Kates, R. W., 2003. "Sustainability Science," in Transition to Sustainability in the 21st Century: The Contribution of Science and Technology. National Academies Press, pp. 140-145.

Overarching Themes of the Conference: Sustainability Science

Robert Kates
U.S. National Academy of Sciences
Independent Scholar

To generate new knowledge, we need to change science itself, to go beyond what we already know and expand the world's capacity system for discovering new things. In the last quarter century, four related but distinct research-based programs relevant to sustainability have developed:

1. biological research, emphasizing the joint fates of humanity and the natural resource base on which it depends for sustenance
2. geophysical research, focusing on the earth as a system with interconnections among the earth's climate, biogeochemical cycles, and human activities
3. social research, focusing on how human institutions, economic systems, and beliefs shape the interactions between societies and the environment
4. technological research, concentrating on the design of devices and systems to produce more social goods with less environmental harm

Already these programs have come together in what is loosely called "global change science." However, sustainability science needs to be broader yet, spanning the individual branches to ask how, over the large areas and the long run, the earth, its ecosystems, and its people could interact with mutual sustenance.

The report *Our Common Journey: Transition Toward Sustainability* (U.S. National Research Council, 1999) foes not describe the precise paths such science would take. However, it does conclude that the most serious threats to people and their life support systems arose from multiple, cumulative, and interactive stresses resulting from a variety of human activities rather than one at a time. Thus, sustainability science must be, above all, integrative science, committed to bridging the barriers that separate the traditional scientific disciplines and the sectoral distinctions between integrated, interconnected human activities, such as energy production, agriculture, urban habitation, and transportation. It also needs to integrate across geographic scales to eliminate the sometimes convenient but ultimately artificial distinction between global and local perspectives. Finally, it needs to integrate across styles of knowing, bridging the gulf that separates the detached practice of scholarship from the engaged practice of engineering and management.

The first steps toward an integrated science of sustainability are readily found within the International Global Change Research Program. This community has made great progress in linking the relevant natural science disciplines, especially the sciences of the oceans, air, and water and the biota they support. However, it has made far less progress, despite significant national and international efforts, in understanding the interactions of natural and social systems and in the incorporation of biodiversity considerations in contemporary global climate change studies. As a result, we know much about which emissions cause various global environmental changes, but less about what drives those emissions, what impacts they will have on people and other species, and most important, what to do about them. Likewise, although integrated forest ecosystem management programs have progressed to the point of including people in the ecosystem at a local scale, there is much less progress in planning and assessment at broader regional scales, where issues such as the global economy, air and water pollution, or the determinants of human population migration exert tremendous control.

In short, even if there is little doubt about whether integrative approaches to research are needed in support of a sustainability transition, how to achieve such integration in rigorous and useful research programs remains a problem. If almost everything is connected to almost everything else, how do we avoid the practical impossibility of having to study everything in order to know anything?

In trying to answer this question, my colleagues rediscovered an approach long pursued by geographers, integrating research for sustainability not around particular disciplines or sectors of human activity but rather around the study of interactions between development and environment in particular places.

Sustainability science is regional and place based. The major threats and opportunities of the sustainability transition are not only multiple, cumulative, and interactive but also place based. In other words, it is in specific regions, with distinctive social, cultural, and ecological attributes, that the critical threats to sustainability emerge and in which a successful transition needs to be based. Fortunately, place also provides a conceptual and operational framework within which progress in integrative understanding and management is possible, for it is at this scale that complex interactions become more tractable, understandable, and manageable.

What constitutes an appropriate classification of place? In part, the distinction is surely one of scale, and a grand query of sustainability will be these scale relationships. At a global scale, which is implicit in this effort, is the search for parsimony, that is, the smallest number of regions that can capture the diversity of environment development relationships and still be manageable within scientific understanding, organizational capacity, and research budgets. Regardless of the definition of a region or a classification of a place, it will need science, and one of the most challenging elements of sustainability science is to build the capacity to do science where it is needed most. One of the clear implications of sustainability science is that it is democratic science, that as we move downscale and ask what are the scientific necessities of local places, we will discover wholly new ways to understand what is important about science, how to teach science; and what science means.

Sustainability science is also new and novel science and needs focused research programs addressing key issues of the transition to sustainability. *Our Common Journey* identifies areas that were under-studied, and many more have been identified during the conference. One is the need to evaluate the thresholds, critical loads, and carrying capacities for limits beyond which the life support systems of the planet should not be pushed. Another is to understand the many specific transitions that are under way, not only in population but also in globalization of the economy, in energy and materials intensity, and in governance. Further, there is a need to examine the determinants and alternatives to consumption patterns and to identify the incentives, markets, and remedies for market failure in promoting technical innovation that produces more human value with less environmental damage. Finally, further intention is required on the institutions, indicator systems, and assessment tools that are needed for navigating this transition.

To pursue a goal of preserving and maintaining the environment and the natural resource base is, among other things, to look for limits beyond which those systems should not be pushed. However, our understanding of process and practical experience suggests that relatively sharp boundaries do sometimes exist separating normal and radically transformed states of environment and natural resources.

Thus, the effort to establish safety limits for the earth's life support and ecological systems are longstanding and widespread. For example, a recent study that was supported and published by the United Nations University in Tokyo sought to identify critical thresholds of damage beyond which whole regional ecosystems lose their ability for self-renewal and slide inexorably into deeper and deeper degradation.

While many of the efforts to specify safety limits for human pressures in the book *The Biosphere* (Vernadskii, V. I, et al., 1998) have sometimes been helpful, the underlying concepts have proven to be contentious, ambiguous, and frustrating. Global carrying capacities, the first evidence of which was made by Leuwenhoek in 1679, are dependent on available technologies and consumption practices. Efforts to specify the actual critical loads or safety levels are undermined by differences in the environment and population at risk. Thresholds turn out to be less often absolute than relative, with sufficient resources or time frequently able to restore a system towards its previous state. For instance, the state of Maine, which 100 years ago was 50 percent deforested, is now 87 percent forested.

We encountered all these difficulties in our own study. Though we had no trouble identifying cases in which environmental systems had been degraded or even destroyed, we were unable to turn the concepts of critical loads, carrying capacities, or their cousins into useful tools for navigating the sustainability transition. Either a robust scientific foundation needs to be built under the idea of safe limits; in other words, we have to demonstrate how to do that scientifically and repeatedly and confirm those analyses, or the scientific community needs to develop alternative concepts for guiding action towards the sustainability transition.

We are living in an age of transition—in health, with early deaths by infectious diseases to late death by cancer, heart attack, and stroke; in economies, which are moving from state to market control; and in civil society, which is moving from single-party, military, or state-run institutions to multiparty politics and a rich mix of nongovernmental institutions. But, are they fundamental transitions that serve as a break in trends concerning the relationship between society and environment, and what do they augur for a transition towards sustainability?

The best of social science has identified one powerful transition that is credible and interesting: the change in population regimes from ones of high birth and death rates to ones of low birth and death rates. The S-shaped demographic transition is credible because it meets scientific criteria; that is, it is partly supported by theory, matches the data well, and has predictive power. It appears to be not simply a continuous trend, but rather a transition from one relatively stable state of affairs to another. The logistics trajectory may also apply to the growth of cities and wealth, but the point of inflection is not known. It also well describes the diffusion of lead technologies within recurrent 60- to 70-year periods. Thus, we have had four major great periods since the beginning of the Industrial Revolution.

Environmental problems may follow a somewhat different trajectory, a normal curve rather than a logistic. Over time, air and water pollution shifts focus from household and neighborhood in developing countries to region in industrializing countries and now to global for all of us. In each, problems seem to follow a bell-shaped trajectory, initially rising and then falling. One theory thinks it tracks wealth as well and argues that richer is cleaner. That remains to be seen.

Several other candidate transitions seem almost as compelling. We have a transition in settlement from predominantly rural to predominantly urban, in agricultural productivity from production derived by increasing land to production derived by increasing yields. The other possible transitions are interesting but are not as well understood or as globally documented. These include the globalization of the economy; changes in consumption patterns, energy intensity, and pollution per unit value produced by the economy; and a transition in the role of the state in global governments.

Taken all together, will these transitions become a sustainability transition? Documenting and understanding these, especially for the transitions that transcend the normal disciplinary boundaries of scholarship, should be a priority objective for sustainability science.

Sustainability science is also fundamental curiosity-driven science. It is filled with grand queries that seem to transcend the form and substance of the various sciences, the great questions appearing as fundamental simultaneously in many disciplines. One recurring grand question is that of scale: how to relate the universal with the particular, the whole with its parts, structure and agency, macro processes with micro behavior, the global with the local. Across the disciplines, in somewhat similar ways, biologists ponder the linkages among molecules, cells, and organisms; ecologists, among patches, ecosystems, and biomes; economists, among firms, industries, and economies; and geographers, among places, regions, and Earth. As sustainability science seeks to integrate the global and local, it integrates these disciplinary versions of the grand question of scale and learns from the specific disciplines but also cross-checks their particular answers.

Related to the question of scale is the question of nonlinear processes and complexity, where the understanding of the component parts can explain the properties of the larger system or whether indeed the properties of larger systems are knowable at all, roughly predictable if we can but penetrate the strange attractors of chaotic complexity.

Finally, there is the grandest question of all. Alexander von Humboldt, thought by some as the last individual who could hope to master the world's knowledge about the earth, would surely be comfortable in an integrative, place-based sustainability science that seeks to understand how the forces of nature and society interact upon one another.

As he left Spain in 1799, on his great voyage of discovery that would take him up and down the Orinoco River and across the Andes, he wrote to a friend: "In a few hours, we sail around Cape Finisterre [in Spain]. I shall collect plants and fossils and make astronomic observations, but that is not the main purpose of my expedition. I shall try to find out how the forces of nature interact upon one another and how the geographic environment influences both plant and animal life. In other words, I must find out about the unity of nature."

Returning to Europe, he labored to publish his many works. By the time the last volume of the *Cosmos* appeared in 1862, after his death, German science had discovered reductionism and modern disciplines, and their graduate training of the Ph.D. was being created. More than 200 years later, having benefited from the great gains in fundamental science that reductionism made possible, we again turn our attention to fundamental integration. Whether it is called conciliance or theories of everything or sustainability science, it returns to ask the question about the unity of nature. It builds upon the ongoing work of global change science that asks the profound and seemingly simple question, a question that children might ask, "How does the earth work?" In the years to come, we will extend the question to "How does the earth, its living biota, and our human species work?"

Finally, sustainability science is caring, caring for the earth, its living biota, and its people. When scientists are asked by those who encourage, support, and fund our endeavors as to the relevance of our work to the challenges faced by people and societies, we too frequently show our portfolio of activity and ongoing work and then tell them how our discoveries promise some improvement in the human condition. Sustainability science is different because it begins not with a current agenda of science but with its concerns for the human condition.

Thus, in the Statement of Scientific Academies, we identify three issues: meeting the needs of a larger population; reducing hunger and poverty and preserving human well-being; and preserving and maintaining the environment and natural resource base, moving towards sustainable human consumption patterns. Sustainability science cares about these issues. It asks not how our current efforts address these issues but what should the scientific and technological community do to help society reach these goals.

In conclusion, sustainability science under that name may never appear. The title may not take hold, and its practitioners may rally under different banners, but sustainability science itself—integrated, place based, novel, fundamental, and caring—is already here. It can be found in the 350 cities around the world that are identifying their bundle of greenhouse gases—5 percent of the world's gases—in order to reduce them, using simple but scientifically based software developed by a lone physicist in Ottawa, Canada; in the Biocomplexity in the Environment (BE) Program of the U.S. National Science Foundation, which integrates the disciplines across the scale of molecules and biomes; in the work of the European Community that produced such items as *Towards Sustainable Consumption* (2000); in the advanced integrated assessment and scenario models that have extended their reach to embrace the driving forces of change from both nature and society; and it can be found in Tokyo, as the members of the world academies join together in our common journey.

REFERENCES

Humboldt, A. van, E. C. Otte (trans.). Reprinted May 1997. Cosmos: A Sketch of a Physical Description of the Universe (Foundations of Natural History). Baltimore, MD: Johns Hopkins University Press.

National Research Council. 1999. Our Common Journey: A Transition Toward Sustainability. Board on Sustainable Development. Washington, D.C.: National Academy Press.

Towards sustainable consumption: A European perspective. 2000. London: The Royal Society.

Vernadskii, V. I., D. B. Langmuir (trans.), and M. A. S. McMenamin. 1998. The Biosphere. New York: Copernicus Books.