Sustainability Science: A room of its own

Sustainability science has emerged over the last two decades as a vibrant field of research and innovation. Today, the field has developed a core research agenda, an increasing flow of results, and a growing number of universities committed to teaching its methods and findings. Like "agricultural science" and "health science," sustainability science is a field defined by the problems it addresses rather than by the disciplines it employs. In particular, the field seeks to facilitate what the National Research Council has called a "transition toward sustainability," improving society's capacity to use the earth in ways that simultaneously "meet the needs of a much larger but stabilizing human population, . . . sustain the life support systems of the planet, and . . . substantially reduce hunger and poverty" (1).

In early 2005, Bruce Alberts and Ralph Cicerone, in their respective roles as outgoing and incoming presidents of the National Academy of Sciences, proposed that the maturing field of sustainability science might be ready for a "room of its own" in PNAS. After a committee study and extended discussion, the PNAS Editorial Board approved a new section on Sustainability Science, which now shares the masthead with other long-term residents such as Physics, Genetics, and Cell Biology. This editorial constitutes a progress report on the field itself and on the role of PNAS in fostering its development.

Research relevant to the goals of sustainable development has long been pursued from bases as diverse as geography and geochemistry, ecology and economics, or physics and political science. Increasingly, however, a core sustainability science research program has begun to take shape that transcends the concerns of its foundational disciplines and focuses instead on understanding the complex dynamics that arise from interactions between human and environmental systems. Central questions (2) include the following. How can those dynamic interactions be better incorporated into emerging models and conceptualizations that integrate the Earth system, social development, and sustainability? How are long-term trends in environment and development reshaping nature–society interactions? What factors determine the limits of resilience and sources of vulnerability for such interactive systems? What systems of incentive structures can most effectively improve social capacity to guide interactions between nature and society toward more sustainable trajectories? How can science and technology be more effectively harnessed to address sustainability goals?

From its core focus on advancing understanding of coupled human–environment systems, sustainability science has reached out with focused problem-solving efforts targeted to urgent human needs. As most recently delineated by the World Summit on Sustainable Development, these efforts include improving access to water supplies of adequate quality and quantity, advancing cleaner energy and manufacturing systems, mitigating the human health impact of pollution and environmentally mediated disease, enhancing agricultural production and food security, encouraging more benign trajectories of rapid urbanization, and more generally making more effective use of environmental and natural resources to promote poverty alleviation. Likewise, sustainability science is being applied to devise practical protections for the earth's key life-support systems. Special attention in recent years has been given to mitigating pressures on the global climate, conserving ecosystem services, and protecting biodiversity. Finally, and most ambitiously, sustainability science research is seeking to support the integrative task of managing particular places where multiple efforts to meet multiple human needs interact with multiple life-support systems in highly complex and often unexpected ways.

Just as sustainability science has reached out to contribute to and learn from the world of applied problem-solving, so has it remained closely linked with curiosity-driven research across a range of disciplines. Efforts to provide useful knowledge for solving the very practical but highly complex problems sketched above has often required fundamental advances in our conceptualization and understanding of coupled human–environment systems. This has meant that scientists seeking to promote a sustainability transition have needed to tap into, and indeed engage in, cutting-edge research in areas ranging from complex systems theory to cultural and political ecology.

Sustainability science is thus most usefully thought of as neither "basic" nor "applied" research. Rather, it is an enterprise centered on the "use-inspired basic research" that the late Donald Stokes characterized as "Pasteur's Quadrant" of the modern science and technology enterprise (see Fig. 1) (3). The field reaches out beyond this core, however, to encompass relevant work in both the blue-sky theorizing of "Bohr's Quadrant" and pragmatic problem solving of "Edison's Quadrant." In so doing, it serves the quest for advancing both useful knowledge and informed action by creating a dynamic bridge between the two.

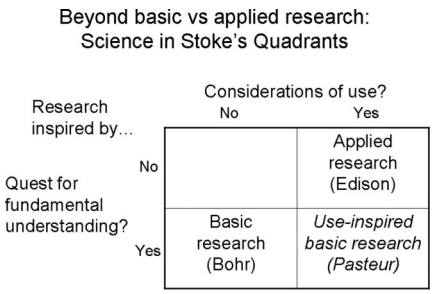

Fig. 1. Research characterized by the motivations that inspire it. (Redrawn from ref. 3.)

The resulting field of sustainability science has been expanding at an accelerated pace and in multiple directions, as can be tracked through its (appropriately) virtual "Forum on Science and Innovation for Sustainable Development" (http://sustainabilityscience.org). The forum monitors an increasing number of major conferences, including the entire 2007 Annual Meeting of American Association for the Advancement of Science, convened under the theme of "Science and Technology for Sustainable Well-Being." It also reflects an expanding set of fellowships, programs, institutes, and even schools devoted to training the next generation of sustainability scientists. Above all, however, the forum documents a growing flow of research results, published across an immense variety of journals and disciplines.

The National Academies and Sustainability Science

For two different reasons, PNAS recently responded to this growing supply of sustainability science by giving the field a "room of its own" among the journal's more established sections. First, as the NAS presidents emphasized when they suggested the PNAS initiative, the Academy has been a leader for more than a decade in efforts to harness science and technology in the service of sustainable development. Building on long-standing strengths across the Academies and National Research Council, the NAS initi-

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ated in 1995 a study that became the best-selling National Research Council report "Our Common Journey: A Transition Toward Sustainability"(1). This was the U.S. contribution to the World Scientific Academies' Tokyo 2000 meeting on a "Transition to Sustainability in the 21st Century: The Contribution of Science and Technology"(4). Leaders of these early Academy efforts helped to found the Initiative on Science and Technology for Sustainability and through it to help shape an increasingly robust and productive international agenda for sustainability science (2, 5, 6). The Academy followed up on its initial work by establishing in 2002 a standing Program and Roundtable on Science and Technology for Sustainability (http://www7.nationalacademies.org/sustainabilityroundtable/index.html), which is now actively reaching out to engage not only academics from around the world but also relevant leaders from government, the private sector, and civil society. The PNAS initiative was launched in part to provide a research-oriented complement to these other Academy activities that are in the forefront of the developing field of sustainability science.

A second reason for launching the PNAS section on Sustainability Science arose in the course of the review conducted by the study committee named by the presidents to consider the merits of such a section. The committee found that the field of sustainability science was growing rapidly, with the number of articles published annually increasing by 15–20% per year over the last decade. These publications are appearing across a huge range of fields in the natural and social sciences, engineering, and medicine. As a result, there are simply no dominant journals in the field. The most popular single journals carrying sustainability science articles capture no more than 5% of all of the important papers published and even then tend to focus on a single discipline or pair of disciplines (e.g., ecological economics) or a single issue area (e.g., agriculture or energy). The committee concluded that this extreme dispersion was limiting the opportunities for cross-fertilization and thus inhibiting development of the field. The committee recommended that the Academy provide a dedicated section on Sustainability Science in PNAS as a means of creating a high-profile, high-quality, interdisciplinary venue for publication of the best work produced in the field.

A Room of Its Own at PNAS

Since its launch a year ago, the PNAS section on Sustainability Science has been attracting an increasing flow of excellent submissions. The complete set of papers published to date can be seen via a drop-down list on the "Sustainability Science" page of the PNAS web site (www.pnas.org/misc/sustainability.shtml). The list illustrates both the scope and quality of work in the field, with articles addressing topics ranging from geography and macroeconomics, through the impact of atmospheric brown clouds on rice harvests in India, to a comparison of natural and anthropogenic iron cycles. Beyond these and similarly diverse papers submitted to the section, PNAS has invited a number of leading scholars in the field to prepare special features on key themes of sustainability science. These include efforts organized by Elinor Ostrom on "Beyond panaceas: Crafting diverse institutional arrangements for governing diverse social-ecological systems," Pamela Matson and Gretchen Daily on "Ecosystem services: From theory to implementation," Robert Kates and Partha Dasgupta on "Poverty and hunger," John Schellnhuber on "Tipping points in the Earth system," Barry Bloom on "Sustainable health," and Bill Turner on "Land change science."

Over the coming year, the PNAS section on Sustainability Science will seek to accelerate its present rapid growth through a number of initiatives. We will intensify our efforts to seek out the best research from around the world, striving to become a truly international forum for sustainability science. We will aim to capture more of the new research being carried out on fundamental properties of the complex, adaptive human–environment systems that are the heart of sustainability science. We will attempt to expand our coverage of work relevant to some of the most urgent practical challenges of sustainability not yet well represented in the journal, notably rapid urbanization and the provision of adequate water supplies. Above all, we will be working to make the section a home where scholarship on the development and poverty alleviation dimensions of the sustainability transition achieves prominence in the journal comparable with that now accorded the environment and conservation dimensions.

We invite researchers from around the world to join us in the adventure of making the Sustainability Science section of PNAS as exciting as the field on which it reports. Let us hear from you with your questions, suggestions, and above all contributions of your very best sustainability science research papers to furnish this wonderful new room of our own at PNAS.

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1. National Research Council Policy Division Board on Sustainable Development (1999) *Our Common Journey: A Transition Toward Sustainability* (Natl Acad Press, Washington, DC).
2. Kates RW, Clark WC, Corell R, Hall JM, Jaeger CC, Lowe I, McCarthy JJ, Schellnhuber HJ, Bolin B, Dickson NM, *et al.* (2001) *Science* 292:641–642.
3. Stokes DE (1997) *Pasteur's Quadrant: Basic Science and Technological Innovation* (Brookings Institution, Washington, DC).
4. World's Scientific Academies (2000) *Transition to Sustainability in the 21st Century: The Contribution of Science and Technology. Statement of the World's Scientific Academies, May 2000, Tokyo, Japan* (Interacademy Panel on International Issues, Trieste).
5. International Council for Science (2002) *Science and Technology for Sustainable Development* (Int Council for Sci, Paris).
6. Schellnhuber HJ, Crutzen PJ, Clark WC, Claussen M, Held H (2004) *Earth System Analysis for Sustainability* (MIT Press, Cambridge, MA).