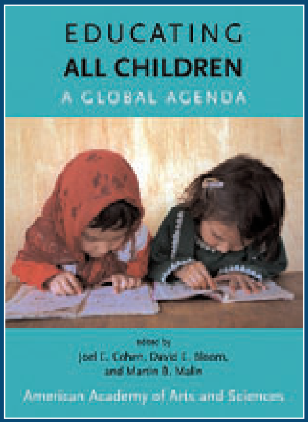
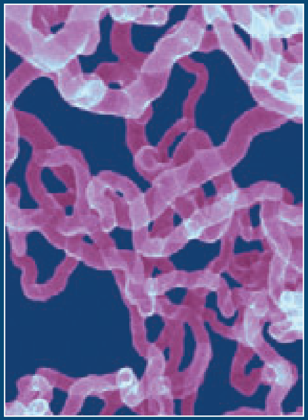
AMERICAN ACADEMY OF ARTS & SCIENCES

Bulletin

SUMMER 2009

VOL. LXII, NO. 4





INSIDE:

Contents

AMERICAN ACADEMY
OF ARTS & SCIENCES

Calendar of Events

Save the Date:

Thursday, September 17, 2009

Meeting – Palo Alto

The Challenge of Mass Incarceration in America

Speakers: Glenn Loury, Brown University, and **Bruce Western**, Harvard University

Location: Stanford University

Thursday, September 24, 2009

Meeting – Cambridge

A New Literary History of America

Speakers: Werner Sollors, Harvard University, and **Greil Marcus**, Berkeley, California

Location: House of the Academy

Saturday, October 10, 2009

2009 Induction Ceremony – Cambridge

Sunday, October 11, 2009

Meeting – Cambridge

Science, Energy, and the Environment

Moderator: Richard Meserve, Carnegie Institution for Science

Speakers include: Steven Koonin, United States Department of Energy; **Paul Joskow**, Alfred P. Sloan Foundation; **John W. Rowe**, Exelon Corporation; **John Doerr**, Kleiner Perkins Caufield & Byers

Wednesday, November 11, 2009

Meeting – Cambridge

The Education of an American Dreamer: How a Son of Greek Immigrants Learned His Way from a Nebraska Diner to Washington, Wall Street, and Beyond

Speaker: Peter Peterson, Peter G. Peterson Foundation

Location: House of the Academy

Wednesday, December 9, 2009

Meeting – Cambridge

Holiday Concert – An Evening with Malcolm Bilson

Introduction: Christoph Wolff, Harvard University

Speaker: Malcolm Bilson, Cornell University

Location: House of the Academy

For information and reservations, contact the Events Office (phone: 617-576-5032; email: mevents@amacad.org).

Academy Projects

Educating All Children

Joel E. Cohen

David E. Bloom

In 2001, the American Academy began the Universal Basic and Secondary Education (UBASE) project to advance the promise of a quality education for all children worldwide. The project presumed that universal education has the potential to help alleviate poverty, raise living standards, increase human dignity, and improve health (including reproductive health); but at the same time, the project understood that various obstacles stand in the way of meeting that goal, including:

- Nearly 30 percent of school-age children worldwide are not enrolled in school.
- Of school-age children who enter primary school in developing countries, more than one in four drops out before attaining literacy.
- There are gross disparities in education that separate regions, income groups, and genders.

Yet in advocating for universal education, the project quickly recognized a significant roadblock: the lack of knowledge of the basic facts about global education, as well as lack of knowledge of how these facts are produced and whether they are reliable. Education is one of the largest and most important investments made by governments and people. Understanding whether this investment leads to the desired ends is crucial to effective government policy and private decision-making.

To this end, the project endeavored to create a methodology, a new theoretical research base to underpin any inquiry into the role that primary and secondary education might play in creating positive global change. The Academy brought together an international team of scholars, program officers, educators, public servants, and business leaders, headed by Project Directors **Joel E. Cohen** (Rockefeller and Columbia Universities) and **David E. Bloom** (Harvard University), to consider fundamental questions about the costs, means, and consequences of providing education to all children:

- What do we know about global education and how do we know it?
- What would be the consequences of providing every child with primary and secondary schooling?
- What is the history of efforts to expand education?
- What obstacles stand in the way of achieving universal education?
- What are the best practices and innovations for overcoming those obstacles?
- What will it cost to provide primary and secondary schooling for all children?

Universal education has the potential to help alleviate poverty, raise living standards, increase human dignity, and improve health (including reproductive health).

By beginning with these questions, the project tackled first the soundness of advocating for universal education – the question of *whether* – before moving to questions of *what to do* and *how*.

Ultimately, the project offered five major recommendations:

- That a commitment must be made to extending a full cycle of high-quality primary and secondary education to all children;
- That more reliable data must be created and used in studying what children learn, what alternative pedagogical techniques and technologies exist, and which countries are performing best;
- That discussions about what stakeholders want primary and secondary education to achieve must take place openly at the national, regional, and international levels;
- That the diverse character of educational systems in different countries must be internationally recognized, and aid policies and assessment requirements must be adapted to local contexts; and
- That education must be allotted both more money and higher priority, especially in terms of the amount of funding that developed countries provide for education in developing countries.

The Academy has made the project's findings and recommendations public through a series of five Occasional Papers – *Measuring Global Educational Progress*; *Global Educational Expansion: Historical Legacies and Political Obstacles*; *Achieving Universal Basic and Secondary Education: How Much Will It Cost?*; *Education, Health, and Development: An Under-Explored Nexus*; and *Improving Education Through Assessment, Innovation, and Evaluation* – and two edited books: *Educating All Children: A Global Agenda* (MIT Press, 2006) and *International Perspectives on the Goals of Universal Basic and Secondary Education* (Routledge, forthcoming 2009). Many of the UBASE publications are posted on the Academy's website, www.amacad.org, and some of the publications have been translated and distributed in multiple languages.

PROJECT PUBLICATIONS

Edited Volumes

Educating All Children: A Global Agenda, edited by Joel E. Cohen, David E. Bloom, and Martin B. Malin, argues that universal education, urgently needed, can be achieved. The volume explores a key project finding: that it should be possible to give all children a decent primary *and* secondary education at a cost of up to an additional $70 billion per year. On the one hand, this seems a rather modest sum, less than one-seventh of the U.S. government's annual military budget, and only one-fourth of the foreign aid goal of 0.7 percent of the $37 trillion of gross national income of developed countries. On the other hand, it is a formidable amount, since foreign aid currently is substantially below the 0.7 percent target, especially in the United States.

What obstacles stand in the way of achieving universal education?

In addition, the project developed a methodology for estimating how many children worldwide are not in school. Project Co-Director David Bloom continues to develop this methodology.

The second book – *International Perspectives on the Goals of Universal Basic and Secondary Education*, co-edited by Joel E. Cohen and Martin B. Malin – explores the goals of education and addresses the "lack of focused international discussion on the desired content and aims of basic and secondary education," as Cohen explains in the introduction.

International Perspectives draws together experts from many different regions, cultures, professions, and religious backgrounds to present a compelling, unified case for reassessing the goals and overhauling the methods of education systems that were designed and established at the height of an industrial period and that no longer fit with the experience and needs of a globalizing world. Vimala Ramachandran, of the Educational Resource Unit in India, sounds the book's major theme when she calls for "the re-imagination of education" in order to link it to "life, livelihood, peace, and social justice." For many of the contributors this means addressing the basic needs of children – secure classrooms, clean drinking water, hygienic bathrooms, nutritious food, and

What will it cost to provide primary and secondary schooling for all children?

well-trained and well-compensated teachers – as well as building on that foundation to enrich education, without spending resources that may not be available in every society. Mexico's *dia* program, for example, integrates the teaching of knowledge, skills, attitudes, and values through the use of art in the classroom, as Claudia Madrazo, of La Vaca Independiente, highlights in her chapter.

The volume takes up topics as varied as bilingual education, the coexistence of art and science in the curriculum, the importance of critical thinking, global civility and peaceful negotiation, and appreciation of cultural diversity. Indeed, many of the authors agree that an increased appreciation of cultural diversity and an ability to work across different linguistic and knowledge-acquisition systems are necessary in the twenty-first century. The volume also weighs the balance between *access to* education and *quality of* education.

Related Publications

In addition to the Occasional Papers listed above, UBASE has been featured in *Dædalus*, the journal of the Academy; in *Finance & Development*, a publication of the International Monetary Fund; in *Prospects*, UNESCO's journal of comparative education; in an op-ed published in several languages in news outlets around the world; in an article by Joel Cohen for the December 2008 issue of *Nature*; and on the PBS *Wide Angle* series and the PBS website. The project has also produced numerous "spinoff" publications, such as a special issue of the *Comparative Education Review* on health and education, guest edited by David Bloom; articles in the journals *World Development* and *World Economics*; and a book published by the Pontifical Academy of Sciences.

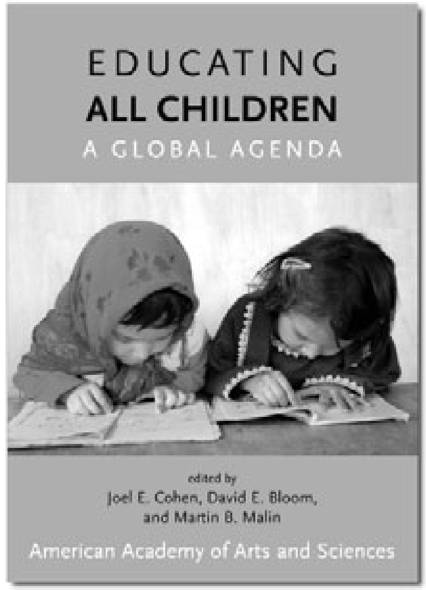
NEXT STEPS

The Academy is seeking additional funding to translate the significant body of research developed from the UBASE project into concrete goals and strategies for implementation. Drawing on the Academy's extensive international network in the field of educational development, we are looking to partner directly with donors, local universities, and other institutions responsible for training educators and delivering education in specific countries in sub-Saharan Africa, South Asia, and Latin America, to build indigenous capacity for assessing and improving educational expansion efforts. The Academy will actively engage local representatives as we jointly consider what needs to be done to make educational improvement and expansion possible. Underlying this effort is the belief that a participatory approach that combines the expertise of local, national, and international practitioners, scholars, and policy-makers is vital to the reform of educational systems.

The UBASE project has created sound methodology for studying global education and has outlined concrete recommendations for action toward achieving universal education.

The project received generous support from the William and Flora Hewlett Foundation, John Reed, the Golden Family Foundation, Paul Zuckerman, the Zlinkoff Fund for Medical Research and Education, an anonymous donor, and the American Academy of Arts and Sciences.

The UBASE project has created sound methodology for studying global education and has outlined concrete recommendations for action toward achieving universal education.

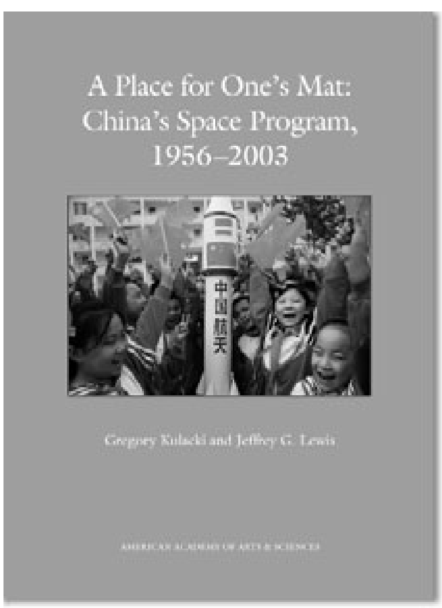


We are confident that these building blocks provide the necessary background for future investigation by academics and policy-makers active in the field of educational development, and that they persuasively make the case for providing basic and secondary education for children worldwide. It may be a big task, but it is one that can be met in the twenty-first century. ■

Reconsidering the Rules of Space

The development of space affects a range of government, commercial, and scientific interests around the world, yet the policies that adequately balance these interests have not been worked out in the necessary detail. The American Academy initiated the *Reconsidering the Rules of Space* project in 2002 under the auspices of the Committee on International Security Studies. This project examines the implications of U.S. policy in space, the international rules and principles needed to maintain a balanced use of space over the long term, and the politics of and potential for greater international cooperation in space.

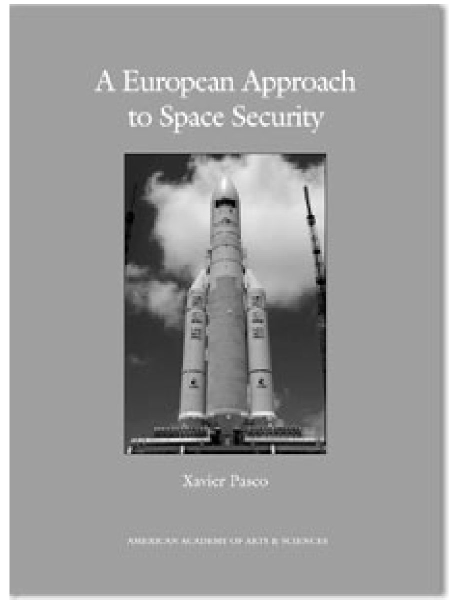
All nations increasingly rely on satellites for communication services, environmental monitoring, navigation, weather prediction, and scientific research. Technological advances have also inspired the development of military capabilities in space that go far beyond the traditional intelligence and early-warning missions of the Cold War period. Protecting and enhancing U.S. civilian and military capability in space raises important policy, planning, and budget questions.



The Academy's project has facilitated discussions between experts from the United States and abroad on various aspects of space policy – international security, scientific advancement, and commercial development. Several papers have been published dealing with, respectively, the basic laws of physics that apply to all space activity (*The Physics of Space Security: A Reference Manual*, by David Wright, Laura Grego, and Lisbeth Gronlund, 2005); the fundamental issues of security policy (*Reconsidering the Rules for Space Security*, by Nancy Gallagher and John D. Steinbruner, 2008); and the policies of the principal national governments (*United States Space Policy: Challenges and Opportunities*, by George Abbey and Neal Lane, 2005, and *Russian and Chinese Responses to U.S. Military Plans in Space*, by Pavel Podvig and Hui Zhang, 2008).

This summer, the Academy published three new papers in the project series, with a fourth to be published in the fall.

A Place for One's Mat: China's Space Program, 1956–2003, by **Gregory Kulacki** and **Jeffrey G. Lewis**, is the fifth paper of the project series. Using Chinese-language sources, Kulacki (Union of Concerned Scientists) and Lewis (New America Foundation) examine three formative events in the development of China's utilization of space: the launch of the first satellite in 1970, the launch of the first communications satellite in 1984, and the first human spaceflight in 2003. They trace the origins and basic purposes of each of these efforts and set them in the context of China's internal history. Their central observation is that China understood each of these efforts to be a measure of national accomplishment necessary to qualify for inclusion among the major spacefaring countries that set the rules. Equity appears to have been the principal concern of China's political leadership.



That goal is more legitimate and less belligerent than the motives typically attributed to China by foreign observers – the U.S. intelligence community in particular. The authors do not claim to provide a comprehensive account of China's space program or an indisputable interpretation of its fundamental purposes. They do, however, provide evidence to be considered in any fair-minded assessment of the program's global significance.

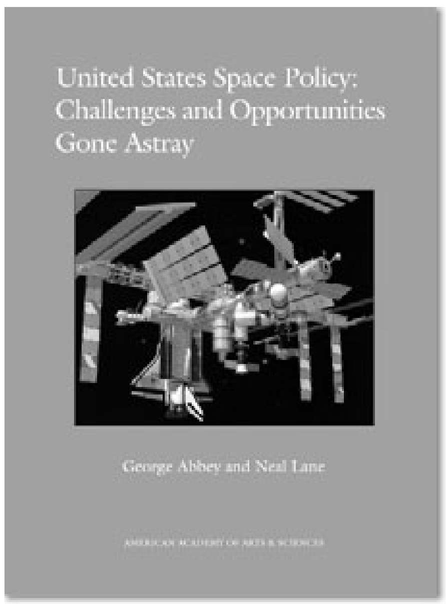
A European Approach to Space Security, by **Xavier Pasco** (Fondation pour la Recherche Stratégique, Paris), is the sixth occasional paper of the series. It documents the efforts of EU members to develop common policies and practical collaboration for space missions related to security. It notes that the European community has not as yet been able to establish authoritative coordination of national military programs and warns that balancing those programs with increasingly important commercial and social interests is a generally unresolved problem. But it also suggests that EU efforts to develop collective rules, confidence-building measures, and codes of re-

Space has proven to be an arena for uplifting collaboration among nations as well as ominous confrontation. The end of the U.S.-Soviet competition that defined the modern space age, as well as an increase in the ranks of spacefaring nations and an expansion of commercial space ventures, dictates a new approach that embraces the equitable utilization of space by all nations for common benefit.

– John D. Steinbruner
Director of the Academy's Reconsidering the Rules of Space project and Professor of Public Policy at the University of Maryland

sponsible conduct can make an important constructive contribution to working out global arrangements for space.

United States Space Policy: Challenges and Opportunities Gone Astray, by **George Abbey** (Rice University) and **Neal Lane** (Rice University), is the seventh paper in this series, updating the 2005 publication by the same authors. It warns of serious misalignment of the purposes, operating principles, and resources of the U.S. space program. It notes that the announced intention to send manned missions to the moon and to Mars as virtually exclusive national ventures has not been adequately financed. As a result, most of NASA's activities are being redirected to those specific purposes, thereby jeopardizing the agency's broader historical functions without assuring that the projected missions can in fact be accomplished. The paper recommends a significant rebalancing of priorities to support the International Space Station, to extend shuttle missions through 2015, and to continue NASA's traditional support for ba-



sic science and aeronautical engineering. It updates the 2005 assessment of impediments to a well-balanced space program, noting that export-control policies, decline in the science and engineering workforce, the state of mission planning, and the degree of international cooperation have all become more serious problems. Overall it provides an urgent appeal for a fundamental reformulation of U.S. space policy.

The Future of Human Spaceflight: Objectives and Policy Implications in a Global Context, by **David A. Mindell, Scott A. Uebelhart, Asif Siddiqi,** and **Slava Gerovitch**, forthcoming this fall, is the eighth paper in the project series. The United States stands at the threshold of a new era of human spaceflight. The Obama administration has an opportunity to reformulate U.S. space policies that are anchored in Cold War-era mindsets. *The Future of Human Spaceflight* rethinks the objectives for government-funded human spaceflight and addresses current policy questions in light of those objectives. The authors describe the primary and secondary objectives of human spaceflight and examine the human spaceflight programs of other countries, notably Russia, China, India, the European Space Agency, and Japan, with a focus on how each articulates its own human spaceflight program. For the United States, the authors recommend that the country develop a broad and well-funded plan to utilize the International Space Station through 2020 to support the primary objectives of exploration; that NASA restore its support for fundamental research in the new technologies that will enable these explorations; and that the United States reaffirm its long-standing policy of international leadership in human spaceflight and remain committed to its existing international partners. They also recommend that the United States begin to engage with China, India, and other aspiring space powers on human spaceflight.

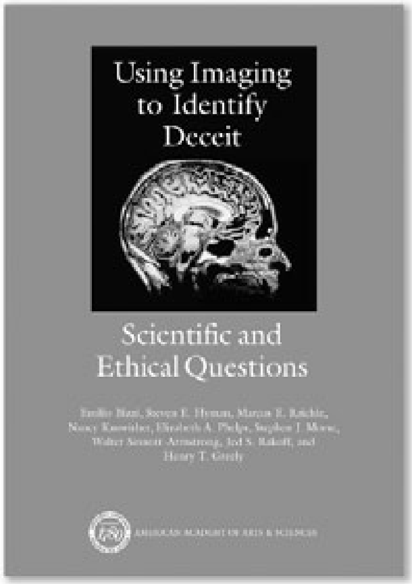
Copies of these publications are available on the Academy's website at http://www.amacad.org/projects/space.aspx.

The Reconsidering the Rules of Space project is supported by a generous grant from the Carnegie Corporation of New York. We are grateful to **Carl Kaysen** and **John Steinbruner**, cochairs of the Committee on International Security Studies, for their dedication to the project, and we would especially like to thank John Steinbruner, who has served as the principal leader and director of the project.

Academy Publications

New Occasional Papers

The Academy is pleased to announce the release of several new volumes in its Occasional Paper series.

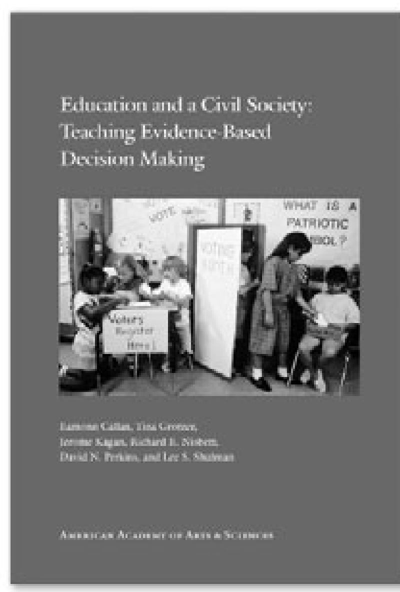


Using Imaging to Identify Deceit: Scientific and Ethical Questions examines the scientific support for using functional magnetic resonance imaging (fMRI) to recognize deception. The essays, written by scholars of neuroscience, law, and philosophy, consider the legal and ethical concerns that emerge when machine-based means are employed to identify deceit. The contributors express a dim view of lie detection based on fMRI technology. As **Emilio Bizzi** (MIT) and **Steven E. Hyman** (Harvard University) state in the introduction, "Often in science when a new technique such as fMRI appears, the scientists who promote its use argue that, yes, problems exist but more research will in the end give us the magic bullet. Perhaps. In the case of lie detection through fMRI, however, the problems seem insurmountable." The volume's authors include **Emilio Bizzi** (MIT), **Steven E. Hyman** (Harvard University), **Marcus Raichle** (Washington University in St. Louis), **Nancy Kanwisher** (MIT), **Elizabeth A. Phelps** (New York University), **Stephen J. Morse** (University of Pennsylvania), **Walter Sinnott-Armstrong** (Dartmouth College), **Jed S. Rakoff** (United States District Court, Southern District of New York), and **Henry T. Greely** (Stanford University).

A collection on ***Media, Business, and the Economy*** explores how well the media inform the public about the economy and how that role can be improved. Economist **Alan Blinder** (Princeton University) investigates what Americans already know about economic policy, and how the media contribute to that understanding. Financial journalist **Jeffrey Madrick** (Schwartz Center for Economic Policy Analysis, The New School) describes the evolution of business journalism over the past 30-plus years. Former newspaper editor **Lou Ureneck** (Boston University) surveys the formal training programs in the United States that specialize in the preparation of newspeople for the finance and economy beat. This study, which draws from an earlier Academy project on *Corporate Responsibility in America*, was launched during a period of relative prosperity and stability in the world's financial markets. Today the global economy is far less settled, making the need for sound economic information even more crucial. The volume provides a better understanding of the role of a changing media amid a changing economy. The collection is available online at the Academy's website (http://www.amacad.org/projects/mediaBusiness.aspx).

Education and a Civil Society: Teaching Evidence-Based Decision Making explores evidence-based thinking in K-16 education. It is part of an Academy project that hypothesizes that citizens who value and know how to use evidence will be better prepared to participate in the democratic process as informed thinkers. The project proposes that the educational system of the United States should consider how to prepare young people more effectively for the kind of decision making that is required to understand change, to advocate, and to vote with knowledge about public policy. As the volume reveals, more work needs to be done in the schools, but determining what should be done and how to do it raises additional complex issues. The publication is intended to encourage further conversation about critical thinking and its importance. The authors in the collection include **Lee S. Shulman** (Carnegie Foundation for the Advancement of Teaching and Stanford University), **David N. Perkins** (Harvard Graduate School of Education), **Richard E. Nisbett** (University of Michigan), **Jerome Kagan** (Harvard University), **Eamonn Callan** (Stanford University), and **Tina Grotzer** (Harvard Graduate School of Education).

Online versions of ***Using Imaging to Identify Deceit*** and ***Education and a Civil Society*** are available on the Academy's website at http://www.amacad.org/publications/occasional.aspx. ■



Academy Fellowships

Early-Career Scholars in Residence

Visiting Scholars Program

The Visiting Scholars Program is an interdisciplinary research institute housed at the Academy in Cambridge. Chaired by **Patricia Meyer Spacks** and **Leslie Berlowitz**, the program enables untenured junior faculty and postdoctoral scholars in the humanities, social sciences, and policy studies to carry out their individual research as well as to collaborate with Academy Fellows on shared scholarly or policy-related interests.

Eight Visiting Scholars will be in residence during the 2009 – 2010 academic year.

2009 – 2010 Visiting Scholars

Daniel Amsterdam – Ph.D., University of Pennsylvania; B.A., Yale University. Field: History. *The Roaring Metropolis: Business, Civic Welfare, and State Expansion in 1920s America*. A study recasting the 1920s as a moment of aggressive governmental expansion that hinges primarily on the interrogation of urban politics, corporate political activism, and the introduction of a new analytic framework, the civic welfare state.

Deborah Becher – Ph.D., Princeton University; B.A., University of Virginia. Field: Sociology. *Valuing Property: Eminent Domain for Private Redevelopment, Philadelphia, 1992 – 2007*. A study of Philadelphia's recent use of eminent domain, revealing how difficult decisions about economic management are made, challenging existing notions of what citizens expect from government, and exploring the tensions between the public and private dimensions of property.

Angus Burgin – Ph.D., Harvard University; A.B., Harvard University. Field: History. *The Return of Laissez-Faire*. A transatlantic history of free-market ideas and the institutions that supported them, focusing on economists in the decades following the onset of the Great Depression who helped to create a theoretical framework for the revival of conservatism in American politics.

Dawn Coleman – Assistant Professor of English, University of Tennessee. Ph.D., Stanford University; M.T.S., Harvard Divinity School; B.A., University of California, Los Angeles. Field: Literature. *Preaching and the Rise of the American Novel*. A project on the intersection of Protestant preaching and literary culture in the nineteenth century, considering a range of antebellum authors who sought to capture for novels the spiritual authority of the pulpit.

Jason Petrulis – Ph.D., Columbia University; A.B., Harvard University. Field: U.S. History. *Marketing the American Way, 1932 – 1950*. An examination of how U.S. government policy intersected with corporate marketing to mobilize Americans during World War II and the early Cold War through "idea advertising," a process that uses marketing techniques to sell ideas about companies, people, and even nations.

Jamie Pietruska – Ph.D., Massachusetts Institute of Technology; A.B., Brown University. Field: History. *Propheteering: A Cultural History of Prediction in the Gilded Age*. An analysis of changing practices and perceptions of prediction in late nineteenth- and early twentieth-century America, including weather prediction, agricultural forecasting, fortune telling and spiritualism, and utopian literature.

Associate Scholars

Crystal Feimster – Assistant Professor of History, University of North Carolina at Chapel Hill. Ph.D., Princeton University; B.A., University of North Carolina at Chapel Hill. *Sexual Warfare: Rape and the American Civil War*. A study describing how sexual violence during the Civil War and the decades that followed went beyond the immediate effects of the physical attack and had long-lasting political and social consequences. She was a Visiting Scholar in 2003 – 2004.

Andrew Jewett – Assistant Professor of History and Social Studies, Harvard University. Ph.D., University of California, Berkeley; B.A., University of California, Berkeley. *Against the Technostructure: Critics of Scientism Since the New Deal*. An exploration of the political meanings attributed to science by mid-twentieth-century critics of American liberalism. He was a Visiting Scholar in 2002 – 2003.

Hellman Fellowship in Science and Technology Policy

Part of the Academy's Initiative for Science, Engineering, and Technology, the Hellman Fellowship in Science and Technology Policy is open to early-career professionals with training in science and engineering who want to transition to a career in public policy or to acquire experience working on science-policy issues.

2009 – 2010 Hellman Fellows

Kimberly J. Durniak – Ph.D., Molecular Biophysics and Biochemistry, Yale University; B.A. and B.S., University of Pittsburgh. As a member of the laboratory of Thomas A. Steitz at Yale, Durniak studied the process by which RNA is synthesized during gene expression. She was also a McDougal Fellow in the Yale Graduate Career Services Office and worked as a liaison to the New York Academy of Sciences to provide career workshops for fellow graduate students. She began her Hellman fellowship in 2008.

John C. W. Randell – Ph.D., Virology, Harvard University; B.S., University of Iowa. Field: Molecular Biology. Randell has just completed a postdoctoral fellowship in the laboratory of Stephen P. Bell at MIT. His research focuses on the connection between DNA replication and the cell division cycle. He has published papers in major journals and has taught at the Kathmandu University Medical School in Nepal. ■

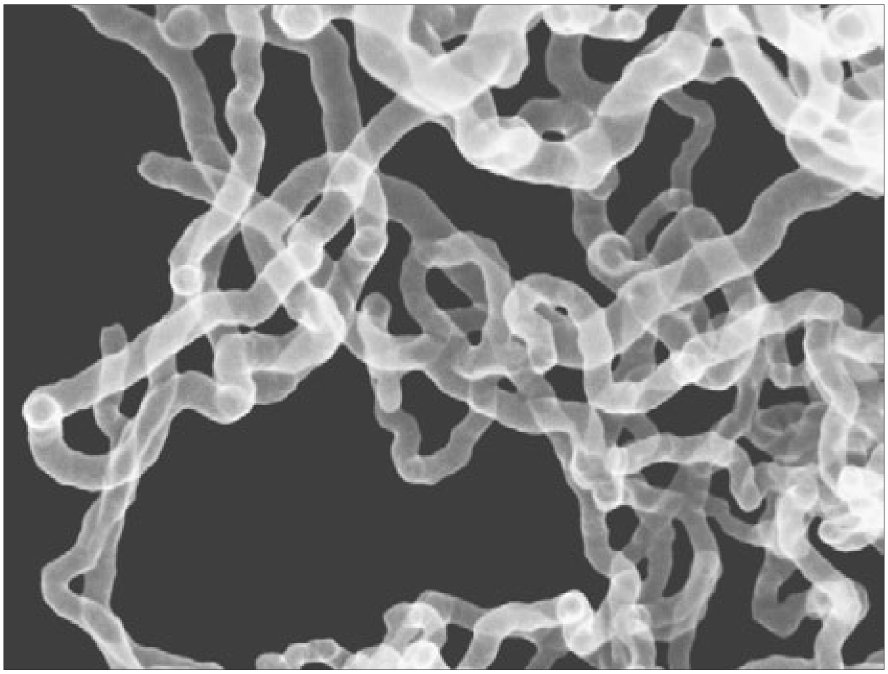


Image © Visuals Unlimited/Corbis

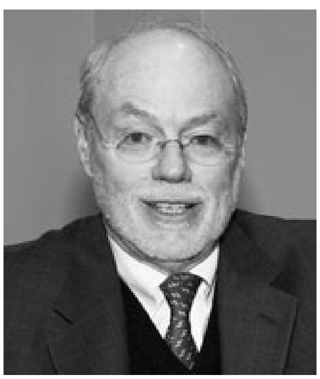
Magnified image of carbon nanotubes

Nanotechnology: Novel Applications

Robert Langer, Angela Belcher, and Evelyn L. Hu

Phillip A. Sharp, Moderator

This presentation was given at the 1941st Stated Meeting, held at the House of the Academy on March 11, 2009.



Phillip A. Sharp

Phillip A. Sharp is Institute Professor at the Massachusetts Institute of Technology. He has been a Fellow of the American Academy since 1983.

Introduction

Tonight's program on novel applications of nanotechnology features three outstanding engineers, some of the very people who created this field in which material is fabricated on a nanometer scale. Such materials are smaller than the single proteins that are components of human cells, much smaller than organelles. And these materials usually are composites, comprising multiple components capable of directing the nanoparticle to certain sites, reporting on the environment of those sites, and – when appropriately fabricated – changing the environment; for example, by releasing a drug or modifying an electrical signal. To be useful in a variety of applications, nanoparticles must be made in quantity, with uniformity, and at reasonable cost. Once made, however, they can be applied to any number of problems in fields ranging from health care to electronics to computing. Already nanotechnology has changed how we approach many problems in fundamental and exciting ways.

In my time at MIT I have learned to love engineers. (You either love them or you don't stay there!) Engineers do not approach problems in the same way scientists do. The engineer's primary approach to a problem – as I interpret engineering – is to solve the problem he or she faces. Sometimes engineers might need to understand the physics, chemistry, and/or biology behind a problem, but if that's too complex they solve the problem with the tools they do have without understanding the process. Those tools are describing, measuring, quantitating, modeling, and then gaining control of the complex system and changing it to their own ends. Their tools have been remarkably powerful, and with them they have created many of the benefits of modern society. Now comes a new tool, a new science, for creating the present and the future: nanotechnology.

The first of our guides through this new science will be Robert Langer, currently Institute Professor at MIT but long associated with MIT's Department of Chemical and Biomedical Engineering. Robert has been doing pioneering work for decades at MIT in the area of delivery systems and tissue engineering. He has published more than a thousand articles and holds over six hundred patents. For this outstanding record he has received numerous awards, including the U.S. National Medal of Science, the Charles Stark Draper Prize, and the Millennium Technology Prize. He is a member of the Institute of Medicine, the National Academy of Engineering, the National Academy of Science, and the American Academy of Arts and Sciences. Just today I discovered that the latest issue of *Nature* includes a profile titled "Being Bob Langer" that in three pages follows his activities over one day.[1] He has created an enormous amount of technology that has benefited all of us.

Our second speaker is Angela Belcher, Germehausen Professor of Materials Science and Engineering and Biological Engineering at MIT, where she also directs the Biomolecular Materials Group. She has been at MIT for six years. Her research is interdisciplinary in nature, bringing together the fields of inorganic chemistry, material chemistry, biochemistry, and molecular biology. In addition to receiving a MacArthur Fellowship Award, the Presidential Early Career Award in Science and Engineering, and the DuPont Young Investigator Award, Angela has been named a Top Ten Brilliant Scientist by *Popular Science* magazine (2002) and *Scientific American*'s Researcher of the Year (2006).

Our final speaker is Evelyn Hu, Gordon McKay Professor of Applied Physics and Electrical Engineering at Harvard University. She just made the transition to Harvard from the University of California, Santa Barbara. She has worked on nanodevices made from solid semiconductors in novel devices by integrating various materials, both organic and inorganic. She and Angie Belcher have combined efforts in a new biotech start-up in Boston. Evelyn is a member of the IEEE, the American Physical Society, and the American Association for the Advancement of Science. She was elected to the National Academy of Engineering and to the National Academy of Sciences.

Robert Langer

Robert Langer is Institute Professor at the Massachusetts Institute of Technology. He has been a Fellow of the American Academy since 1994.

Presentation

Nano means "one billionth" and in the word "nanotechnology" it refers to one billionth of a meter, or about one ten-thousandth the width of a human hair. Nanoparticles have a number of important properties: nanoparticles have much greater surface area than larger particles such as microparticles; you can give them novel surface patterns; and they are small enough not to clog the bloodstream. Particles less than 200 nanometers wide have the potential to get into cells, at which point all sorts of potential uses open up; for example, novel treatments for cancer and other diseases.

A lot of recent pharmaceutical research has been guided by the metaphor of the magic bullet – the idea that you can target drugs to specific cells. The drawback to this approach is that it uses a single molecule. If, instead, you could put a thousand to a hundred thousand molecules in a nanoparticle and deliver that nanoparticle to a target, you would (to use a hockey metaphor) be able to take a lot more shots on goal, potentially more of which would make it into the net.

What challenges need to be overcome in order to make a nanoparticle that targets a particular cell, say a tumor cell? First you need to trick the body's own defenses. If you simply injected a regular nanoparticle into the bloodstream, cells called macrophages would come along and eat it. So that's no good. But we discovered a way to fool the macrophages. By using materials that the U.S. Food and Drug Administration (FDA) has already approved and by adding in some polyethylene glycol (PEG) – which is useful because it gets surrounded by a lot of water on their surface – we created nanoparticles that look like water. When the nanoparticles are cloaked in this way, the macrophages don't recognize them as foreign and thus don't quickly eat them.

We tested this idea by injecting rats either with nanoparticles that were not coated in PEG or with nanoparticles coated in one of several weight chains of PEG. Then we watched to see which nanoparticles the macrophages ate. (Nanoparticles attacked by the macrophages appear as an orange

Having made nanoparticles that could pass through the bloodstream undisturbed by the body's own defenses, the next challenge was to get them to target specific cells.

dye.) The nanoparticles without PEG were devoured by the macrophages. The nanoparticles with PEG fared much better, mostly escaping detection or, in the case of particles with 5,000 molecular weight, triple-chain PEG, completely escaping detection. Thus, we showed that by making nanoparticles with PEG on them, we could greatly frustrate the macrophages' ability to detect and eat them. (See Figure 1.)

Having made nanoparticles that could pass through the bloodstream undisturbed by the body's own defenses, the next challenge was to get them to target specific cells. Several types of targeting molecules are known; for example, antibodies and aptamers, which are pieces of RNA. Omid Farokhzad, now a professor at Harvard Medical School, had the idea when he worked with me to put targeting molecules on the PEG particles. Implementing this idea involved its

[1] "Profile: Being Bob Langer," *Nature* 458 (7234) (March 5, 2009): 22 – 24.

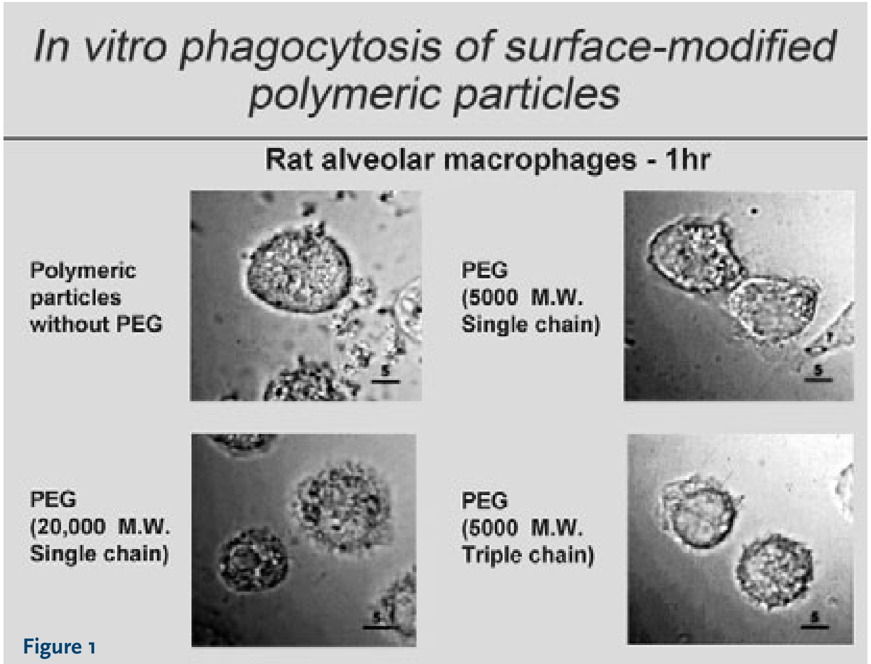


Figure 1

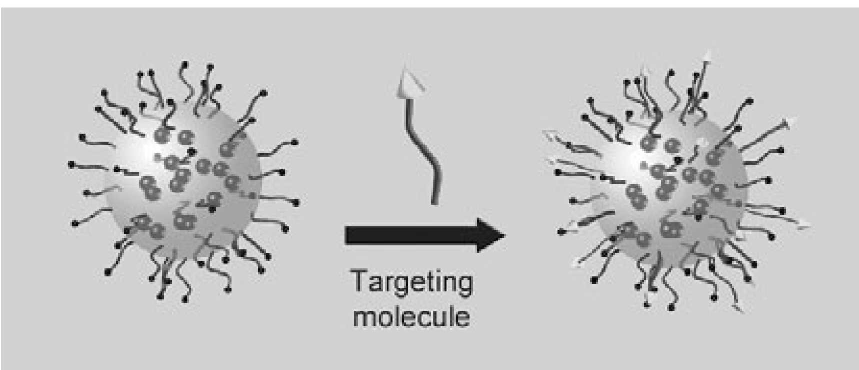


Figure 2

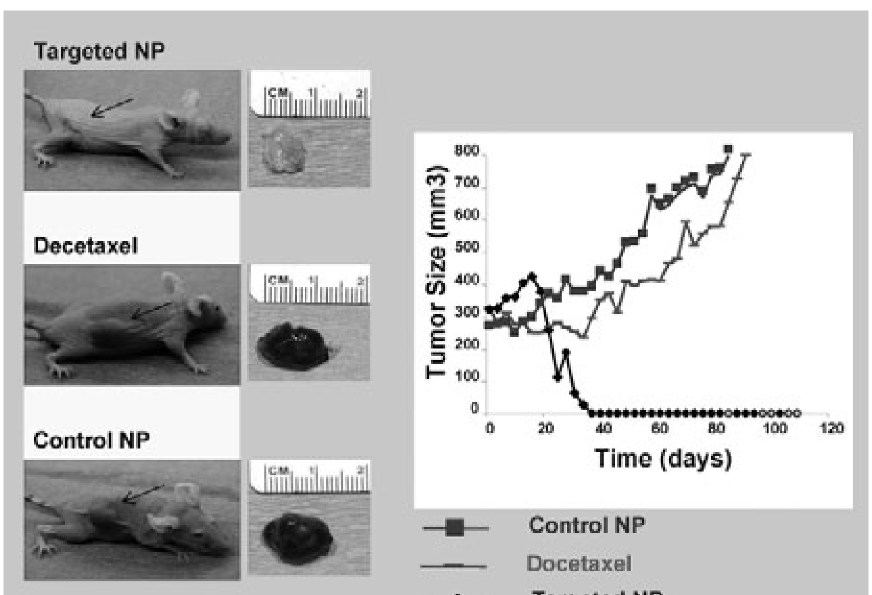


Figure 3

own set of challenges: too much PEG and you don't get targeting; too much targeting molecule and you lose PEG's protective effect against the macrophages. Get the concentration just right, however, and you can both target the cell you want, say a cancer cell, and avoid the macrophages. (See Figure 2.)

In an early animal experiment, Omid used a targeting molecule aimed against prostate cancer cells. We created a targeted nanoparticle to deliver the cancer drug Taxotere (Docetaxel) and tested it against a control nanoparticle (nontargeted) and against Taxotere by itself. With the control nanoparticle, the tumors grew. With Taxotere by itself, the tumors grew. But with targeted nanoparticles delivering Taxotere, the tumors shrunk. The tumors in the control and Taxotere groups got big and were highly vascularized. (See Figure 3.) This was an early experiment, but we are hopeful that with further work we can apply the principle to human beings. Our goal is to start clinical trials within the next year or two.

We proposed the idea of using the magnetic nanoparticles, in conjunction with MRI, to monitor how someone is doing.

Another use for nanoparticles was developed in collaboration with Ralph Weissleder at Massachusetts General Hospital and Michael Cima at MIT. Ralph developed nanoparticles with a metal core for use as an imaging agent. We could also add a binding moiety specific for, say, glucose or a certain type of cancer molecule, like human chorionic gonadotropin (HCG), or whatever else we want. If we use a binding moiety and an analyte to which the moiety binds specifically (like the moiety, the analyte can be whatever we want), the nanoparticles will aggregate rather than remain separate, thus changing the MRI signal.

Michael Cima and I had previously created a series of microchips that can be used for drug delivery. We then proposed the idea of using the magnetic nanoparticles, in conjunction with MRI, to monitor how some-

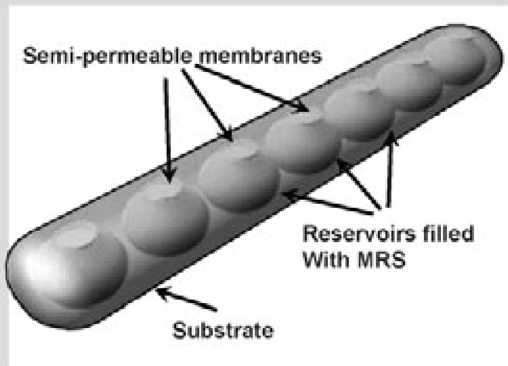


Figure 4

one is doing. The microchips are about the size of a grain of rice, small enough that we can inject them. To modify them for use with MRI, we add different sets of MRI beads to the various wells on the chip. (See Figure 4.) Each well can then be used to determine what the MRI signals are. For example, one could be for glucose, one for the cancer marker HCG, and one for something else. By creating something specific for the different signals in the body, we can monitor how someone is progressing. For example, a chip could be used to monitor for the presence of HCG. If no tumor is present, we get one signal on the MRI; if a tumor is present, we get a different signal. These signals can be followed and quantitated over time. Researchers are even working on wearable MRIs that would allow for continuous monitoring. We hope that before long we will have a system that can detect all kinds of signals in the body, tell you how you are doing, and maybe even deliver the drugs you need to get better.

Another use of nanoparticles is in medical devices.

A third use of nanoparticles is in medical devices. In many situations doctors can use sutures, sealants, and other materials to close wounds. In some situations, however, such as in a gastric bypass surgery, closing wounds can be difficult with the usual materials. So, Jeff Karp – formerly a postdoc in my lab; now a professor at Harvard Medical School – and I began to wonder whether we could find better ways of adhesion by looking at things in nature that build on nanotechnology. Our investigation eventually led us to the gecko, which has tiny nanoprotrusions on its feet. The nanoprotrusions create so much surface area that the gecko can adhere to surfaces. Jeff and I worked out a way to nanopattern structures and make a gecko-like system. We also designed a special polymer called polyglycerol sebacic acid that is rubbery and sticky to begin with but when combined with the nanopattern system and used in wounds has a strength much higher than normal.

A fourth use of nanoparticles involves a field called tissue engineering. With tissue engineering, by putting one type of cell in the right polymer – growing it the right way – we can make different types of tissue. An exciting example of this type of work is the research Yale professor Erin Lavik began when she was a graduate student at MIT. Working with Evan Snyder and Ted Tang, two neuronal stem cell experts, Erin nanopatterned the outer surface of a polymer. In the inner part she then put stem cells. The result was an artificial tissue, a patterned polymer scaffold with neuronal stem cells. The outer part of the tissue has fine, intricate structures that we hoped would help with axonal guidance. To test the tissue, we made rats paraplegic by removing a part of their spinal cord. We then put in a section of the artificial tissue. After a hundred days the control rats showed little sign of improvement. They dragged their limbs, and their paws splayed awkwardly. Rats treated with the artificial tissue faired significantly better. For example, the mean of the treated group was able to bear its own weight, and its paws splayed in a more normal manner. The rats weren't "cured" – their movements were still quite clumsy – but the progress made by the ones in the treatment group was encouraging enough that we have moved on to primate trials. We still have a long way to go before we'll see human applications of this technology, but we are hopeful that it and other applications of nanotechnology will someday prove useful in the medical area.

Photo: Donna Coveney, MIT

Angela Belcher

Angela Belcher is Germehausen Professor of Materials Science and Engineering and Biological Engineering at the Massachusetts Institute of Technology.

Presentation

Bob did a wonderful job talking about manipulating the physical properties of materials – for example, polymers and magnetic materials – in order to probe important biological problems such as cancer and paralysis. I'm going to come at the topic from a different angle and talk about how biology can make use of materials to address problems more commonly associated with electronics, energy, and the environment. My research with biomolecular materials involves harnessing the lessons of biology and millions of years of evolution in order to develop new biotechnologies, using both existing and newly developed materials, chemistries, and technologies. The whole world is my toolbox: biology, chemistry, materials science. As an engineer, I want to make something work; so I'll use chemistry, I'll use biology, I'll use engineering to get the particular kind of device properties I'd like to have.

Can the strategies that life has evolved over millions of years be applied to nonbiological systems?

I am interested in whether we can give genetic information to a solar cell or to a battery so that it can grow itself, assemble in an environmentally friendly way without using toxic materials, and become better, more efficient, over time.

Much of the molecular machinery that biology uses is nanoscale in size: ribosomes, proteins, DNA, chloroplasts. All of these biological molecules are more or less on the same scale as current electronics. So when thinking about how I might go about making new electronics and nanoscale devices, I wonder what I can learn from biology, what new ways of making interesting electronic materials I can tease from millions of years of evolution. Through evolution, biology has "learned" to compartmentalize, to put things exactly where they need to go to have optimal performance. Life is also self-assembling. Wouldn't it be great if your cell phone could self-assemble? If it had a "genetic code" that would allow it to repair itself whenever you broke it? In short, can the strategies that life has evolved over millions of years be applied to nonbiological systems?

The abalone shell is an amazing example of how life evolved to work with nanomaterials. The shell is 98 percent by mass calcium carbonate and 2 percent protein; it's basically chalk. But it's 3,000 times tougher than chalk, which you can easily break with your hands. You can't break an abalone shell with your bare hands. How the abalone evolved to create such a hard material is interesting, but even more interesting is that when a male and a female abalone get together they make millions of offspring to whom they pass the genetic code that explains how to make this exquisite nanomaterial. The same is true of diatoms. Whenever they reproduce, they pass along the genetic code that allows every diatom to make its own beautiful glass structure. What's more, the abalone and the diatom make their shells at room temperature using nontoxic materials! I am interested in whether we can give genetic information to a solar cell or to a battery so that it can grow itself, assemble in an environmentally friendly way without using toxic materials, and become better, more efficient, over time.

My favorite biomaterial is my son. Anyone who has had a three-year-old knows that they are highly complex organisms, fiendishly difficult to train. So when we think about how to train an organism to start working with a completely new toolbox, we think about much simpler organisms such as benign viruses and bacteria. Can we retrain a virus, a bacterium, or yeast to make a battery instead of a protein coat? Can we train it to make a solar cell or a fuel cell? Can we train it to capture and store carbon dioxide?

The answer is yes. In my lab, we have done all of these things. The real challenge, however, is to create nanomaterials that self-assemble; that self-correct (like human beings, who are, for the most part, self-correcting systems); that are self-healing; that can grow and recycle their own templates; that can grow to an exact size and stop (in nanomaterials and much modern electronics, exact size is really, really important). Basically, what I and other scientists and engineers involved in this type of research would like to be able to do is to genetically control the properties of any kind of device that we might want to grow. That is why I am so interested in what can be learned from millions of years of evolution. Can I take simple eukaryotic or prokaryotic cells and have them work with a different tool kit?

Life existed on Earth for billions of years before we had hard materials, before abalone evolved. Organisms with hard structures such as shells and bones and nanoparticles of magnetite and iron oxide are not found in the fossil record until about 500 million years ago. Yet long before this, life was doing replication and photosynthesis. Why was making hard materials so difficult in the Precambrian era? The answer is lack of opportunity. During the Cambrian geological time period life had access to increased iron, increased calcium, and increased silicon in the ocean. Organisms had a new toolbox with which to start building. Life seized the opportunity and started making hard materials.

Life did a great job; it produced the coccolithophorid, a unicellular algae made out of calcium carbonate; it took calcium carbonate and produced the abalone shell; it eventually made people and all kinds of other organisms. But what if it had had more opportunities? Could it have made different kinds of structures and different kinds of materials? And what can we human beings do with the biological tool kit to which we have access? Can we use DNA to make devices and materials?

By looking at the abalone shell with a scanning electron micrograph, we can see that it's actually made up of little tiles, little tablets stacked on top of one another and laterally offset. This stacking, this nanoscale brick wall-like structure is what makes the abalone shell so tough and strong. The amazing thing about the abalone shell's nanostructure is that it's all controlled by DNA. Life figured out how to control the production of these materials – everything from the abalone's calcium carbonate shell to the diatom's glass "skin" to the nanoscale magnetite magnets made by some ocean bacteria to spider silk – all controlled at the genetic level and made in nontoxic ways. DNA provides the blueprint for building proteins with different chemical functionalities that when linked together in the right sequence can grab atoms out of the ocean and build calcium carbonate or silica or iron oxide. Looking again at the abalone shell,

The real challenge, however, is to create nanomaterials that self-assemble; that self-correct; that are self-healing; that can grow and recycle their own templates; and that can grow to an exact size and stop.

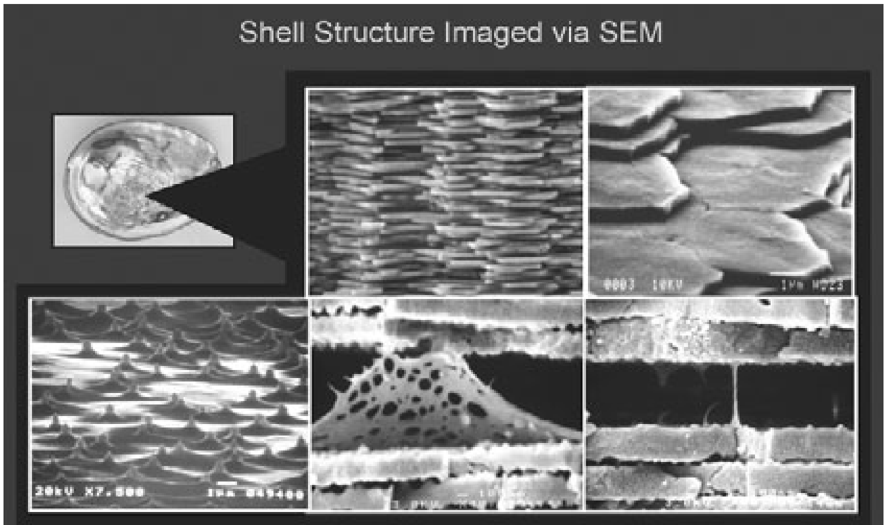


Figure 1

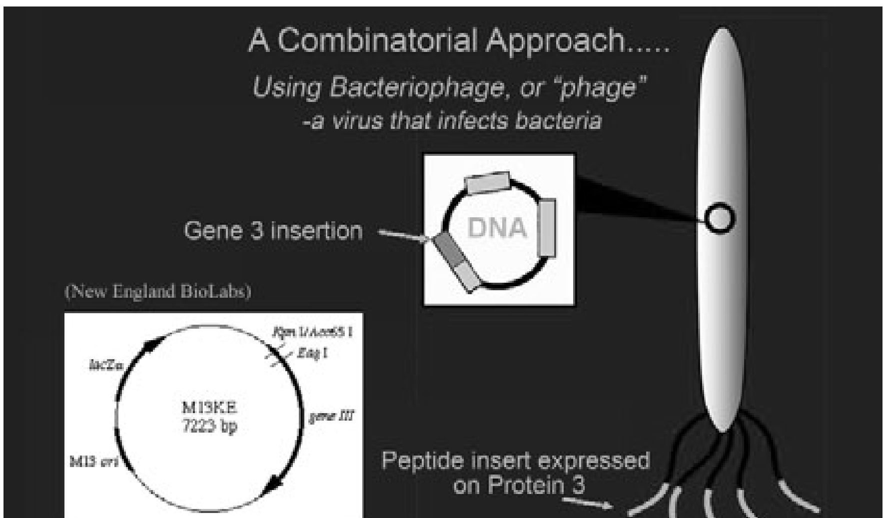
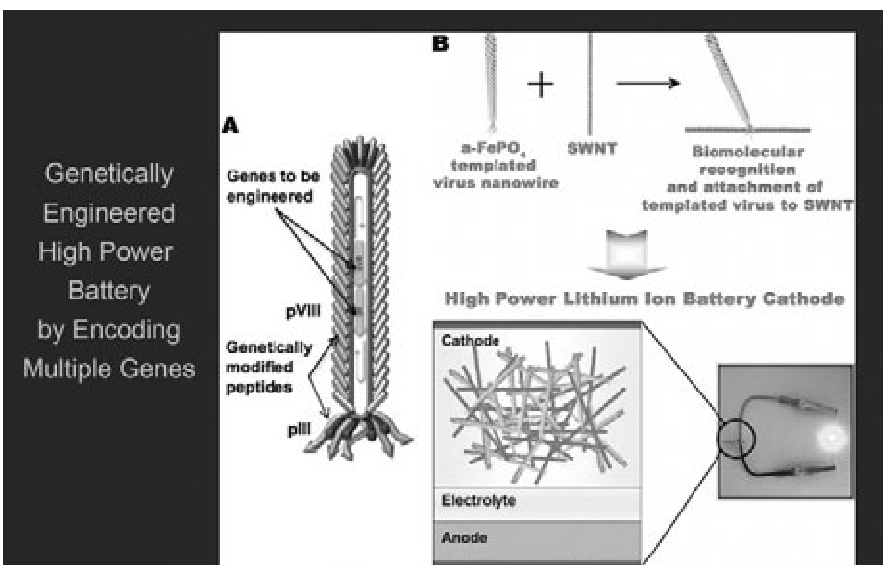


Figure 2



Y.J. Lee, A.M. Belcher et al., *Science* 324 (5930) (2009): 1051–1055.

Figure 3

we see that between the tablets are protein pieces that help give the shell its nanostructured regularity. (See Figure 1.)

In thinking about growing electronic materials, I look to nature for inspiration, starting with those proteins that, because of their different chemical functionalities, can grab ions out of solution. In the case of the abalone, the proteins grab calcium, then carbonate, then calcium, then carbonate, and in that way begin to build the brick structure that we eventually see as the abalone shell. Nature mostly uses calcium, barium, iron, silicon, and phosphorous. But what if biology used materials from different parts of the periodic table, say those elements used in semiconductors and solar cells, lasers and electronics, batteries and catalysis? With different building materials, what new kinds of structures would emerge?

Much of my work involves thinking about the living/nonliving interface. How can I take something produced through evolution, such as an antibody binding to an antigen, and put it together with something human made, such as a microprocessor? Such combinations are called evolved hybrid materials. By giving genetic information to nonliving structures, we make them better than they are without that genetic component. To do this, we use simple viruses called bacteriophages (literally, "bacteria eaters"), viruses that infect a bacterial host. They are beautiful structures about one micrometer by six nanometers in size, and they have single-stranded DNA that is easy to manipulate. (So easy, in fact, that this work is not confined to highly trained postdocs and graduate students. In my lab, every time we invent something new – we've had several new biological batteries this year, biological solar cells, biological displays, and so on – we transition it to the undergraduate teaching lab within a year. The chemistry and materials processing are easy for our sophomores and juniors to pick up. We even have high school students working on this in the lab.) Using traditional molecular biology techniques, we make small changes in the bacteriophage DNA, perhaps adding extra DNA that will then add an extra protein to the tip of the virus. If we do this a billion times, we add a billion possibilities to the virus, and by adding a billion possibilities we are able to perform a billion experiments simultaneously. This is useful when you consider that nature needed about 50 million years before it got good at making hard materials. Fifty million years just won't cut it in today's academic environment where I'm expected to show significant progress every few months. (See Figure 2.)

The reason we need to try so many possibilities is because we just don't know what the sequence for growing a battery or a solar cell looks like. But through a combinatorial, trial-and-error approach, we can in about three weeks train a virus to grow about fifty different kinds of materials in my lab. We can have them figure out the protein sequence that allows you to grow the inorganic sequence that can self-assemble into a battery.

One of the most exciting branches of my work on growing batteries has involved carbon nanotubes. Working with Professors Gerd Ceder and Michael Strano at MIT, we engineered a virus to first grow a benign material, amorphous iron phosphate, at room temperature, on the coat of the virus; second, to pick up a carbon nanotube; and third, to self-assemble into a battery electrode. The resulting battery weighs about 1.5 milligrams and can power a green LED. What's exciting about this is that, except for the carbon nanotubes, everything is made at room temperature and no toxic materials are used in or created by the process. To get to this point took about a year. Even more amazing, though, is that from this point we needed only about six months to train our organisms through selection and genetic engineering to make a high-powered lithium ion battery that is as good as state-of-the-art, traditionally produced batteries. (See Figure 3.)

By using biology to control nanostructure, we are opening up new vistas of opportunity for creating devices and structures that will improve the quality of life in areas as far apart as battery technology, cancer detection and treatment, and environmental remediation.

Evelyn L. Hu

Evelyn L. Hu is Gordon McKay Professor of Applied Physics and Electrical Engineering at Harvard University.

Presentation

The idea of combining novel materials by using nanoscale building blocks is relatively easy to grasp, and one can easily imagine the uses of nanotechnology in medicine or in creating energy-efficient devices. But what applications does nanotechnology have in photonics? What, for that matter, is photonics?

At the nanometer scale, the region between molecules and atoms, we have new opportunities. We can design optical materials that have any kind of performance we want – designer materials not found in nature.

The root of the word *photonics* is *photon*. A photon is a unit of light. So, photonics has to do with light, which comes in different colors and energies. By "colors" I mean more than just the colors in the visible range, which is the vast array of colors that gives us a sense of our external world and helps us to identify and label what's around us that we find aesthetically gratifying. The definition I'm using, however, encompasses the full electromagnetic spectrum, something that's been known since the nineteenth century. Only a small part of this spectrum is visible. Beyond the visible range are radio waves, microwaves, infrared, ultraviolet, X-rays, gamma rays – portions of the spectrum that most people tend to think of as being involved in communications, the transmission of energy, or in sensing parts of the world around us that are not usually accessible to the naked eye.

What is special about the nanoscale? How is nanotechnology applied to photonics? The electromagnetic spectrum is something we've lived with for a long time. How can we hope to change what is a given of nature?

At the nanometer scale, between 10^{-8} and 10^{-10} meters, the region between molecules and atoms, we have new opportunities. We have the ability to make efficient, compact, new light sources that have nanometer scales and functions in environments that are also measured in nanometers. We can design optical materials that have any kind of performance we want – designer materials not found in nature; for example, energy-efficient materials that can take in the full energy of the solar spectrum, store that energy, and then efficiently convert it into electrical signals; or an optical material that is transparent at a certain frequency (i.e., it will let certain frequencies of light go through, blocking all others).

By the very fact that we can see light, we know that photons are active. They travel back and forth. They come into our eyes. They're full of energy. They have unique frequencies, which are related to their energy. Atoms also have energy, and part of their energy is given out in a signal that we can view as light or X-rays, gamma rays or UV signals. If we could design switches that would uniquely tune a particular atom or particular quantum dot – a particular beacon – to the exact frequency we wanted, if we could even change the frequency of the atom's or quantum dot's vibration, we could make uniquely tuned photonic switches and antennas. Such switches and antennas would take the information – the energy that is unique to that beacon – out of the ether and focus it onto that beacon. With the ability to make these uniquely tuned switches and antennas, we would also have the unparalleled capability to make ultra-efficient sources of light: ultra-low-threshold lasers, light-emitting diodes, and other photonic sources.

These individual building blocks could then be combined to make photonic systems – photonic integrated circuits analogous to the electronic integrated circuits that power a PowerPoint presentation on a laptop computer and through an LCD projector. The photonic systems would provide information rapidly and with high output; yet they would be much more energy efficient because, unlike today's electronic integrated circuits, they would dissipate far less energy in delivering information.

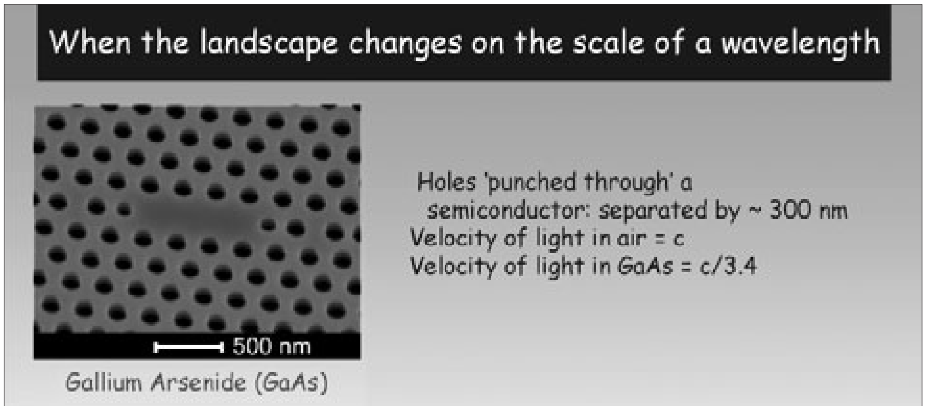


Figure 1

That intrinsically different properties emerge as size changes on the nanoscale is part of the mystery or the wonder of nanotechnology; it's also an incredible capability, an amazing way to go beyond what Mother Nature has given us and design our own optical materials.

Most of the nature-given materials we have to work with come in a certain color, be it red, blue, and so on, and display certain properties such as fluorescence or absorbency. We've found, however, that we can define optical emission if we take, say, a single-crystal cadmium-selenium semiconductor with a regular, checkerboard-like array of atoms and carve little beacons (quantum dots) out of that semiconductor. The color, the absorption of the beacon, changes according to size. Certainly the material matters, but just as important is whether we make the beacons five nanometers in diameter, six nanometers in diameter, or eight nanometers in diameter (and so on). That intrinsically different properties emerge as size changes on the nanoscale is part of the mystery or the wonder of nanotechnology; it's also an incredible capability, an amazing way to go beyond what Mother Nature has given us and design our own optical materials.

A given photon will have a certain wavelength, perhaps 100 nanometers or 10 nanometers or 300 nanometers. What happens when we change the landscape through which one of these photons passes? Specifically, what happens when we change the landscape in a periodic way so that it is no longer smooth and homogenous but is patterned at intervals roughly the same as the photon's wavelength? I experimented with this idea by punching 100-nanometer holes in semiconductors made of gallium arsenide (a material that can also be used to create infrared light sources). The holes were set 300 nanometers apart. I then sent a photon with a 300-nanometer wavelength through the material. The result was incredible: the photon was confined within the landscape I had engineered. (See Figure 1.)

To understand why, we need to recall that light does not always keep the same velocity. The velocity of light in a vacuum is constant and is famously represented by *c*. But when light enters a material like glass or a semiconductor, it doesn't always keep that same velocity. The velocity of light in gallium arsenide is slower than that in air or in a vacuum – slower by a factor of 3.4. (The factor by which light is slowed in a given medium is often called the index of refraction.) Imagine a photon traveling through the gallium-arsenide structure I created. As the photon passes through this landscape, it "sees" a periodic variation where it goes faster, slower, faster, slower. The modulation is on the order of the photon's own wavelength. By going faster, slower, faster, slower through a periodic medium, the photon "learns" that it is going through something, going faster and slower. One of the things that happens is that the photon may encounter – by going faster, slower, faster, slower – a region where this faster, slower, faster, slower ultimately, because of all the variation in the landscape, confines the photon to a unique location in space. Once the photon has been confined in a very, very small volume, a powerful electromagnetic field is generated. The electromagnetic field has a unique identification, a unique frequency that pertains to the engineered structure in which the photon has been confined. Because these kinds of structures are capable of confining photons for very long times without loss, we have, in effect, created a way of storing photons.

Now suppose we were to take this powerful electromagnetic field that is confined to a tiny volume of space and we were to put in the same location a quantum dot, a beacon capable of giving out light. Suppose we then turned on a powerful switch designed to resonate with that particular quantum dot. The result would be an exquisitely sensitive filter with applications ranging from selective transmission of information, controlled generation of single photons, to ultra-low-threshold lasers.

Currently, the filters found in most people's radios allow for tuning to one or a few decimal places. For example, we might tune to a station broadcasting at a frequency of 102.3 MHz. But imagine being able to tune

The most exciting opportunities will come as we combine nanostructure building blocks. For example, by combining the full spectrum of colored quantum dots, we might create a new material that captures the full spectrum of the sun with high efficiency.

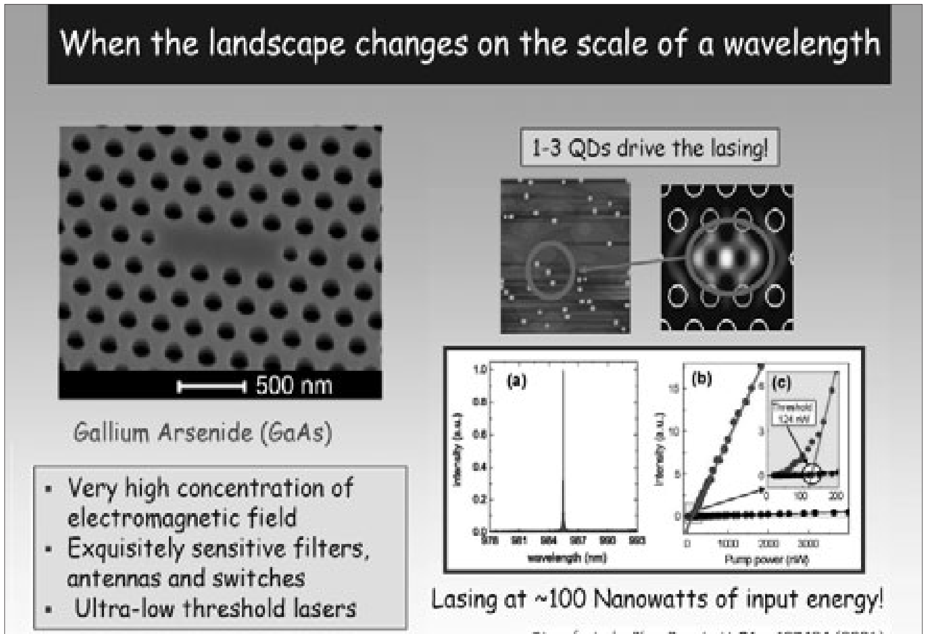


Figure 2

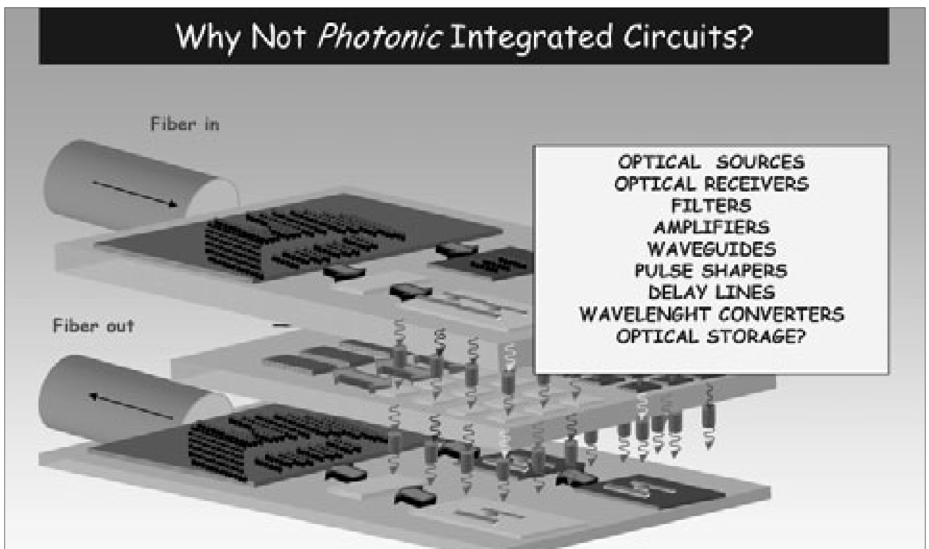


Figure 3

to 102.3444444556 MHz and getting a unique signal. Then tuning to 102.34445629 MHz and getting another unique signal. That's the level of sensitivity we can achieve with our nanoscale filters, antennae, and switches.

This level of sensitivity also allows for the creation of ultra-low-threshold lasers. Because we uniquely match the energy that we give to an optical component with the characteristics of that component, no energy is lost. Lasers that are made in this way have a threshold of about 100 nanowatts, a billionth of a watt: the lasers we use for laser pointers generally require *milliwatts* or more of input energy to turn them on. (See Figure 2.)

The most exciting opportunities will come as we combine nanostructure building blocks. For example, by combining the full spectrum of colored quantum dots, we might create a new material that captures the full spectrum of the sun with high efficiency. This new material could then be used to design ultra-efficient solar cells or designer coatings that reflect, absorb, or generate energy at a desired wavelength. Looking far into the future, we can see computers that process information with photons rather than electrons. Modern computer microprocessors such as Intel's Pentium 4 might make information processing fast and inexpensive and may be marvels of compact design, but as they switch, store, and guide electrons they dissipate tremendous amounts of energy. Photonic microprocessors would operate with almost no energy loss. My colleague Dan Blumenthal suggests that we already possess the necessary building blocks to do with photons what we can now do with electrons. (See Figure 3.)

Despite all we have learned about engineering nanostructures from the inorganic side, we still have far to go before we begin to emulate the engineering prowess of Mother Nature, which has had plenty of time to orchestrate her own nanophotonics. Consider the *Polyommatus* butterfly. The colors of its wings are given by a photonic crystal nanostructure that modulates light on the scale of a wavelength. What is remarkable about this butterfly is the fact that two species – *Polyommatus daphnis* and *Polyommatus marcidus* – have adapted to have different colors (predominantly blue and predominantly brown), which tells us that these nanostructures can somehow be naturally generated. How we might begin to emulate nature's own engineering prowess is a story for another day, however.

Question: The prospects and the possibilities of nanotechnology are fantastic, but we also all know that new technologies always have a reverse side. I'm curious about your views on this and what measures you would take or would like to see taken to prevent the misuse of nanotechnology – either unintentionally in the case of materials that turn out to have toxic effects or intentionally in the case of materials designed to be misused.

Robert Langer: On safety: anything can be toxic, but I don't know that just because something is nano it is necessarily worse. The FDA has already approved nanoparticles that have been used for years on patients, including children, without any problems. So, being small doesn't necessarily equate to being toxic, which is sometimes the impression one gets when reading about nanoparticles in newspapers. I find it curious that although things exist that are smaller than nanoparticles (e.g., smaller molecules) and things exist that are bigger than nanoparticles (e.g., microparticles), neither gets the same kind of bad publicity.

Being small doesn't necessarily equate to being toxic, which is sometimes the impression one gets when reading about nanoparticles in newspapers.

On misuse: I always like to hope and be an optimist that people will use things in a good way and that society will develop rules and laws so that new technologies are not misused. But I have no special expertise in that area. Other people may have better ideas.

By using biology to control nanostructure, we are opening up new vistas of opportunity for creating devices and structures that will improve the quality of life in areas as far apart as battery technology, cancer detection and treatment, and environmental remediation.

Angela Belcher: I agree with everything Bob said. I find it notable that the agencies funding nanotechnology research are also funding centers to study its environmental impact. Traditionally, organizations and individual scientists have not done that. They've just gone ahead and started making materials, doing the science and then twenty years on looking back to see whether anything bad happened. The fact that today's research is being conducted with an awareness of its environmental impact is a positive change. Even more significant is the fact that because research with nanomaterials occurs at a much smaller scale than does traditional materials research, it generates a lot less waste. Thus, even if someone is working with toxic materials – and some of the materials used in biological imaging and in solar cells are quite toxic – a smaller overall amount of those materials is being used, which should have a definite positive impact on the environment.

Question: What was the discovery that permitted nanoparticles? Was it material or theoretical? And, despite the extraordinary and awesome progress in nanoresearch, what is blocking the next advances? Is it material, or is it theoretical?

Evelyn Hu: Long before the launch of the National Nanotechnology Initiative, work was being done on colloidal chemistry, on metallic nanoparticles, on aerosol particles. What brought together the various research of materials scientists, chemists, applied physicists, and so on was the realization that they all shared an intrinsic interest in the properties of materials and how they scale. Many people say that all of a sudden they discovered they had been doing nanotechnology for most of their career, and so they just renamed themselves. I don't think it was quite as superficial as that. I think that people in different fields were made aware of the commonalities – the challenges, the instrumentation, the possibilities of putting materials together. Eventually colloidal quantum dots, semiconductors, and metal nanoparticles came into the hands of people who were interested in biofunctionalizing those materials, who realized they had their hands on materials that could be slipped through a cell membrane and used to do diagnostics or therapy. That's when nanotechnology came into its own and became much more than the various separate types of materials research being conducted in any number of discrete scientific fields.

Despite all we have learned about engineering nanostructures from the inorganic side, we still have far to go before we begin to emulate the engineering prowess of Mother Nature, which has had plenty of time to orchestrate her own nanophotonics.

Looking far into the future, we can see computers that process information with photons rather than electrons.

I think the next major challenges to be overcome in nanoresearch will involve creating the big systems and realizing the potential of nanostructures. Angie and Bob talked about systems. Angie talked about putting everything – all these smart, intelligent components – into a beaker and coming out with a battery or some other full system. The big future challenges will be getting the various components to articulate with one another, working out the secondary interactions, and making something that is robust and durable. In short, it's a challenge of complexity.

Question: Will you eventually develop a variety of nanoparticles that receive different signals? You might want a diagnostic system, for example, capable of bringing together a number of signals through a whole set of nanoparticles. How do you combine those nanoparticles so that they interact with one another? Can the effects of many nanoparticles be combined in an orderly sequence? Similar to antibodies, could you line them up, say, on DNA?

Angela Belcher: Much research has focused on how to put different nanostructures together, how to combine different optical, magnetic, and electrical properties in order to create something that is better than the individual components. A lot of beautiful work has been done decorating DNA at different base pairs by bringing in a semiconductor or a magnetic material, by mineralizing wires, or by using DNA specificity. Such research has been an active part of bionanotechnology for at least fifteen years. In my lab we create diagnostic nanodevices that, for example, use an antibody or a designer protein to grab a magnetic or fluorescent material and put it on a cell that we're interested in while at the same time delivering a therapeutic agent to that cell. Nanostructures can be combined in a lot of different ways. For example, we can grow them together or coat one on top of the other. One of the problems that can arise, however, when we try to put two very different materials together is that chemically or physically or geometrically they don't match. Sometimes working with biological materials makes this less of a problem. For example, we might be working with a protein that will bind a semiconductor and a magnetic material in close proximity, but we don't need to worry about them matching because the protein provides a nice, soft biological template. ■

In Memoriam

Remembering Daniel Charles Tosteson, M.D.

by Mitchell T. Rabkin, M.D.

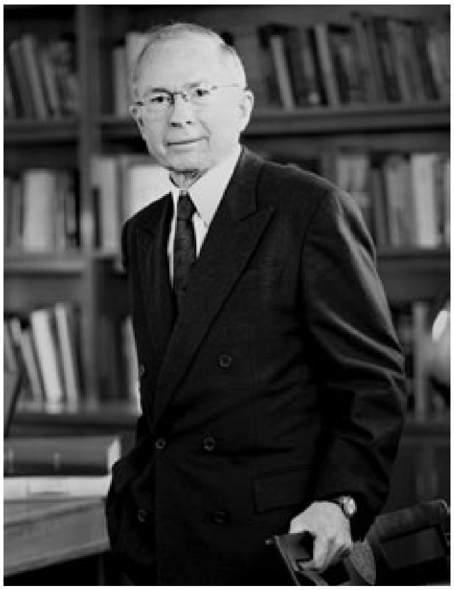


Photo by John Earle

Daniel Charles Tosteson, M.D.

February 5, 1925 – May 27, 2009

Daniel C. Tosteson, M.D., Dean of Harvard Medical School from 1977 to 1997 and Caroline Shields Walker Distinguished Professor of Cell Biology, manifested a breadth of interest, depth of ability, and impressive achievement within his profession and beyond. Elected a Fellow of the American Academy in 1979, he served as President from 1997 to 2000 and oversaw a strategic planning initiative that has reaffirmed the mission and long-term goals of the Academy and serves as a blueprint for the Academy's research initiatives.

His 1985 restructuring of medical education at Harvard Medical School, labeled the "New Pathway," introduced a shift from students' reliance on texts and lectures taken whole to an approach that began with descriptions of patients and their illnesses and led to students' active pursuit of the questions to ask and the answers to seek – ways of developing critical thinking about disease and its underlying mechanisms. His embellishment of this problem-based learning technique, earlier forecast elsewhere, has spread across the globe.

Dr. Tosteson's most recent innovation in teaching, only several years old, is the "Mentored Clinical Casebook" project, whereby students throughout their first year follow a patient, gaining an understanding of the pathology involved, but more importantly, with the help of mentors developing insight into the impact of that pathology on the patient's physiological, emotional, social, and economic situations. The student learns the distinction between *disease* – disembodied as described in a textbook – and *illness* – that complex of the many and various interacting phenomena that impact on the individual patient.

His visionary understanding of the direction of medicine and its science led to advances scholarly, therapeutic, and practical. Dean Tosteson's establishment of the Departments of Genetics, Cell Biology, and Biological Chemistry and Molecular Pharmacology reflected prescient insight into the directions of biomedical scholarship with its unfolding discoveries in molecular biology and molecular genetics. The Biological and Biomedical Sciences program emerged out of his appreciation that the future of research lay not only in interdisciplinary understanding and collaboration among a wider range of basic scientists, but also through greater interaction between clinicians and basic scientists, connecting the bedside with the laboratory bench.

He established the Department of Health Care Policy and the Department of Social Medicine (now Global Health and Social Medicine), grew the Medical School's endowment nearly tenfold, added several new buildings and fashioned increased space within the existing buildings, expanded continuing education for practicing physicians, and created a publishing venture that offers reliable articles on health to the lay public. Appropriately, the new building designed specifically for teaching has been named the Tosteson Medical Education Center.

Concerned that growing business pressures on Harvard-affiliated hospitals were threatening their capacities for student teaching and resident training, in 1996 Dr. Tosteson formed the Institute for Education and Research, a joint program of the Medical School with Beth Israel Hospital and Mount Auburn Hospital, that over succeeding years has made significant advances in the nature and quality of teaching and learning at the Medical School and its affiliated hospitals, and strengthened appreciation on the part of hospital trustees and administrators that quality education within the teaching hospital is a legitimate and necessary cost of doing business.

A native of Milwaukee, Dr. Tosteson was educated at Harvard College and Harvard Medical School. Following a residency at Presbyterian Hospital in New York City and fellowships at Brookhaven National Laboratory, the National Institutes of Health, and Cambridge University, he joined the faculty at Washington University School of Medicine in St. Louis and subsequently became the James B. Duke Distinguished Professor and Chair of the Department of Physiology and Pharmacology at Duke University School of Medicine. He later became Dean of the Pritzker School of Medicine at the University of Chicago and Lowell T. Coggeshall Professor of Medicine before he returned to Harvard Medical School in 1977.

During his years as Dean at Harvard, Dr. Tosteson continued his research scholarship, heading a laboratory studying membrane phenomena and authoring scientific publications as late as 2003, many reporting on work done with colleagues, including his wife, Magdalena Tieffenberg Tosteson, Ph.D., an independent investigator in Harvard's Department of Cell Biology.

Dr. Tosteson savored his retreat in East Boothbay, where a modest sailboat was one key to relaxation and refreshment. Another was poetry, symbolized by the portrait of Robert Frost in his office. His son Joshua commented, "He was an avid sailor, and that's where it all connected for him. All the dimensions of life – the science, the poetry, the nature – it was all encapsulated when he was at the helm of a ship. That is when my dad the full man came out. My enduring image of my father forever will be of him singing *a capella* sea shanties as we sailed along the coast of Maine." His death at 84 years of age followed a lengthy illness against which he refused to buckle. He leaves his wife, Magdalena, daughters Heather, Ingrid, Zoe, and Carrie Marais, sons Joshua and Tor, and a brother, Thomas.

Dan Tosteson's luster as physician, research scholar, teacher, dean, humanist, intellectual, and solidly good human being will remain bright for many decades to come.

Mitchell T. Rabkin, M.D., is Professor of Medicine at Harvard Medical School, CEO Emeritus of Beth Israel Hospital and CareGroup, and a Fellow of the American Academy of Arts and Sciences. ■

Noteworthy

As of press time, several Fellows of the Academy, listed below, have been invited to serve in senior roles in President Barack Obama's administration. They are in addition to the Fellows listed in the Winter 2009 and Spring 2009 issues of the *Bulletin*.

Rolena Adorno (Yale University): Member of the National Council on the Humanities

Marcia McNutt (Monterey Bay Aquarium Research Institute): Director of the United States Geological Survey and Science Advisor to the Secretary of the Interior

Fellows serving on the President's Commission on White House Fellowships:

Tom Brokaw (NBC News)

Vartan Gregorian (Carnegie Corporation of New York)

Maya Lin (Maya Lin Studio)

Pierre Omidyar (Omidyar Network)

Paul Sarbanes (U.S. Senate)

Ruth J. Simmons (Brown University)

Laurence Tribe (Harvard Law School)

Select Prizes and Awards

Presidential Medal of Freedom, 2009

Stephen Hawking (University of Cambridge)

Edward M. Kennedy (United States Senate)

Sandra Day O'Connor (United States Supreme Court)

Sidney Poitier (Los Angeles, CA)

Janet Davison Rowley (University of Chicago)

Other Awards

Pierre Boulez (Institute for Research and Coordination Acoustic/Music, IRCAM) was awarded the 2009 Kyoto Prize in Arts and Philosophy.

Louise Bourgeois (New York, NY) is among the 2009 Inductees to the National Women's Hall of Fame.

Sharon Cameron (Johns Hopkins University) is the recipient of the 2009 Harold D. Vursell Memorial Award in Literature, given by the American Academy of Arts and Letters.

John Cogan, Jr. (Pioneer Investment Management USA, Inc.) is among the recipients of the 2009 Harvard Medal.

Mildred Cohn (University of Pennsylvania School of Medicine) is among the 2009 Inductees to the National Women's Hall of Fame.

Harvey V. Fineberg (Institute of Medicine) is among the recipients of the 2009 Harvard Medal.

Wendy Freedman (Carnegie Institution of Washington) was awarded the 2009 Cosmology Prize of the Peter and Patricia Gruber Foundation. She shares the prize with Robert Kennicutt (University of Cambridge) and Jeremy Mould (University of Melbourne School of Physics).

Apostolos P. Georgopoulos (University of Minnesota) is among the recipients of the 20th annual Neuronal Plasticity Prize, given by La Fondation Ipsen.

Herbert Gleiter (Institut für Nanotechnologie) is the recipient of the 2009 R. F. Mehl Award of the Minerals, Metals & Materials Society and the recipient of the 2009 Blaise Pascal Medal in Materials Science of the European Academy of Sciences.

Richard Goldstone (Constitutional Court of South Africa) is the recipient of the MacArthur Award for International Justice, given by the John D. and Catherine T. MacArthur Foundation.

Ronald Graham (University of California, San Diego) has been selected as a member of the inaugural class of Fellows of the Society for Industrial and Applied Mathematics (SIAM).

Susan L. Graham (University of California, Berkeley) is the recipient of the 2009 IEEE John Von Neumann Medal.

Barbara Rosemary Grant (Princeton University) and Peter Raymond Grant (Princeton University) were awarded the 2009 Kyoto Prize in Basic Sciences.

Mikhail Gromov (New York University; Institut des Hautes Études Scientifiques) was awarded the Abel Prize in Mathematics by the Norwegian Academy of Science and Letters.

Jeffrey C. Hall (University of Maine) was awarded the 2009 Neuroscience Prize of the Peter and Patricia Gruber Foundation. He shares the prize with Michael Rosbash (Brandeis University) and Michael W. Young (Rockefeller University).

John J. Hopfield (Princeton University) received the 2009 IEEE Frank Rosenblatt Award.

J. Larry Jameson (Northwestern University) is the recipient of the Fred Conrad Koch Award, given by the Endocrine Society.

Robert Kennicutt (University of Cambridge) was awarded the 2009 Cosmology Prize of the Peter and Patricia Gruber Foundation. He shares the prize with Wendy Freedman (Carnegie Institution of Washington) and Jeremy Mould (University of Melbourne School of Physics).

Leon Kirchner (Harvard University) is the recipient of the 2009 Gold Medal for Music, given by the American Academy of Arts and Letters.

Jon Kleinberg (Cornell University) is the recipient of the 2008 ACM-Infosys Foundation Award in the Computing Sciences.

Brenda Milner (McGill University) was appointed to the National Order of Quebec.

Thomas Nagel (New York University) was awarded the 2008 Balzan Prize in Moral Philosophy.

Indra Nooyi (PepsiCo) is the recipient of the Barnard College Medal of Distinction, in company with Hillary Rodham Clinton (U.S. Department of State), Kay Crawford Murray (New York City Department of Juvenile Justice), and Irene J. Winter (Harvard University).

Ruth Patrick (Academy of Natural Sciences) is among the 2009 Inductees to the National Women's Hall of Fame.

Christopher Ricks (Boston University) received a Knighthood as part of the Queen's Birthday Honors.

Guy Rocher (University of Montreal) is the recipient of the Canadian Association of University Teachers' Distinguished Academic Award.

Michael Rosbash (Brandeis University) was awarded the 2009 Neuroscience Prize of the Peter and Patricia Gruber Foundation. He shares the prize with Jeffrey C. Hall (University of Maine) and Michael W. Young (Rockefeller University).

Richard Rose (University of Aberdeen) has received a Lifetime Achievement Award of the Council for the Comparative Study of Electoral Systems.

Janet Rowley (University of Chicago) was awarded the 2009 Genetics Prize of the Peter and Patricia Gruber Foundation.

Nicholas Samios (Brookhaven National Laboratory) is the recipient of the 2009 Gian Carlo Wick Gold Medal Award, given by the World Federation of Scientists.

Susan Stewart (Princeton University) is the recipient of a 2009 Academy Award in Literature, given by the American Academy of Arts and Letters.

Mark H. Thiemens (University of California, San Diego) is the recipient of the 2009 V.M. Goldschmidt Medal of the Geochemical Society.

Mitsuko Uchida (London, United Kingdom) was named a Dame Commander of the Order of the British Empire as part of the Queen's Birthday Honors.

Axel Ullrich (Max Planck Institute of Biochemistry, Martinsried, Germany) is the recipient of the 2009 Dr. Paul Janssen Award for Biomedical Research.

Speros Vryonis, Jr. (S.B. Vryonis Center for the Study of Hellenism) is the recipient of the AHEPA Academy of Achievement Award in Education.

George M. Whitesides (Harvard University) was awarded the inaugural Dreyfus Prize in the Chemical Sciences.

Irene J. Winter (Harvard University) is the recipient of the Barnard College Medal of Distinction, in company with Hillary Rodham Clinton (U.S. Department of State), Kay Crawford Murray (New York City Department of Juvenile Justice), and **Indra Nooyi** (PepsiCo).

Richard N. Zare (Stanford University) is the recipient of the 2010 Priestley Medal, given by the American Chemical Society.

New Appointments

Charles Bernstein (University of Pennsylvania) is a Consulting Editor for the *International Literary Quarterly*.

Peter Brooks (Princeton University) is a Consulting Editor for the *International Literary Quarterly*.

Albert Carnesale (University of California, Los Angeles) was appointed to the Board of Directors of NanoPacific Holdings, Inc.

Denis Donoghue (New York University) is a Consulting Editor for the *International Literary Quarterly*.

Alessandro Duranti (University of California, Los Angeles) was appointed Dean of Social Sciences at the University of California, Los Angeles.

Corey S. Goodman (Oakland, CA) was appointed to the Board of Directors and Scientific Advisory Board of iZumi Bio, Inc.

Linda Greenhouse (Yale Law School) was elected a member of the Harvard University Board of Overseers.

Edith Grossman (New York, NY) is a Consulting Editor for the *International Literary Quarterly*.

David A. Hollinger (University of California, Berkeley) is President-Elect of the Organization of American Historians.

William L. Jorgensen (Yale University) was appointed Divisional Director for the Physical Sciences and Engineering at Yale University.

Julia Kristeva (Université de Paris VII) is a Consulting Editor for the *International Literary Quarterly*.

Jeffrey Leiden (Abbott Laboratories) was appointed to the Board of Directors of Vertex Pharmaceuticals Incorporated.

Walter E. Massey (Morehouse College) was elected Chairman of the Board of the Bank of America Corporation.

Martha Minow (Harvard Law School) was named Dean of Harvard Law School.

Robert C. Post (Yale Law School) was named Dean of Yale Law School.

Jeremy A. Sabloff (University of Pennsylvania) was appointed President of the Santa Fe Institute.

George C. Schatz (Northwestern University) was appointed Editor-in-Chief of the *Journal of Physical Chemistry Letters*.

Werner Sollors (Harvard University) is a Consulting Editor for the *International Literary Quarterly*.

Claude M. Steele (Stanford University) was named 21st Provost of Columbia University.

Select Publications

Fiction

Peter Ackroyd (*London Times*, United Kingdom). *The Casebook of Victor Frankenstein*. Doubleday/Talese, October 2009

Margaret Atwood (Toronto, Canada). *The Year of the Flood*. Knopf, September 2009

Paul Auster (New York, NY). *Invisible*. Henry Holt & Company, October 2009

E. L. Doctorow (New York University). *Homer & Langley*. Random House, September 2009

Ward Just (Vineyard Haven, MA). *Exiles in the Garden*. Houghton Mifflin Harcourt, July 2009

Sandra Day O'Connor (Supreme Court of the United States). *Finding Susie*. Knopf, June 2009

Richard Powers (University of Illinois at Urbana-Champaign). *Generosity: An Enhancement*. Farrar, Straus and Giroux, September 2009

Jane Smiley (New York, NY). *The Georges and the Jewels*. Knopf, September 2009

Nonfiction

Roger S. Bagnall (New York University). *Early Christian Books in Egypt*. Princeton University Press, September 2009

Gary S. Becker (University of Chicago) and **Richard A. Posner** (United States Court of Appeals, Seventh Circuit). *Uncommon Sense: Economic Insights, from Marriage to Terrorism*. University of Chicago Press, November 2009

May Berenbaum (University of Illinois at Urbana-Champaign). *The Earwig's Tail: A Modern Bestiary of Multi-Legged Legends*. Harvard University Press, September 2009

William G. Bowen (Princeton, NJ), Matthew Chingos (Harvard University), and Michael S. McPherson (Spencer Foundation). *Crossing the Finish Line: Completing College at America's Public Universities*. Princeton University Press, September 2009

Theodore L. Brown (University of Illinois at Urbana-Champaign). *Imperfect Oracle: The Epistemic and Moral Authority of Science*. Pennsylvania State University Press, September 2009

Theodore L. Brown (University of Illinois at Urbana-Champaign). *Bridging Divides: The Origins of the Beckman Institute at Illinois*. University of Illinois Press, September 2009

Bruce Bueno de Mesquita (Stanford University/New York University). *The Predictioneers Game: Using the Logic of Brazen Self-Interest to See and Shape the Future*. Random House, September 2009

Michael Chabon (Berkeley, CA). *Manhood for Amateurs: The Pleasures and Regrets of a Husband, Father, and Son*. Harper, October 2009

Arthur C. Danto (Columbia University). *Andy Warhol*. Yale University Press, October 2009

Robert Darnton (Harvard University). *The Devil in the Holy Water, or the Art of Slander from Louis XIV to Napoleon*. University of Pennsylvania Press, November 2009

Frans de Waal (Emory University). *The Age of Empathy: Nature's Lessons for a Kinder Society*. Harmony, September 2009

William L. Fash, Jr. (Harvard University) and Leonardo López Luján (Museo del Templo Mayor, Instituto Nacional de Antropología e Historia, México), eds. *The Art of Urbanism: How Mesoamerican Kingdoms Represented Themselves in Architecture and Imagery*. Harvard University Press, September 2009

Carol Gluck (Columbia University) and Anna Lowenhaupt Tsing (University of California, Santa Cruz), eds. *Words in Motion: Toward a Global Lexicon*. Duke University Press, December 2009

Jane Goodall (Jane Goodall Institute, Arlington, VA). *Hope for Animals and Their World: How Endangered Species Are Being Rescued from the Brink.* Grand Central, September 2009

E.D. Hirsch, Jr. (University of Virginia). *The Making of Americans: Democracy and Our Schools*. Yale University Press, September 2009

Jerome Kagan (Harvard University). *The Three Cultures: Natural Sciences, Social Sciences, and the Humanities in the 21st Century.* Cambridge University Press, May 2009

Richard Kramer (Graduate Center, City University of New York). *Unfinished Music.* Oxford University Press, April 2008

Julia Kristeva (Université de Paris VII). *The Incredible Need to Believe*. Columbia University Press, October 2009

T. J. Jackson Lears (Rutgers University). *Rebirth of a Nation: The Making of Modern America, 1877–1920*. Harper/HarperCollins, June 2009

James M. McPherson (Princeton University). *Abraham Lincoln*. Oxford University Press, February 2009

Joel Mokyr (Northwestern University). *The Enlightened Economy: An Economic History of Britain, 1700–1850*. Yale University Press, October, 2009

Peter Paret (Institute for Advanced Study, Princeton, NJ). *The Cognitive Challenge of War: Prussia 1806*. Princeton University Press, November 2009

Peter G. Peterson (Peter G. Peterson Foundation). *The Education of an American Dreamer: How a Son of Greek Immigrants Learned His Way from a Nebraska Diner to Washington, Wall Street, and Beyond*. Twelve, June 2009

Francine Prose (New York, NY). *Anne Frank: The Book, the Life, the Afterlife*. Harper, October 2009

Jack Rakove (Stanford University), Introduction and Notes. *The Annotated U.S. Constitution and Declaration of Independence.* Harvard University Press, November 2009

Harriet Ritvo (Massachusetts Institute of Technology). *The Dawn of Green: Manchester, Thirlmere, and Modern Environmentalism.* University of Chicago Press, October 2009

Felix Rohatyn (FGR Associates LLC). *Bold Endeavors: How Our Government Built America, and Why It Must Rebuild Now.* Simon & Schuster, February 2009

Michael J. Sandel (Harvard University). *Justice: What's the Right Thing to Do?* Farrar, Straus and Giroux, September 2009

Manfred Schroeder (Universität Göttingen). *Fractals, Chaos, Power Laws: Minutes from an Infinite Paradise.* Dover Publishers, October 2009

Amartya Sen (Harvard University). *The Idea of Justice*. Harvard University Press, September 2009

Richard A. Shweder (University of Chicago), ed. *The Child: An Encyclopedic Companion*. University of Chicago Press, September 2009

Seymour Slive (Harvard University). *Rembrandt Drawings*. Oxford University Press, August 2009

Werner Sollors (Harvard University) and Greil Marcus (Berkeley, CA), eds. *A New Literary History of America*. Harvard University Press, September 2009

Robert A.M. Stern (Yale University). *Architecture on the Edge of Postmodernism: Collected Essays*. Yale University Press, November 2009

George M. Whitesides (Harvard University) and Felice C. Frankel (Harvard University). *No Small Matter: Science on the Nanoscale.* Harvard University Press, November 2009

Harriet Zuckerman (Andrew W. Mellon Foundation), Ronald G. Ehrenberg (Cornell University), Jeffrey A. Groen (Bureau of Labor Statistics), and Sharon M. Brucker (Princeton University). *Educating Scholars: Doctoral Education in the Humanities*. Princeton University Press, December 2009

Exhibitions

David P. Billington (Princeton University): *Félix Candela: Builder, Engineer, Structural Artist,* MIT Museum, Cambridge, MA, April 2–September 27, 2009.

We invite all Fellows and Foreign Honorary Members to send notices about their recent and forthcoming publications, scientific findings, exhibitions and performances, and honors and prizes to bulletin@amacad.org. ■

From the Archives

"For Diving &c"

On the advice of Academy member John Prince, Benjamin Franklin Stickney of Salem, Massachusetts, sent a communication to the Academy in March 1800, describing his experiments in "descending and remaining under water." Stickney, a great-grandnephew of Benjamin Franklin, served as Indian Agent for the United States at Fort Wayne and in the U.S. Army under Andrew Jackson. The Academy's archives record the receipt of this manuscript communication, one of many sent in hopes of publication in the *Memoirs*.

Stickney's cover letter begins: "In the spring of 1798 I conceived the means of producing a circulation of air that might be supplied under water, for a person's furnishing himself with a constant supply of fresh air, in a vessel of proper dimentions, and of sufficient strength to resist the pressure of the ambient water. Not knowing at that time that any other means had been used for descending than the Diving Bell; I was under the necessity of contriving a vessel myself, to which I gave the name of Water Balloon."

Illustrations by Benjamin Franklin Stickney for his "Water Balloon," 1800

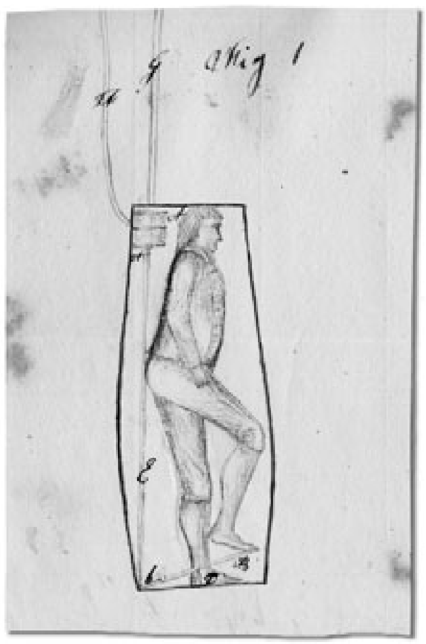


Figure 1: a "profile of the vessel with a person making use of the machinery for producing the circulation of air"

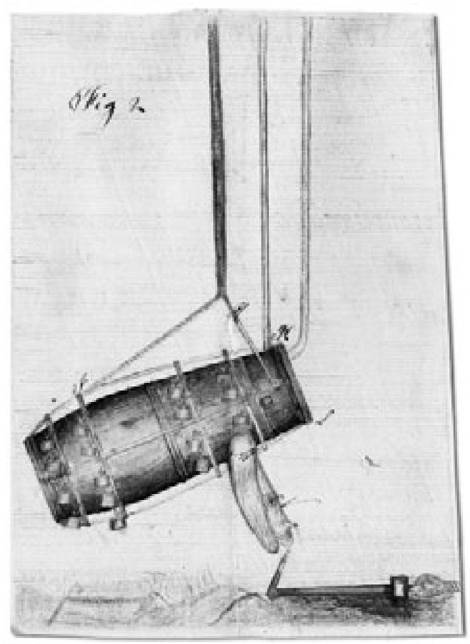


Figure 2: "the machine complete in the act of descending"

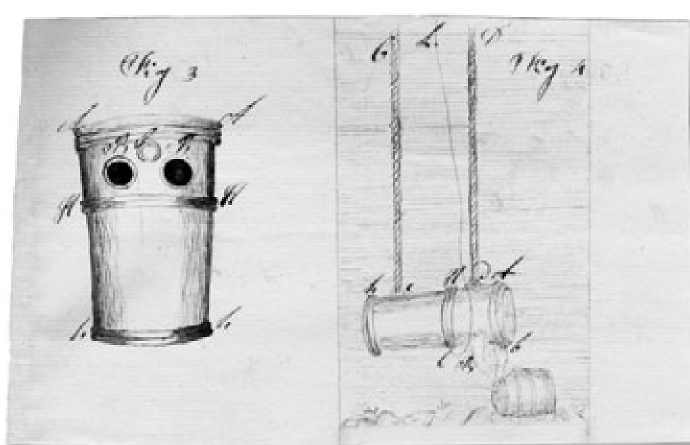


Figure 3: a design by Captain Rowe, of a "tub or truncated cone made in the shape of a tub Snuff-mill, in which the Diver is shut up by a cover AA fortified with hoops, as is also the Body of the Machine"

Figure 4: "the machine let down from a ship"

Notice to Fellows

New Academy Bylaws Approved

The Fellows voted to approve the proposed new Bylaws of the Academy. The vote was entered based on proxies submitted by the Fellowship on June 24, 2009, at a Special Meeting of the Academy called for this purpose. One thousand, three hundred, and fifty-seven Fellows voted in favor of the amendments; sixteen Fellows voted against the proposed changes. The Academy's new Bylaws conform to modern nonprofit governance practice and law and reflect the Academy's national character and research mission. We are grateful to the many Fellows who contributed to the bylaw revision process and look forward to implementing the new Bylaws during the forthcoming transition period.

– **Emilio Bizzi**, *President*

AMERICAN ACADEMY
OF ARTS & SCIENCES

Norton's Woods, 136 Irving Street, Cambridge, MA 02138
telephone 617-576-5000, *facsimile* 617-576-5050,
email aaas@amacad.org, *website* www.amacad.org

Bulletin Summer 2009
Issued as Volume LXII, Number 4

The Bulletin of the American Academy of Arts & Sciences (ISSN 0002–712X) is published quarterly by the American Academy of Arts & Sciences. Periodicals rate postage paid at Boston, MA, and at additional mailing offices. Postmaster: Send address changes to *Bulletin*, American Academy of Arts & Sciences, 136 Irving Street, Cambridge, MA 02138.

PHOTO CREDITS

Steve Rosenthal	inside front cover
Wendy Barrows	page 1, left
Martha Stewart	pages 1, right; 8, 9, 14

AMERICAN ACADEMY OF ARTS & SCIENCES
Norton's Woods
136 Irving Street
Cambridge, MA 02138-1996 USA

telephone 617-576-5000
facsimile 617-576-5050
email aaas@amacad.org
website www.amacad.org

AMERICAN ACADEMY
OF ARTS & SCIENCES