

# Preface

“Every now and then I receive visits from earnest men and women armed with questionnaires and tape recorders who want to find out what made the Laboratory of Molecular Biology in Cambridge . . . so remarkably creative. They . . . seek their Holy Grail in interdisciplinary organization. I feel tempted to draw their attention to 15th century Florence with a population of less than 50,000, from which emerged Leonardo da Vinci, Michelangelo, Raphael, Ghiberti, Brunelleschi, Alberti, and other great artists. Had my questioners investigated whether the rulers of Florence had created an interdisciplinary organization of painters, sculptors, architects, and poets to bring to life this flowering of great art? Or had they found out how the 19th century municipality of Paris had planned Impressionism, so as to produce Renoir, Cezanne, Monet, Manet, Toulouse-Lautrec, and Seurat? My questions are not as absurd as they seem, because creativity in science, as in the arts, cannot be organized. It arises spontaneously from individual talent. Well-run laboratories can foster it, but hierarchical organization, inflexible bureaucratic rules and mountains of futile paperwork can kill it. Discoveries cannot be planned; they pop up, like Puck, in unexpected corners.”

— Max Perutz, in *I Wish I'd Made You Angrier Earlier* (1998)

The seminal discovery of Max Perutz, a method for phasing the X-ray diffractions from a protein crystal, provided the means for the calculation of atomic structures of macromolecules. This remains one of the most stunning achievements of interdisciplinary science. It is noteworthy that Perutz's early work, which transformed modern Biology, was carried out at the Cavendish Laboratory, a Physics laboratory in Cambridge that also yielded the remarkable interdisciplinary collaboration of Perutz's doctoral students, James Watson and Francis Crick.

Although the editors of this volume agree wholeheartedly with Perutz's view that the ultimate sources of scientific advances are found in individual perspicacity, we also recognize that institutional features that foster genuine integration of traditional scientific disciplines, like those existing in Cambridge at the Cavendish and later at the Laboratory of Molecular Biology, are essential to meet the needs of 21st century science. Indeed, the emergence of new scientific fields at the intersections of traditional, scientific disciplines and the increasing dependence on multidisciplinary

approaches to solving problems at the frontiers of science demand responses and reformations at the institutional level.

Our goal in creating this “virtual roundtable” of discussants on the topic of integrative science, most decidedly, is not to attempt to provide a “Holy Grail in interdisciplinary organization.” Recognizing that reform efforts are likely to be as varied as the institutions in which they occur, we have attempted to assemble, in a rather novel format, a symphony of voices that address the pluralistic nature of approaches to institutionalizing integrative science.

A few words about the virtual roundtable format of this book. As an enterprise, its goal is to synchronize the asynchronous: to assemble eminent thinkers on the subject of integrative science. The “participants” come from different perspectives and experiences, and include Nobel Laureates, University Presidents, serious scholars, and distinguished scientists. Although their comments, talks, articles, and interviews on this subject may have taken place at different times and in widely different venues, we have collected them into an organized, coherent ensemble of integrated conversations about the necessity, promises, challenges, and implementation of integrative approaches to scientific research and education. We have chosen to frame the roundtable conversations by posing a series of central questions. We hope that the answers to these questions will be of interest to a wide range of scientists, educators, and university and college administrators facing the exciting, if daunting, hurdles involved in integrative reform. The discussions of the questions are certainly not meant to be comprehensive. Rather, we asked 10 of the most pressing questions related to integrative science and sought answers from 21 of the world’s experts on the subject. At times, their voices are mutually reinforcing. In other instances, divergent answers to the same question arise, a sign of the timeliness and vigor of discussions on integrated science.

The book is divided into three parts. The first and second parts focus on integration at a large, structural level. Here, integration refers to the relationship between academic science and government (Part I) and between academic science and industry (Part II). Throughout these discussions, a second form of integration emerges. Academic science itself is seen as increasingly interdisciplinary – depicting a convergence of disciplines often resulting in new fields of study – or multidisciplinary – an approach that emphasizes the integration of disciplines employed to solve specific problems. The final part of this work analyzes the implications of interdisciplinary and multidisciplinary approaches to modern scientific investigation and education.

Former Vice President Al Gore begins the discussion with the intriguing notion of “distributed knowledge” – a metaphor drawn from computer science. Of critical importance to this distributed system, he emphasizes scientific literacy among policy makers and politicians. If we are seriously to confront global issues such as climate change, Mr. Gore argues, we must have policy makers who are part of the distributed knowledge system of science that emanates from, in large part, the universities and cycles through the government. On a global or macro-level, the promise of integrated science is accompanied by a grave sense of urgency, according to both Mr. Gore and Dr. Bruce Alberts, former president of the National Academy

of Sciences. “Today,” Dr. Alberts says, “we find it difficult to meet the basic needs of the Earth’s six billion people. How, then,” he asks, “can we hope to meet the basic needs of the nine billion people expected to inhabit our planet by 2050?”

Dr. Elias Zerhouni, Director of the National Institutes of Health, also encourages a new, more integrative, structure of organizing science to respond to the discovery of a unifying set of “principles that link apparently disparate diseases through common biological pathways and therapeutic approaches.” In his discussion, he guides us through the NIH Roadmap effort that includes the support of novel, interdisciplinary, organizations of research teams and grants awarded to high risk scientific enterprises.

Dr. James Duderstadt, former President of the University of Michigan system, analyzes the convergence of government, academic science, and private industry. Specifically, he provides an overview of the ramifications of the pivotal Bayh-Dole Act of 1980, which engendered a fundamental shift in the ways in which technology transfer of academic research occurred. Whether the diverse fields of integrative science in the academy lend themselves more or less to the guiding hands of industry remains to be seen. Dr. Duderstadt warns that the traditional values of the academy must be preserved while institutions of higher education respond to the demands of the market place.

The discussion of integration in relation to industry and capital continues in the contribution by Dr. Stanley Aronowitz, Distinguished Professor of Sociology and Director of the Cultural Studies Program at the Graduate Center, City University of New York. Dr. Aronowitz argues for the de-comodification of the University. In contrast to Dr. Duderstadt’s desire to maintain the integrity of traditional values of the university while responding to market realities, Dr. Aronowitz argues that the line is too often blurred between the idealized curriculum of the academy and the focused priorities of industry. Dr. David Kirp, Professor of Public Policy at the Goldman School of Public Policy is equally skeptical of such integration of education and industry. “While the public has been napping, the American university has been busily reinventing itself,” Professor Kirp begins. The new shape of the university has been tailored to the demands of the marketplace.

Hank Riggs, Founding President of the Keck Graduate Institute, reflects on the roles of leadership in industry and higher education respectively. Having had experience in both, President Riggs suggests that although we should be mindful of their differences, leadership in these areas is surprisingly similar, particularly in respect to the challenges that both educational and industrial leaders confront. Dr. William Haseltine discusses the trends in science from a very different vantage point. As a former professor at Harvard Medical School and now entrepreneur, Dr. Haseltine likens disciplines within science as a wonderful tool set. But, he warns, innovation, discovery, and development demand that scientists have access to more than one single tool – one single disciplinary approach to solve problems.

Exploring the material and sociological factors involved in such interdisciplinary training, Dr. Steven Brint, Associate Dean and Professor of Sociology at the University of California, Riverside, offers a balanced account of whether integrative science is a passing fancy of the academy. From a reservoir of data, Dr. Brint reports

on factors from technological change and federal and private funding projections to demographic trends and global competition that may determine whether new directions in science will have a lasting impact on the landscape of higher education. Dr. Paul Grobstein addresses some of the challenges that academics confront in developing these new directions in science education. In terms that reflect evolutionary psychology, he likens disciplines to tribes who express an inclination to share observations and stories only with people who are in some sense “like themselves.”

The implication of the integration of science at the undergraduate level is tackled first by Dr. William Wulf, former President of the National Academy of Engineering, in his discussion of question six. Namely, that a major change is occurring, albeit gradual, beginning with a re-definition of “the fundamentals” through to an articulation of faculty motivations and incentives for gaining practical experience in industry. Dr. Donald Kennedy, President Emeritus at Stanford University, continues by succinctly describing the competition between depth and breadth in undergraduate science education. He also enumerates the inexorable fiscal challenges associated with the capital-intensive nature of science education at the undergraduate level. He concludes with a concise and insightful summary of the obstacles which must be overcome in supporting undergraduate faculty. Together, these two essays capture the essential benefits, opportunities and difficulties in world-class, undergraduate integrative science education.

Dr. Kennedy and Dr. Rita Colwell, former director of the National Science Foundation, then discuss whether new directions in scientific training encourage a more diverse body of scientists. Both point to recasting science training as fundamental to the flourishing of diversity. “The interconnectedness of life is a very deep law,” Dr. Colwell remarks, “and greater diversity makes for a more robust ecosystem than does a monoculture. The environment must nourish any organism, or it will not survive – just like the environment for a young scientist, which can be chilling or nurturing.” Dr. Kennedy suggests that just such an environment can be found in liberal arts institutions where one-on-one mentoring is part of the institutional culture.

In question eight, Dr. Colwell takes up the issue of graduate training. She provides a broad view of new directions at the Master’s level with focus on professional training rather than preparation for the Ph.D. As an example of such a program, Dr. Colwell refers to the Professional Science Master’s (PSM) degree, a program supported by the Alfred P. Sloan Foundation. Until 2005, the National Outreach Coordinator for the Sloan Science Master’s Initiative was Ms. Sheila Tobias. Ms. Tobias discusses the details of this new approach; an approach that integrates elements of industry and education, emphasizes interdisciplinarity, and subsequently changes the goals of the traditional Master’s Degree for those students seeking work in the science industry.

In response to a question about the challenges of training interdisciplinary Ph.D.s, Dr. David Baltimore, a Nobel Laureate, and past president of both Rockefeller University and The California Institute of Technology, provides a historical perspective that highlights the important role of combining technology and instrumentation with molecular biology. He then sketches out the implications of this

paradigm for the future training of practitioners of integrative science, and suggests institutional changes that will enhance this training. In responses to the same question, Drs. Golde and Gallagher of the Carnegie Foundation for the Advancement of Teaching provide a cogent discussion of obstacles that doctoral students face if they wish to conduct interdisciplinary research. Finally, Drs. Cech and Rubin, of the Howard Hughes Medical Institute (HHMI), describe the considerations that led to the *de novo* establishment of an interdisciplinary research institute, the Janelia Farm campus of HHMI.

The volume ends with Robert Venturi offering a short course on the philosophy and grammar of space. He applies these concepts to the design of science buildings. In this discussion, he articulates a new vocabulary for creating scientific space for the 21st century. Dr. Claire Fraser offers her observations on developing the building plan for the Institute for Genomic Research in Rockville, Maryland. In conclusion, she claims, more by luck than design, the proximity of scientists created the relationships needed for the integrated science that the Institute sought to establish.

We hope that the reader finds the roundtable discussions stimulating, and that some reformatory utility will be found in the viewpoints contained herein. The roundtable is intended as a launching pad for further discussions amongst colleagues who are focused on promoting integrative approaches at a variety of institutions. If this volume stimulates even a modicum of such, we will be satisfied with our efforts.

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Integrated Science

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Discussion

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