An analysis of public policy issues and how they affect MRS members and the materials community...

An Alchemy of Disciplines

The Public Affairs Forum feature is an edited transcript of a talk presented by Rita Colwell, director of the National Science Foundation, given on December 2, 1998 at the International Union of Materials Research Societies Forum on International Collaboration at the 1998 Materials Research Society Fall Meeting in Boston.

I have titled my talk "An Alchemy of Disciplines" to highlight the materials science field's extraordinary aptitude for making unexpected, imaginative, and fertile connections and transformations. What I see in the future for science and technology draws strongly upon your experience and practice over the years.

We all know that the interdisciplinary nature of materials is central to its character. We also know that materials science has been at the vanguard in using the power of computing to drive research. Science and—increasingly—society profit from your example in harnessing information technology. The importance of your leadership will increasingly be appreciated. This interdisciplinary outlook, amplified and firmly underpinned by information technology, will pervade the future of science. Allow me to look at both themes just a little bit more fully.

To provide a context, let's begin by taking stock of where we are right now and how quickly we are moving. It's not hyperbole to say that discoveries bolstered by materials research have spurred breakthroughs in every sphere of the global economy. As Philip Ball writes in his book, *Made to Measure*, "We can make synthetic skin, blood, and bone. We can make an information superhighway from glass. We can make materials that repair themselves, that swell and flex like muscles, that repel any ink or paint, that capture the energy of the sun."

In this very exciting and rapid-paced world of materials, innovation is key. I'd like to draw your attention to a recent report by the Council on Competitiveness, a high-powered group of industry, university, and government leaders. The report, *Going Global: The New Shape of American Innovation*, reminds us that "innovative capacity plays a dominant, and probably decisive, role in determining who will prosper in the global arena."

The pace of change is quickening. As the Council notes, "The technology cycle times, particularly in information technologies, are so rapid that few industry executives are complacent about sustaining leadership....Countries are leapfrogging generations of technology within the span of a single decade." Leadership in this era of what has been called "technology churn" can shift quickly if innovation slows.

It's no secret that one reason for the power and foment of materials research is its porous boundaries. There is no better refutation of the archaic distinction between fundamental and applied science than the field of materials. It is a superb example of the seamless fusion between basic science and technological advancement.

Take materials themselves. It is the surfaces and the interfaces that offer the most intriguing possibilities. Similarly, at the junctures between the biological, the physical, and the social sciences, the greatest progress can be made in understanding our world. This is where the advances in coming years will be most striking. The breadth of the materials field itself mirrors the complexity of nature better than the rigid channels of traditional disciplines.

I envision a sort of disciplinary alchemy. This concept is captured by Stanley Ovshinsky, president of a company called Energy Conversion Devices. He is quoted in the Council on Competitiveness report. "We turn chemists into physicists and physicists into materials scientists," he said. "We don't allow any differentiation by disciplines, which are not nature-made but man-made."

The biomaterials area, in particular, encapsulates new linkages. An NSF working group on interdisciplinary macromolecular research stated it like this: "The three billion-year-old laboratory of evolution by natural selection is sure to suggest new routes to improved materials properties and performance."

The parallel worlds of physics and biology are on a fortuitous collision course—indeed, they've already met. We are sure to reap greater things from this union than from either world in isolation. As we know, by looking at biological substances as materials, certain principles begin to emerge. Almost all biologically produced materials are composites. Life creates structures with different-length scales. And it uses templates to control its processes with a precision unknown in synthetic production. We do know we have not yet discovered the ideal materials to repair the human body. Medical devices have been designed up to now using the substances at hand.

An interdisciplinary approach might instead target new materials specifically for biological systems. The blending of physical, chemical, and biological approaches opens up new vistas on sensors for diagnosis, selective membranes, even the manufacture of tissues. NSF can play a strong part in supporting the science behind these innovations.

The merger goes both ways. Take drug delivery, for example. A drug—now untargeted and unprotected when ingested in the body—could be "packaged" or surrounded with receptors that could bind to cancer cells or other unwelcome invaders. The biologists and physicists who do this sort of research require a common language. To travel freely between disciplines, we can no longer afford the luxury of speaking in the tongues of our own individual fields. These esoteric languages are unintelligible even to the researcher in the next department, not to mention the person who lives down the street.

To cross disciplinary boundaries, we need to be able to speak with great clarity to one another, to develop a common language, a "scientific Esperanto." This is not just an academic issue but a societal and economic one as well. Industry executives say that university training has become more specialized and highly "stovepiped." They stress the need for graduates who can speak across disciplines.

We need to reach out much further than this. Many of you may have seen the wonderful website called "Macrogalleria." The site bills itself as "the Internet mall where you netsurfers can learn all kinds of nifty stuff about polymers and polymer science." The higher the level in the mall, the more complex are the concepts conveyed.

Another example is Bob Chang's Materials World Modules. With these, students in middle and high school test and make their own materials, from biosensors to food packaging. Designing materials lets students learn science and math through real-world tasks.

Let us now turn to an area of stunning technological advancement whose future is central for our science, our societies, and our economies. This is information technology, a field where materials have already played a sweeping role. The development of the computer, in fact, has been called a "benchmark" for the revolutions in both information and materials.

You may have seen the recent preliminary report by the President's Information Technology Advisory Committee (PITAC). It noted that federal investment in information technology has reaped a "spectacular return." President Clinton often cites the fact that one-third of U.S. economic growth in the 1990s can be credited to the IT sector.

At the same time, PITAC concluded that the United States is gravely underin-

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vesting in long-term research in information technology, calling federal support "dangerously inadequate." PITAC recommended that NSF coordinate federal support for computing research.

For our part, we are strongly committed to playing a leadership role in this cooperative federal effort. We have a strong record in the key areas of information technology research, from software to the human/computer interface, from scalable infrastructure to the framework for high-end computing. The NSF would forge the strongest possible links between information technology and fundamental research in science and engineering. This makes sense because we have the most comprehensive research jurisdiction of any federal agency or department. With all disciplines represented, with cross-disciplinary work a primary goal, and with a solid record in developing both the Internet and supercomputing, NSF is the natural choice.

While we advance research in this sphere, we must also employ information technology in the same way that a rich mix both defines and blends the ingredients in a good stew. Investing in information technology will provide a super stock, including everything from materials research to biotechnology, from global change to advances in agriculture. This will be one of the most important ventures NSF can launch in the coming years.

Let me share some reflections from my own research on how this can work. These experiences have shaped my thinking about the links between disciplines and about information technology.

In the 1960s, I was working on my PhD thesis at the University of Washington. I was the first to use computers to classify marine bacteria—or for that matter, any bacteria—in the environment. I wrote the classification program for the IBM 650 computer. Over time, we were able to show that the disease-causing strain of cholera is the same species as harmless strains. Now we can follow the pathogenic strain by satellite because of its natural association with plankton—and, ultimately, mitigate the devastation of this disease. We could not even begin to hope for that without the power of information technology.

There are many such instances where information technology has let us combine and process massive data sets from diverse fields, at almost lightning speed. But while we make plans for advanced information technology research, our entire society is frenetically embracing the technology in practical ways—PCs, pagers, cell phones, e-mail, even Palm Pilots.

Materials will certainly continue to play a seminal role for us since much of the rest of science mines this field for its wisdom.

In the social sciences, there has also been wide discussion about how computers have been able to decouple work from any particular location. We also know that many private sector managers can have more frequent contact with their counterparts on the other side of the world than with the worker in the next cubicle.

The implications are profound. An *Atlantic Monthly* piece on the computer and the economy recognized this, noting that "in the end, the primary payoff from advances in information technology may not be in new and better goods and services but in new and better democracies."

Why engage in such discussion when what matters is cutting-edge research in information systems? Because both elements matter—making plans and the life you lead while you are planning.

The National Science Foundation is likely the only federal institution involved in research at both ends of that spectrum. For example, social scientist Rachelle Hollander, head of NSF's Ethics and Values Studies Program for the last 25 years, was recently highlighted as one of ten "Information Age Heroes" in a *Los Angeles Times* article. As she says, "Information technology has the ability to transform the social as well as physical landscape, perhaps even beyond what the automobile has done. We need to understand those implications at least as much as the more narrow technical parameters. We need to know how this technology can affect what it is to be a person, a community, a society."

Materials science has had an equally powerful impact on society. The science writer Ivan Amato, in his book called *Stuff*, links some of the seminal points of human history to breakthroughs in understanding of materials. He suggests that we are approaching another such turning point now. "The practitioners of materials research," he writes, "are coming to a point where they are gaining the ultimate level of control over the material world."

And he continues, "...contemporary materials science is likely to have as profound an effect on posterity as did that original act of materials engineering in eastern Africa's Rift Valley, where the sound of stone against stone first snapped into the Paleolithic air."

We need to integrate our science—whether the insights and impacts of materials research or of information technology—into our societal understanding. Materials will certainly continue to play a seminal role for us since much of the rest of science mines this field for its wisdom.

We will look to your continued alchemy—your ability to blend disciplines, to forge international networks based on information technology—to help show us the way.

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