perspective of Science and Technology Studies (STS).

This is less surprising, however, when one appreciates that such a critical perspective needs to be historically informed and often involves intimate acquaintance with the research process. Accordingly, this book on the historical, analytical, and ethical study of nanoscience and -technology – ^{nano}STS, for short – was several years in the making. Though it presents only first results, these results for the most part stem from sustained investigations of nanoscience and nanotechnologies and of the contexts that are shaping their development.

Nanoscience and technologies are developing very quickly, and for this reason both pose a challenge to the more reflective approach commonly taken by science studies, while at the same time requiring the perspective provided by science studies scholars. Indeed, this book serves as a corrective to two commonly held, but equally mistaken beliefs.

First, many are convinced that nothing meaningful can be said at this early stage of their development about the social and ethical implications of nanotechnologies. While, indeed, not much has come out of nanoscale research as of yet to warrant critical assessment, one can already see what programmatic attitudes go into nanoscale research, what metaphors are shaping it, and what conception of nature is implicit in its vision. This volume shows that all of this is already open to analysis and questioning.

The second common misconception points in the opposite direction. It is often assumed that in order to consider ethical, legal, and social aspects of nanotechnologies it is sufficient to know a bit of the science and to have some ethical intuitions. This collection of papers establishes that this is not enough but that one also needs to appreciate nanoscale research and development in the larger context of the changing relations of science, technology, and society.

Most public discussion of nanotechnologies, including that of ^{nano}STS, concerns what Arne Hessenbruch in this volume calls the "negotiation of novelty". To be sure, nothing would be "wrong" with nanoscience or nanotechnologies, if they turned out to be far less novel and far more normal than some of their propagandists are making them out to be. Indeed, for purposes of rational political discourse it is important to treat them not as unfathomably new but as just so many ordinary innovations that need to be discussed and perhaps regulated in the political sphere, and that await to be accepted, rejected, or modified by consumers in the marketplace like all other innovations.

And yet, even if the research, development, diffusion, and appropriation of nanotechnologies ought to be considered in normal rather than mystifying terms, it cannot be denied that, indeed, nanotechnology may herald large changes in a variety of areas from manufacturing to the way research is done to how we conceive ourselves as humans. Even if nanosciences and nanotechnologies are not in principle new but continue familiar trajectories of materials science, synthetic chemistry, solid state physics, surface science, molecular biology, electrical, mechanical, and chemical engineering, and so on, their current prominence and visibility are symptomatic of cultural changes in science and technology and of

societies at large. Independent of the issue of novelty, understanding those changes is what [nano]STS is particularly concerned with.

The present volume is the first offspring of an emerging international community of [nano]STS scholars. Starting with a pair of conferences in Columbia, South Carolina, and Darmstadt, Germany (March and October 2003), scholars from a wide array of disciplines assembled together, including philosophers, historians, and sociologists of science and technology, scholars from art, literature, communication, media, policy, and legal studies, as well as nanoscientists and nanoengineers. Further conferences have been held since or are forthcoming, both in the US and Europe, on more specific topics, such as imaging and imagining nanotechnology and ethical issues. Many research groups are being established in different countries to study social and ethical implications of nanotechnology. Two journals, *Hyle* and *Techne*, specialized in philosophy of chemistry and philosophy of technology, respectively, are preparing a joint special issue on "Nanotech Challenges" for fall 2004. A website at the University of South Carolina has been set up to provide various resources (www.cla.sc.edu/cpecs/nirt/), including an online bibliography of which we publish the current version here.

For the present volume, we made a selection of 25 papers from more than 40 contributions to the mentioned pair of inaugural conferences. The succession of conferences assured that the contributors could speak to and learn from each other before they prepared their final papers. Despite their various disciplinary backgrounds, contributors assembled around six main topics that provide the structure of this book. The very first question is how to characterize nanoscale research, especially in regard to established science and engineering disciplines (I). This leads to the problem regarding the theoretical and methodological basis of nanoscience or nanotechnology and what it might be (II). In terms of scientific practice, the production and interpretation of nanoscale images has been central to nanoscale research from its very beginning (III). Also, from its very beginning, nanotechnology has been defined by way of the rhetoric and metaphors used to propagate it to a wider public (IV). Moving outward from the consideration of research to its societal contexts, the contributions finally consider the politics of nanotechnology (V) and ethical issues (VI).

Since researchers from most of the classical science and engineering disciplines are currently engaged in nanoscale research at rapidly increasing numbers, nanoscale research is arguably a broad scientific movement across the disciplines. Is that going to undermine the identities of the disciplines and the disciplinary landscape as we know it? Does nanoscale research require a complete re-organization of our received knowledge structure? In Part I of this volume, "Configuring the Disciplines", five papers provide different answers to these questions. Based on empirical findings, JOACHIM SCHUMMER argues that each discipline currently does its own nanoscale research without much interaction, because different disciplinary perspectives on the nanoscale and different technological paradigms prevent the politically desired interdisciplinarity. Opposed to the segmentation of nanodisciplines, two authors suggest quite different unification views. JAN SCHMIDT sees in nanotechnology the attempt to establish a fundamental technology that is guided by a misguided technological reductionism and driven by physicists. GEORGE KHUSHF suggests a systems-theory approach that allows for the nonreductionist convergence of nanotechnology, biotechnology, information technology, and cognitive science in which also the humanities find their appropriate place. Instead of taking a bird's eye view, two papers explore the disciplinary issues in detailed case studies. In his analysis of a debate between two research schools in molecular electronics, ALFRED NORDMANN identifies a shift of nanoscience from classical theory-driven science towards a new form of technoscience that differs from classical science as much as from engineering. Finally, MICHAEL GORMAN,

JAMES F. GROVES, and JEFF SHRAGER present a model of successfully interdisciplinary collaboration between the humanities and nanoengineers for scientific research that is directed towards socially beneficial results.

Despite popular portraits of moving atoms around like balls and sticking them together with ultra-precision, successful nanoscience and nanotechnologies depend on advanced theories of molecular, atomic, and sub-atomic behavior that are traditionally provided by chemistry and physics. Is the classical canon of theories and theoretical methods sufficient to cope with the challenges posed by the nanotechnology movement, by its strong technological orientation across the disciplines? In Part II, "Searching for Theories of the Nanoscale", three papers explore how nanoscientific approaches differ from mathematical physics. PIETER VERMAAS argues that, since a theory of nanotechnology requires describing technological functions that cannot be derived from quantum mechanics, new/particular interpretations of quantum mechanics are required. JOHANNES LENHARD points out that nanoscience, because it relies heavily on computer simulations that combine epistemological features of theory and experimentation, is set apart from the received methodology of physics. OTÁVIO BUENO goes beyond physics and argues that John von Neumann's theory of automata and self-reproduction is the historical and methodological background of Eric Drexler's "theoretical applied science" approach to self-assembling devices.

More perhaps than any other field of research, nanotechnology lives from the production and mediation of images. Binnig's and Rohrer's Nobel prize winning invention of the scanning tunneling microscope (STM) in 1981 and IBM's logo written with pointy bright-blue xenon atoms on a smooth dark-gray nickel surface have been made visually compelling highlights of standard narrations of nanotechnology. In part III "Imaging the Nanoscale", five papers analyze from historical, sociological, epistemological, and artistic points of view images of the nanoscale and the instruments used for their production. They all question popular understandings of the role of STMs in nanotechnology and of "seeing atoms". The first three papers by CYRUS MODY, ARNE HESSENBRUCH and DAVIS BAIRD & ASHLEY SHEW each provide detailed historical narratives of scanning probe microscopy, of the various researchers, communities, companies, and politics involved in its development. Mody concludes that, although the connection to nanotechnology had been contingent, probe microscopists were trying to create their own nano field. Hessenbruch analyses the negotiation of novelty of the instruments' capacities and suggests that this is part of the visionary rhetoric that is generally required nowadays to promote science in the public sphere. BAIRD & SHEW argue that the commercialization and black-boxing of scanning probe microscopes represents an epistemological shift characteristic of post-academic science. The two remaining papers focus on the role of visual images. JOSEPH PITT critically analyses the notion of "seeing atoms" with STMs and argues for a metaphorical reading, because visualization by scientific instruments fundamentally differs from actual seeing. CHRIS ROBINSON relates nanotechnological image production to the broader culture of visual arts, warns of uncritical image use, and suggests distinguishing carefully between schematics, documentation, fantasy, and fine art.

Apart from visual images, the language used by nanoscale researchers, visionaries, and politicians in public speeches and publications for broader readerships plays an important role in propagating nanotechnology and negotiating its identity. The term "nano" itself has become a buzz word, prefixed to almost any other term to build compound words that indicate little more than the author's commitment to the nano movement. Powerful old metaphors have been incorporated into the nano discourse and new ones are being created to communicate specific messages. Part IV "Communicating Nanotechnology" presents four critical analyses of the rhetoric of nanotechnology. DAVID BERUBE provides a rhetorical analysis of Eric Drexler's publications on molecular nanotechnology with emphasis on how risks have been communicated to a broader readership. In his discourse analysis of the

emerging field of nanomedicine, ANDREAS LÖSCH investigates how innovation is negotiated within research communities by referring to different notions, such as miniaturization (the top-down approach) and hybridization of nature and technology. GREGOR SCHIEMANN examines how the US brochure "Shaping the World Atom by Atom" exploits the common sense distinction between nature and technology as an effort to legitimize nanotechnology to the public. ASTRID SCHWARZ, by carefully distinguishing different concepts of sustainability, points out the inconsistencies in the public discourse on nanotechnology.

Given the strong political efforts – through enormous governmental funding, the foundation of numerous national initiatives, and the competition for global leadership – nanotechnology almost appears like a creation by politicians. Part V "Examining the Politics of Nanotechnology" addresses such questions as: What specific interests are guiding the politics of nanotechnology? How can the political control of nanotechnology be further democratized? Based on her survey of the history of research policy in the US, ANN JOHNSON argues that the current focus on nanotechnology is only the final step of a two-decade long shift towards commercially exploitable research at the expense of pure science. From a sociological point of view, HANS GLIMELL analyzes the development of the US National Nanotechnology Initiative, its actors and their responses to critical concerns, as well as the role conceived for the social sciences. JODY A. ROBERTS, with reference to prior legal studies on the regulation of nanotechnology, discusses several approaches to increase and decrease public participation in the creation, acceptance, and use of nanotechnology. EDWARD MUNN argues for democratic deliberation about nanotechnology and a culture in which the role of experts is restricted to the promotion of informed decision-making by the citizens.

Since nanotechnology emerged from the efforts of visionaries, promises of unprecedented benefits have been accompanied by warnings of great threats, such that the demand for "Societal and Ethical Implications of Nanotechnology" has become an essential component of the nano movement. This has made philosophers and ethicists quite reluctant to engage in such visionary speculations. It is time, however, to approach the field from perspectives that are detached from the visionary propagation of nanotechnology. Part VI "Exploring Ethical Dimensions" therefore comprises four papers that deal with ethical issues that are likely to arise in the near future. JÜRGEN ALTMANN & MARK GUBRUD focus on possible military applications of nanotechnology and argue that they are would undermine current arms-control treaties, humanitarian laws, and military stability, such that new arms control measures are required now. EMMANUELLE SCHULER claims that, against the background of current scientific knowledge, the perceived risks of nanoparticles for health and the environment are overestimated and overrated. WADE ROBISON distinguishes between ethical issues that are internal to the practice of nano-engineers, like error-provocative designs, and those that are external and result from misguided application, like constraints of health risks, and environmental harm. JAMES MOORE and JOHN WECKERT, while acknowledging the uncertainties in defining the terrain of nanotechnology, discuss the ethical issues of privacy, human longevity, and "runaway nanobots" that will arise if certain promises come true.

As Arne Hessenbruch and Ed Munn point out, the negotiation of novelty hinges on contentious claims. To the extent that the papers in this volume sift through such claims and end up taking a stance regarding the novelty and particular interest of nanoscience and nanotechnologies, they leave us with contentious claims of their own. Whether they mark beginnings of ^{nano}STS research trajectories or present results of sustained investigations, all of them invite dissent. What this book therefore needs most are readers willing to take on the various claims and counter-claims of the book, to examine them carefully and critically and to constructively move the field ahead. Only then can we say to have "discovered the

nanoscale" as an important and contentious territory for Science and Technology Studies. Inasmuch as nanoscience and nanotechnologies challenge our ways of thinking, judging, and acting, ^{nano}STS helps developing a better understanding of who we are, which times we live in, and what science and technology mean in contemporary culture.

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