Science and the world's future

Academia Sinica

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Bruce Alberts
Editor-in-Chief, Science magazine
Emeritus professor of Biochemistry and Biophysics, UCSF

My failed PhD exam

Nature

October 28, 2004

A wake-up call

How failing a PhD led to a strategy for a successful scientific career.

Bruce Alberts

One of my most important formative experiences as a scientist was very traumatic at the time. In the spring of 1965, I had finished writing my PhD thesis at Harvard University, in Cambridge, Massachusetts, and had purchased aeroplane tickets to take my wife Betty and our one-year-old daughter with me for a postdoctoral year in Geneva, Switzerland. Only one step remained — a meeting of my thesis committee to approve the granting of my PhD degree in biophysics. No one in recent memory had failed at this late stage. But to my great surprise, the committee failed me, specifying the need for more experiments that eventually required six more months of research.

This was, of course, a great embarrassment and a shock to my ego. There were the practical problems of having to remain at Harvard — our apartment had already been rented to the next tenant and my small family had nowhere to live. But most importantly, I was to spend the next few months struggling to answer two questions that would be critical for my future. What had gone wrong, and did I really have what it takes to be a scientist?

As an undergraduate working with Jacques Fresco in Paul Doty's laboratory at Harvard, I was handed a research project that proved to be very successful. My undergraduate thesis was quickly converted into two important papers in 1960. This largely undeserved success gave me a false image of how easy it would be to do science. It also enabled me to persuade Paul Doty to allow me to test my own theoretical model for the initiation of chromosome replication as the centrepiece of my PhD research.

Bruce Alberts: 'failure' was a blessing in disguise.

critical step in shaping me as a scientist, because it forced me to recognize the central importance of the strategy that underlies any major scientific quest.

I had witnessed the frustration of scientists who were pursuing obvious experiments that were simultaneously being carried out in other laboratories. These scientists were constantly in a race. It had always seemed to me that, even if they were able to publish their results six months

choose? The months of analysis triggered by the wake-up call of my PhD failure finally produced an answer. I would look for a unique experimental approach, but one that would have a high probability of increasing our knowledge of the natural world, regardless of the experimental results obtained.

After a great deal of soul-searching, I decided that I would begin by developing a new method — one that would allow me to isolate proteins required for DNA replication that had thus far escaped detection. I knew that the enzyme RNA polymerase, which reads out the genetic information in DNA, binds weakly to any DNA sequence — even though this protein's biologically relevant binding sites are specific DNA sequences. If the proteins that cause DNA to replicate have a similar weak affinity for any DNA molecule, I would be able to isolate them by passing crude cell extracts through a column matrix containing immobilized DNA molecules.

Arriving in Geneva in late 1965 with my PhD degree finally in hand, I found that by drying an aqueous solution of DNA onto plain cellulose powder, I could construct a durable and effective 'DNA cellulose' matrix. A large number of different proteins in a crude, DNA-depleted extract of the bacterium *Escherichia coli* bound to a column containing this matrix. Moreover, these DNA-binding proteins could be readily purified by elution with an aqueous salt solution. Using this new biochemical tool and a large library of mutant T4 bacteriophages obtained from Dick Epstein in Geneva, I discovered the T4 gene 32 protein after moving to Princeton a year later as an assistant professor. This proved to be the first

My Bottom Line:

It is critically important that science, and scientists, achieve a much higher degree of influence throughout both their nations and globally

This talk will focus on some current strategies that promote this goal

- But first a little personal history

My unintended entry into science policy, 1985

Cell, Vol. 41, 337–338, June 1985, Copyright © 1985 by MIT

Limits to Growth: In Biology Small Science Is Good Science

Commentary

These days, many people grow up believing that bigger is better. Giant factories that produce Wonder Bread have replaced thousands of corner bakeries, driven by the increased efficiency of scale. There is an unfortunate tendency to extend this view to the biological research community, and I have on occasion heard a major symposium speaker introduced in glowing terms as the coauthor of more than fifty papers per year. While I can admire the energy and management skills required to maintain a very large laboratory, the best biology is rarely done in this way. With a few notable exceptions, the biochemists and molecular biologists I most respect run relatively small laboratories and publish when they have something important to report. As I shall argue here, doing good science is very different from producing bread, and there are compelling reasons why large laboratories are in general less efficient and less interesting than small ones. To reflect this fact, I believe that changes in funding patterns and expectations would be useful in the biological sciences.

to choose priorities carefully, as is required to use one's limited intellectual resources wisely. Moreover, because of the need to maintain the operation at a certain level of activity, it is inevitable that most of the work being done is rarely innovative or outstanding. Some large laboratories tend to jump quickly to exploit the original observations of others, believing that their extensive resources will enable them to compete effectively.

Many large laboratories represent a poor training environment for young scientists. Graduate students and postdoctoral scientists are treated as though workers in a factory, contributing strictly to their own part of the production line. This does not prepare them to function as independent scientists and may even impede their development by preventing the acquisition of habits of independent research at a crucial point in their careers. Even those rare individuals who succeed can become disillusioned and cynical, when they see their own ideas and efforts credited to a group leader who made no scientific contribution to the research that they performed.

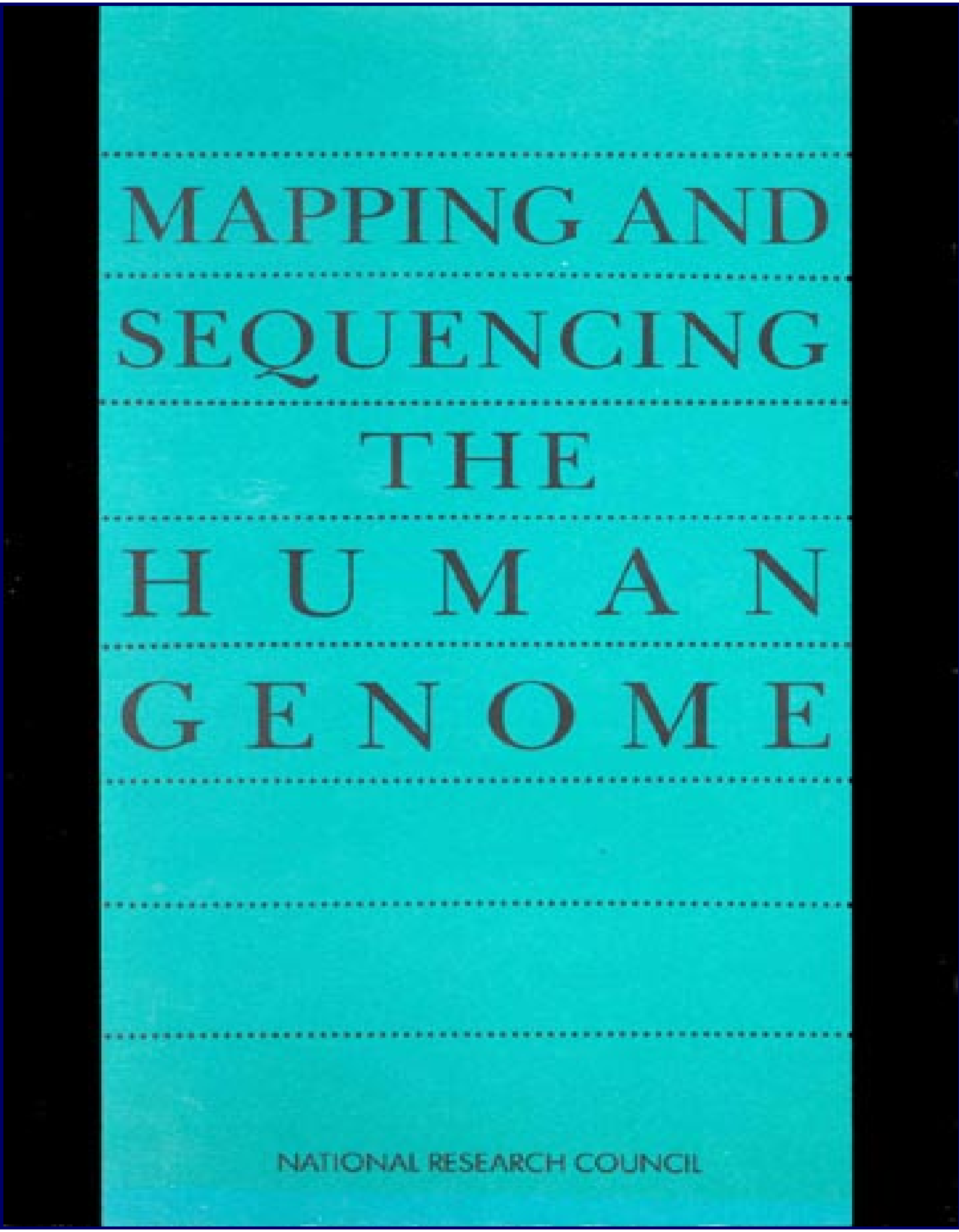
A fateful phone call in 1986

- Should there be a special project in the US to map and sequence the human genome?
- A very prestigious committee had just been established by the National Academy of Sciences to address this question.
- The committee contained members who had spoken out strongly on both sides of the argument.
- Since I had not even thought about the question previously, “I would be the ideal chair for this important committee”.

Why was any special human genome project so controversial in 1986?

- With available technology, our genome of 3 billion nucleotides would require 30,000 person years to sequence!
- The idea was broadly viewed as a big science threat to the successful small science culture and small science funding in biology.

The final report
February 1988



Another fateful phone call in late 1992

- The special nominating committee to select the next president of the National Academy of Sciences had, after a year of deliberations, selected me for this full-time job in Washington, DC.
- I had decided not to be a candidate when they had phoned me 9 months earlier.
- But please have the courtesy of meeting with the committee to discuss the possibility.

Full-time job as president of the US National Academy of Sciences

THE NATIONAL ACADEMIES

National Academy of Sciences
National Academy of Engineering
Institute of Medicine
National Research Council

My education in Washington, DC
1993-2005

U.S. National Academy of Sciences Charter (1863)

"The academy shall, whenever called upon by any department of the government, investigate, examine… and report upon any subject of science or art ,… but the Academy shall receive no compensation whatsoever for any services to the government of the United States".

Independent policy advice from the National Academies

- More than 200 reports a year,
  85 percent requested by the US government

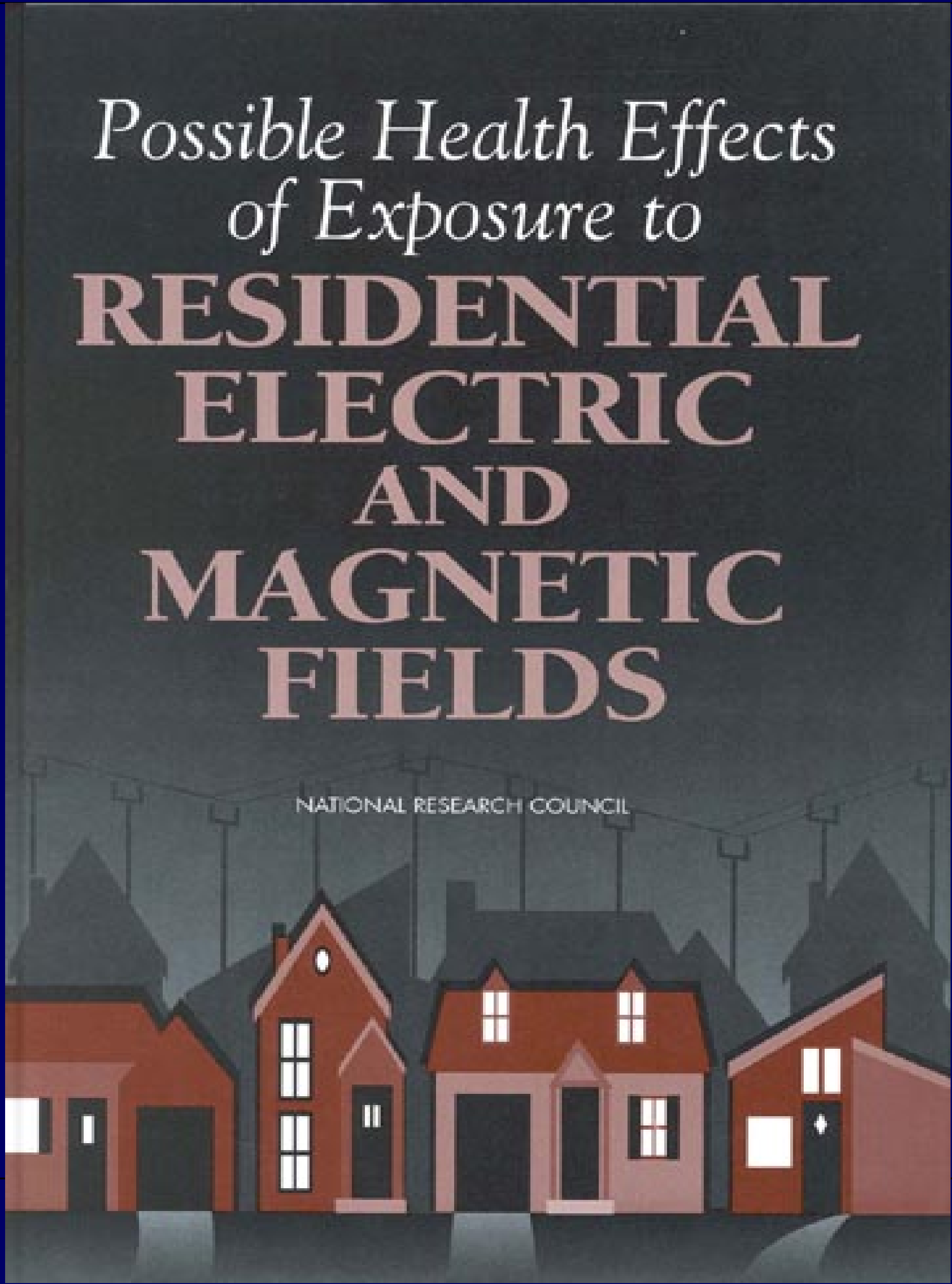
- Full text released to the press, and to the public on our Website, when report is delivered to government

How the Academies work to promote the use of science for wise decision making

I will give you four examples

Conclusion:

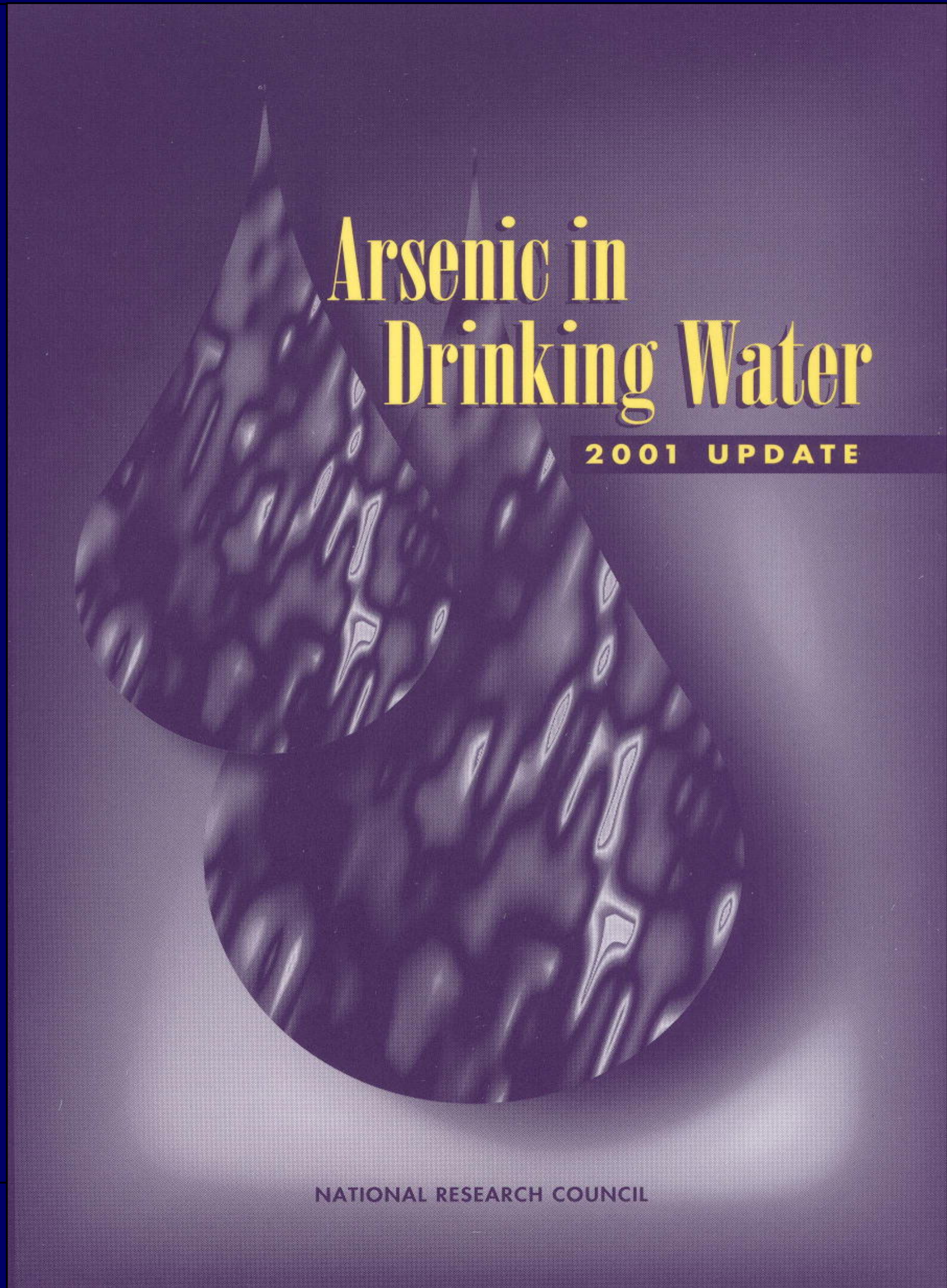
No evidence that these fields are dangerous



THE NATIONAL ACADEMIES
Advisers to the Nation on Science, Engineering, and Medicine

Conclusion:

Good
evidence
that very low
levels of
arsenic are
dangerous



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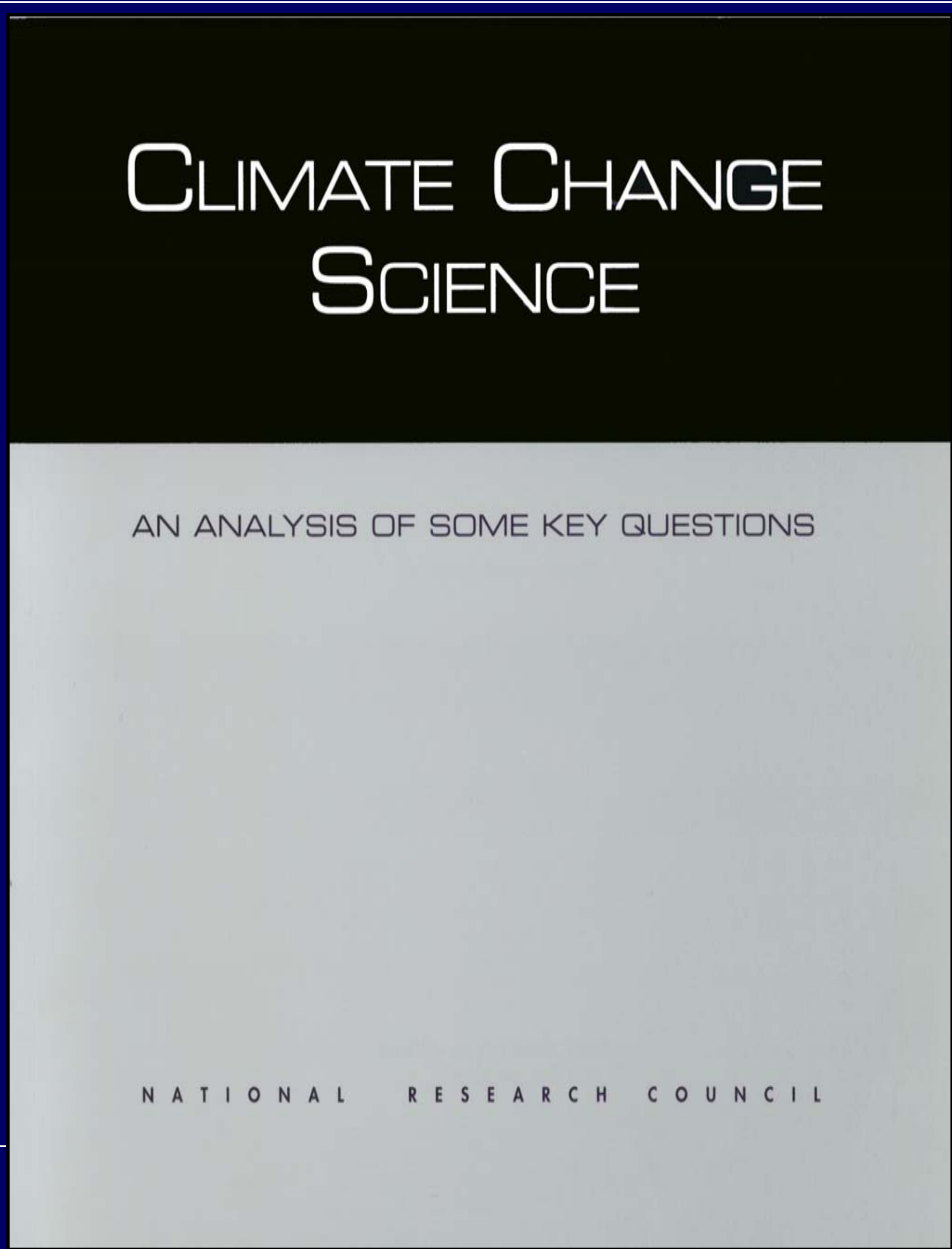
Conclusion:

Strong scientific consensus that human-induced increases in greenhouse gases will cause serious global warming



THE NATIONAL ACADEMIES
Advisers to the Nation on Science, Engineering, and Medicine

Very large 2009 report with multiple sections for Obama administration

America's Energy Future

TECHNOLOGY AND TRANSFORMATION

Committee on America's Energy Future

NATIONAL ACADEMY OF SCIENCES

NATIONAL ACADEMY OF ENGINEERING

NATIONAL RESEARCH COUNCIL OF THE NATIONAL ACADEMIES

THE NATIONAL ACADEMIES PRESS
Washington, D.C.
www.nap.edu

These are examples of “science for policy” reports

Why is science so useful for policymakers?

- Science has allowed humans to gain a deep understanding of the natural world
- In many cases, we can therefore predict the effects of current actions on the future

In cartoon form

Why does it work?

- Our government prides itself on “basing decisions on the best science”. Both sides of an argument usually claim to have science supporting it.
- Through the National Academies’ report review processes, we have made a great effort to avoid non-scientific statements, as required to be seen as a neutral advisor
- The US press pays attention to what the National Academies say, which puts pressure on government to respond

HOME EDITION

The Washington Post

TUESDAY, SEPTEMBER 11, 2001

Broader Stem Cell Research Backed

Key Science Group Differs With Bush

By Rick Weiss
Washington Post Staff Writer

Research on human embryonic stem cells deserves generous funding by the federal government and will not live up to its therapeutic potential if the work is restricted to a small number of cells from a limited number of embryos, according to a report to be released today by the National Academy of Sciences.

Moreover, scientists should be allowed to pursue research that involves the cloning of human embryos because cells derived from such embryos may prove to be especially useful for the treatment of many degenerative conditions, the report concludes.

The report by the academy, an independent organization chartered by Congress to advise the government on science issues, comes one month after President Bush announced his policy regarding federal funding of human embryo cell re-

THE DISTRICT'S LOST CHILDREN | *Babies at Risk*

A twin who died: *A photo of Tyrika Perry, who died at 5 months in 1999, is held by her sister.*

EPA to Urge Tighter Rules For Arsenic

Report Raises Agency Concern About Drinking Water Limits

By Eric Pianin
Washington Post Staff Writer

The Environmental Protection Agency has concluded that it must adopt a new standard for the amount of naturally occurring arsenic allowed in the nation's drinking water that is at least as tough as the one proposed by the Clinton administration, officials said yesterday.

EPA Administrator Christine Todd Whitman decided to recommend a stringent new limit after receiving a report from the National Academy of Sciences that found that the health risks posed by arsenic are much greater than previously assumed by the EPA, according to agency officials.

"This increases our concern about arsenic and what the level should be," an EPA official said last night.

The decision addresses one of the most controversial environmental decisions the Bush administration has made since coming into office. In March, the administration set aside a Clinton administration regulation tightening the 50-year federal standard for arsenic levels in drinking water from 50 parts per billion to 10 parts per billion. The move touched off criticism from Democrats, environmentalists and moderate Republicans and prompted a House vote seeking to reverse the action.

Whitman charged at the time that the Clinton rule had been hastily crafted without adequate scientific study or consideration of the costs for small communities that would have to change their filtration systems. She ordered further examination by the academy and other bodies

www.NAP.edu

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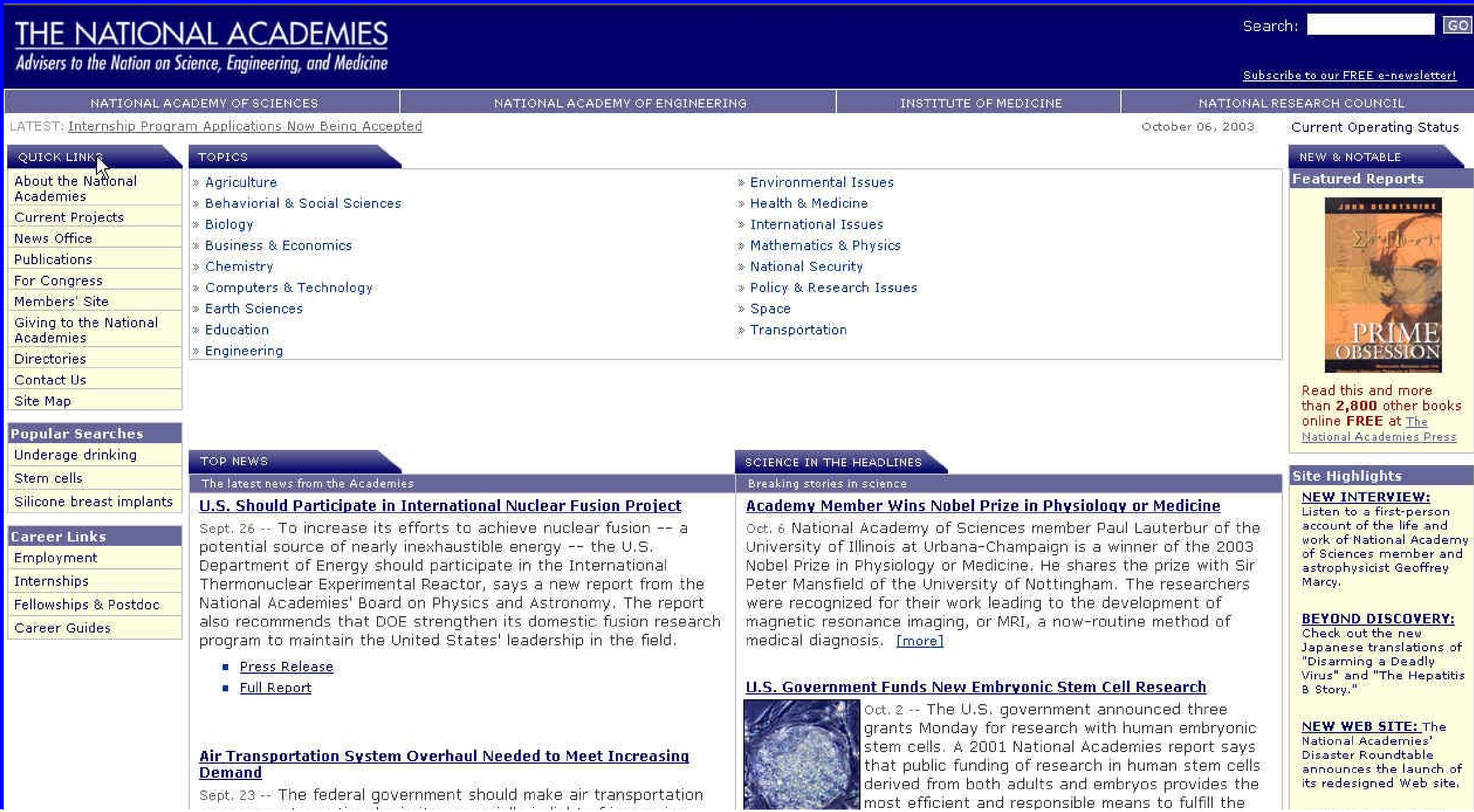
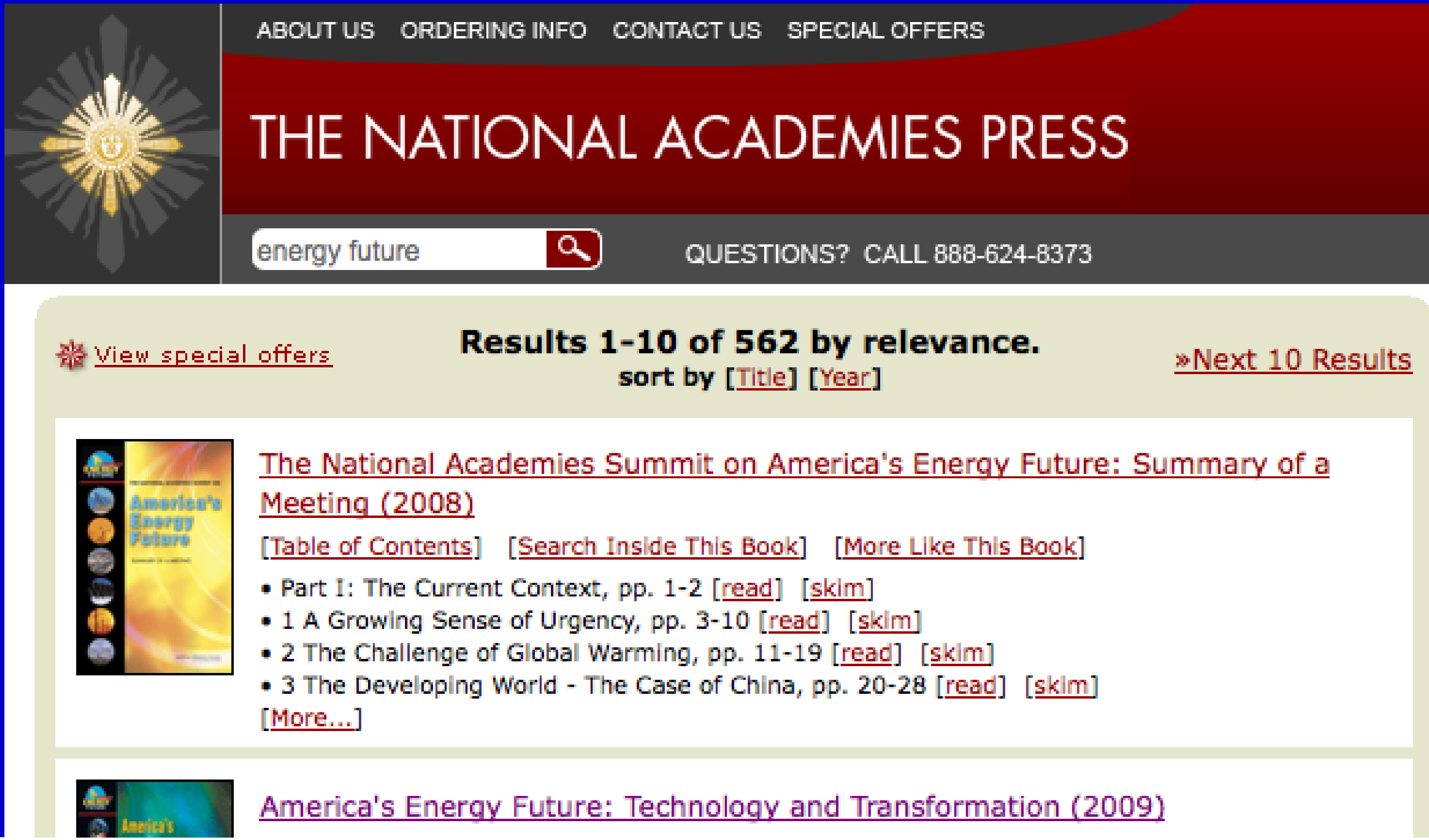
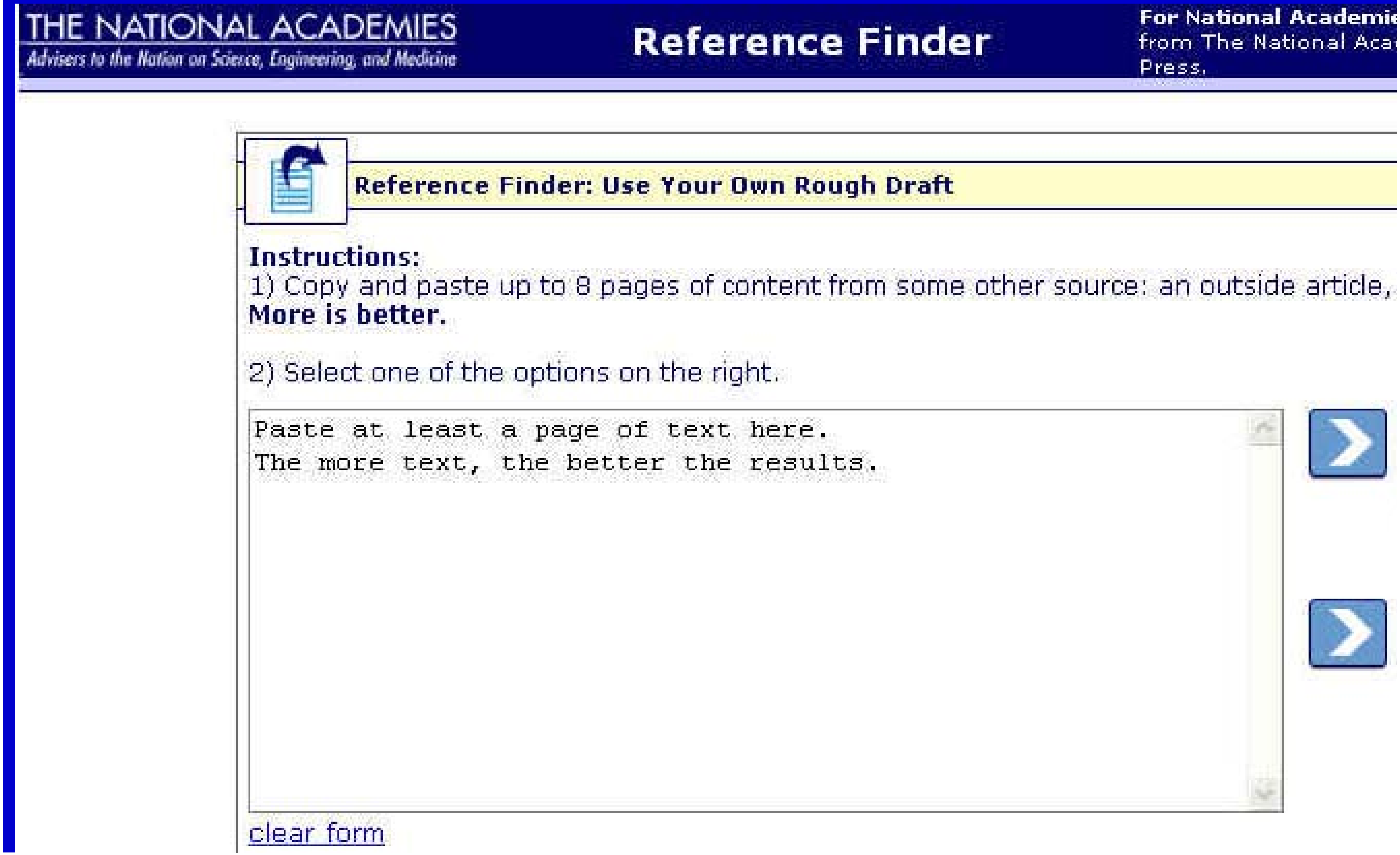


A Custom-produced Search Engine

Discovery Engine, integrates search results with intrinsic exploration tools

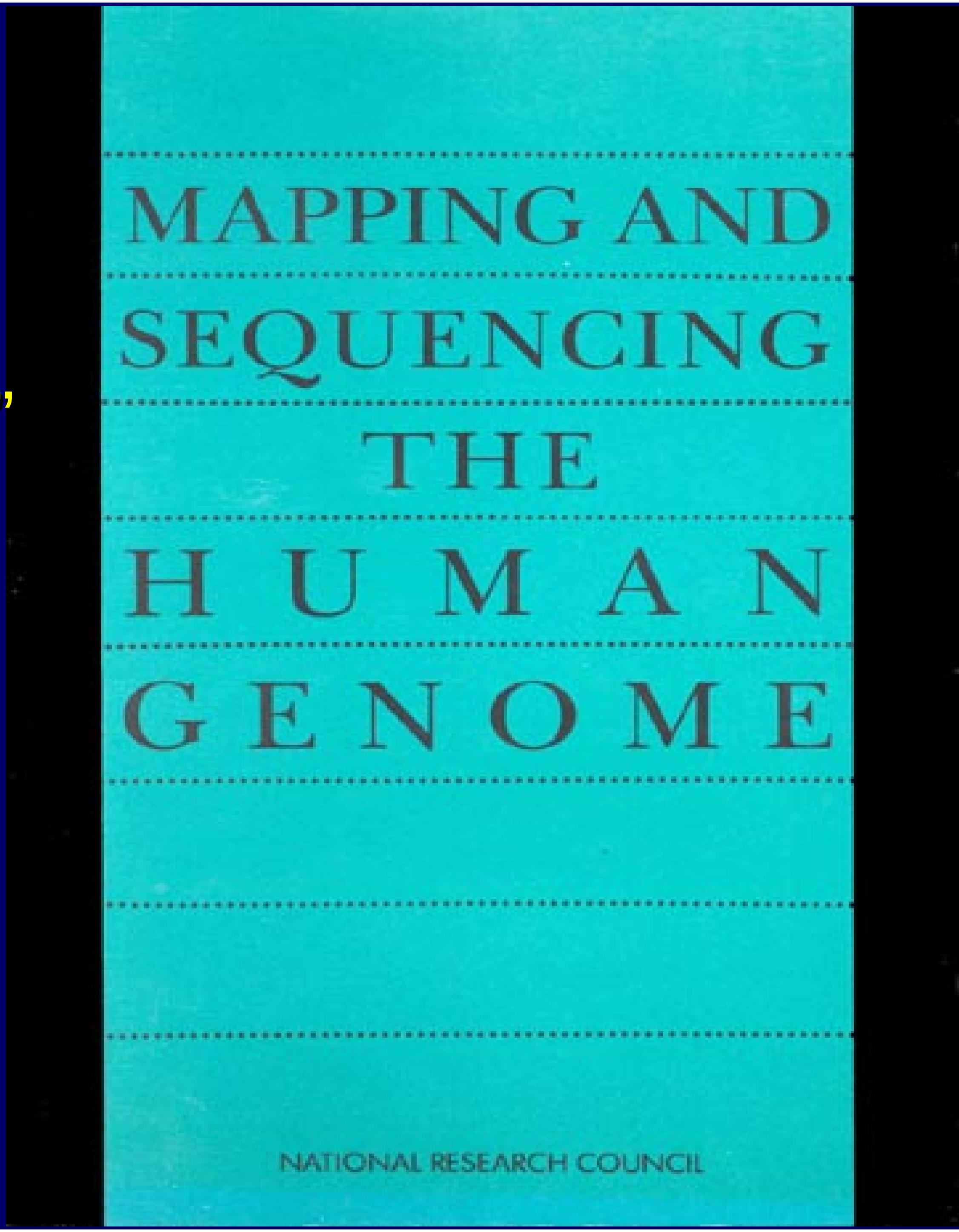


Knowledge Discovery Tool: Reference Finder, a Web form into which one can paste any text to "find more like" it



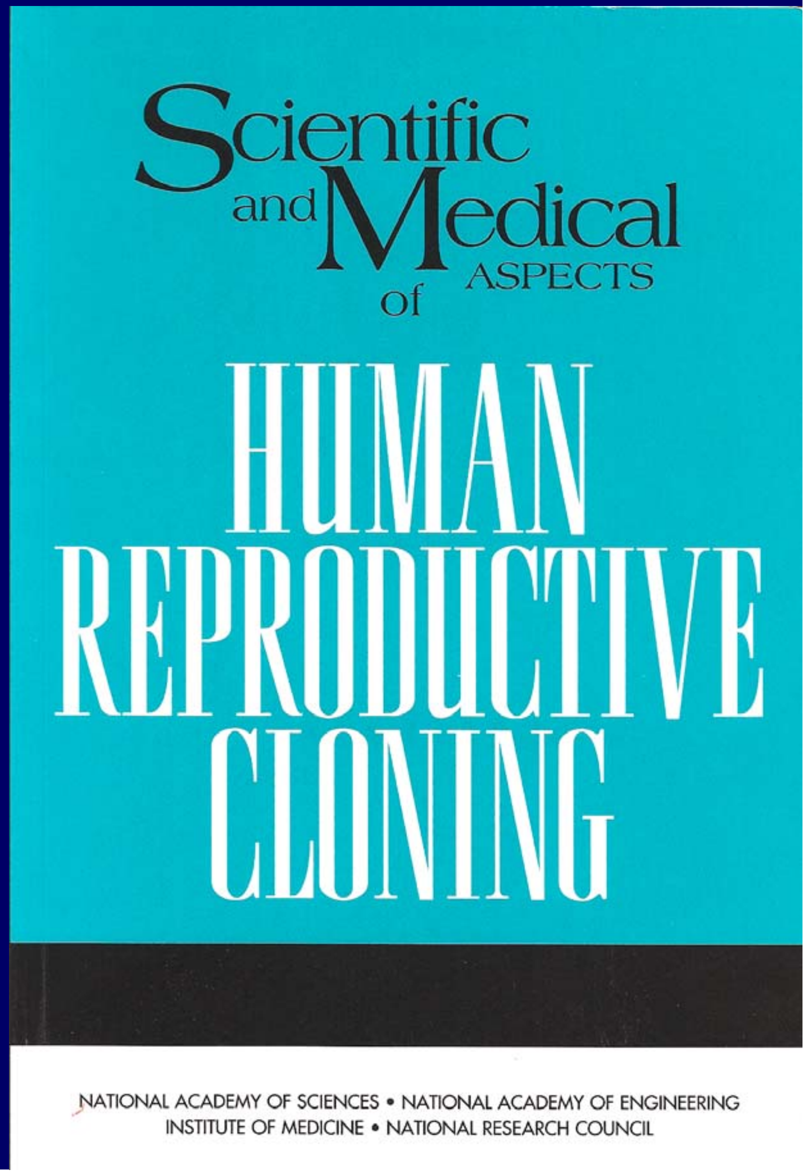
What about policy for science?

This was a
"policy for science"
report



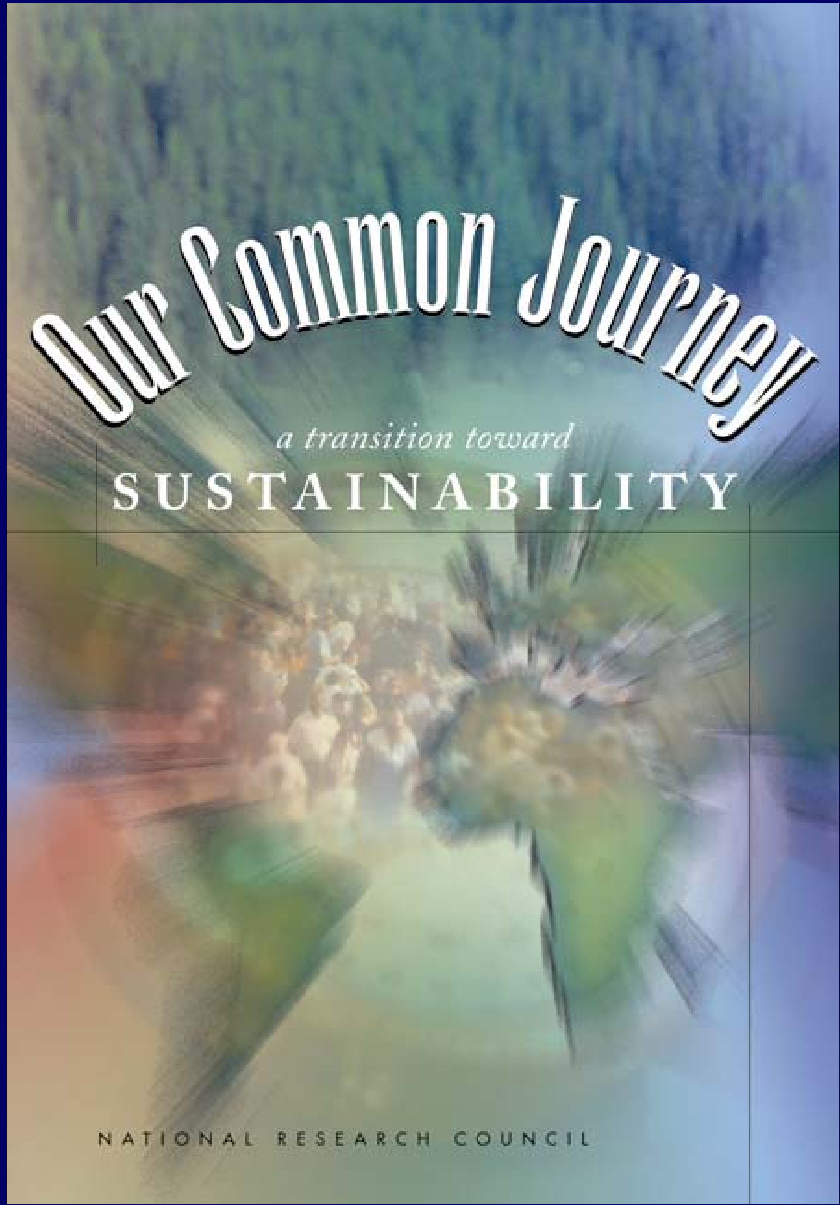
The Academies on Human Cloning, 2002

Human reproductive cloning should not now be practiced.
It is dangerous and likely to fail.
There should be a legally enforceable **ban on the practice.**



Our academy's attempt to promote an enlarged agenda for science in the 21st century

Emphasizes that -- in addition to physics, chemistry, biology, etc. -- a second, more applied type of science, termed "sustainability science" is also critical

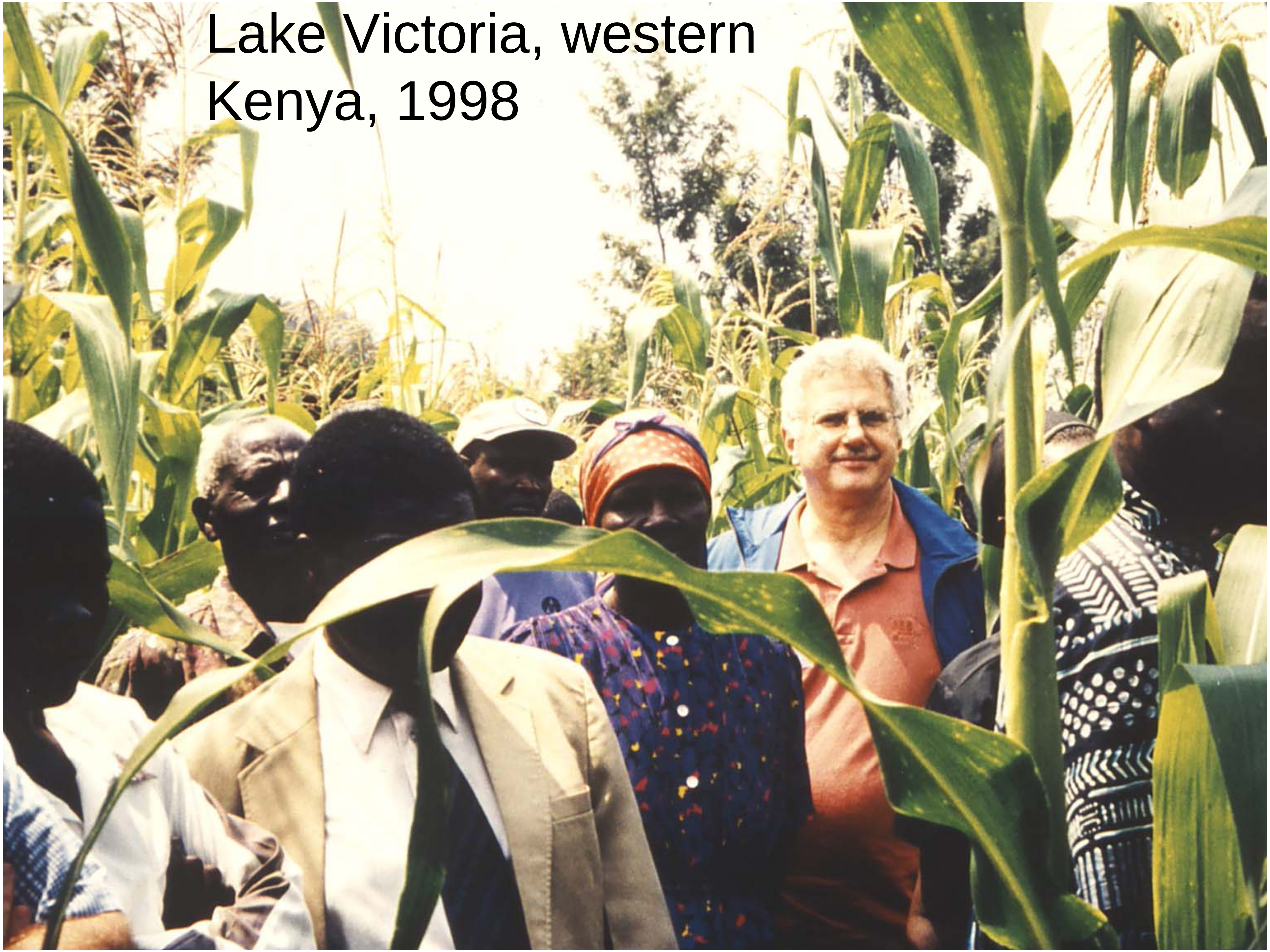


Integrating Knowledge And Action

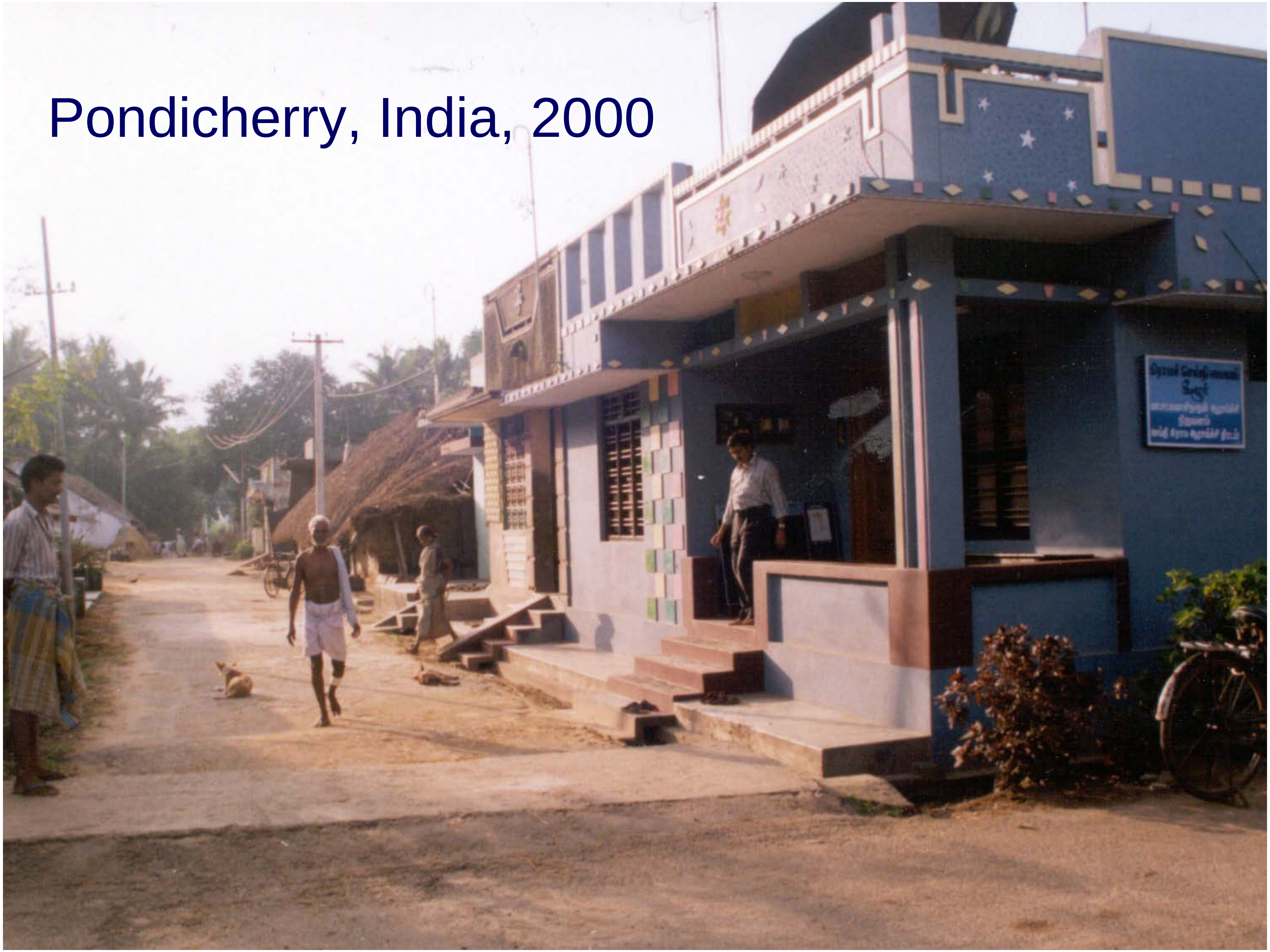
Because the pathway to sustainability cannot be charted in advance, it will have to be navigated through trial and error and conscious experimentation. The urgent need is to design strategies and institutions that can better integrate incomplete knowledge with experimental action--- into programs of adaptive management and social learning.

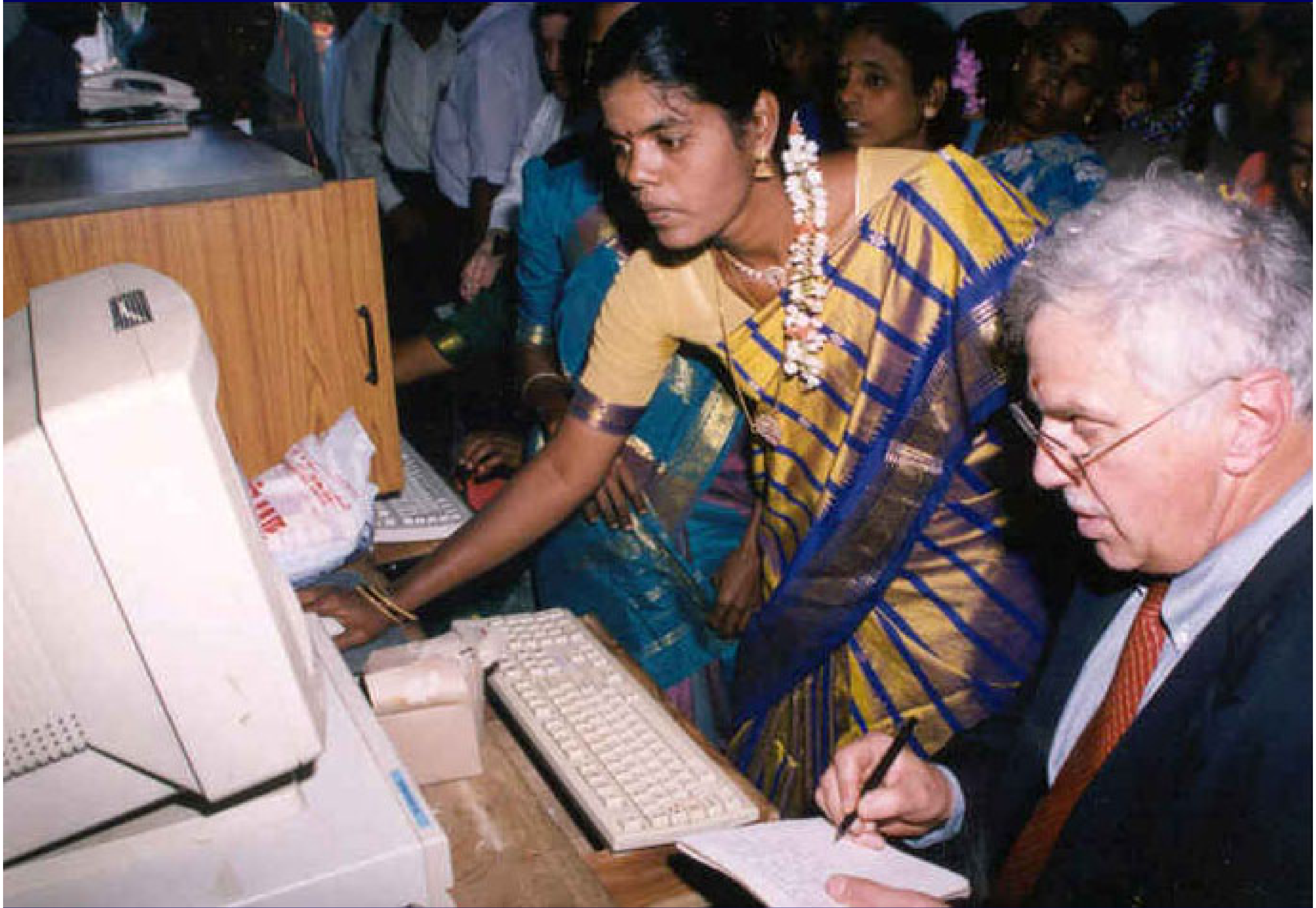
Our Common Journey, 1999

What does this mean in practice?


Lake Victoria, western
Kenya, 1998

Pondicherry, India, 2000





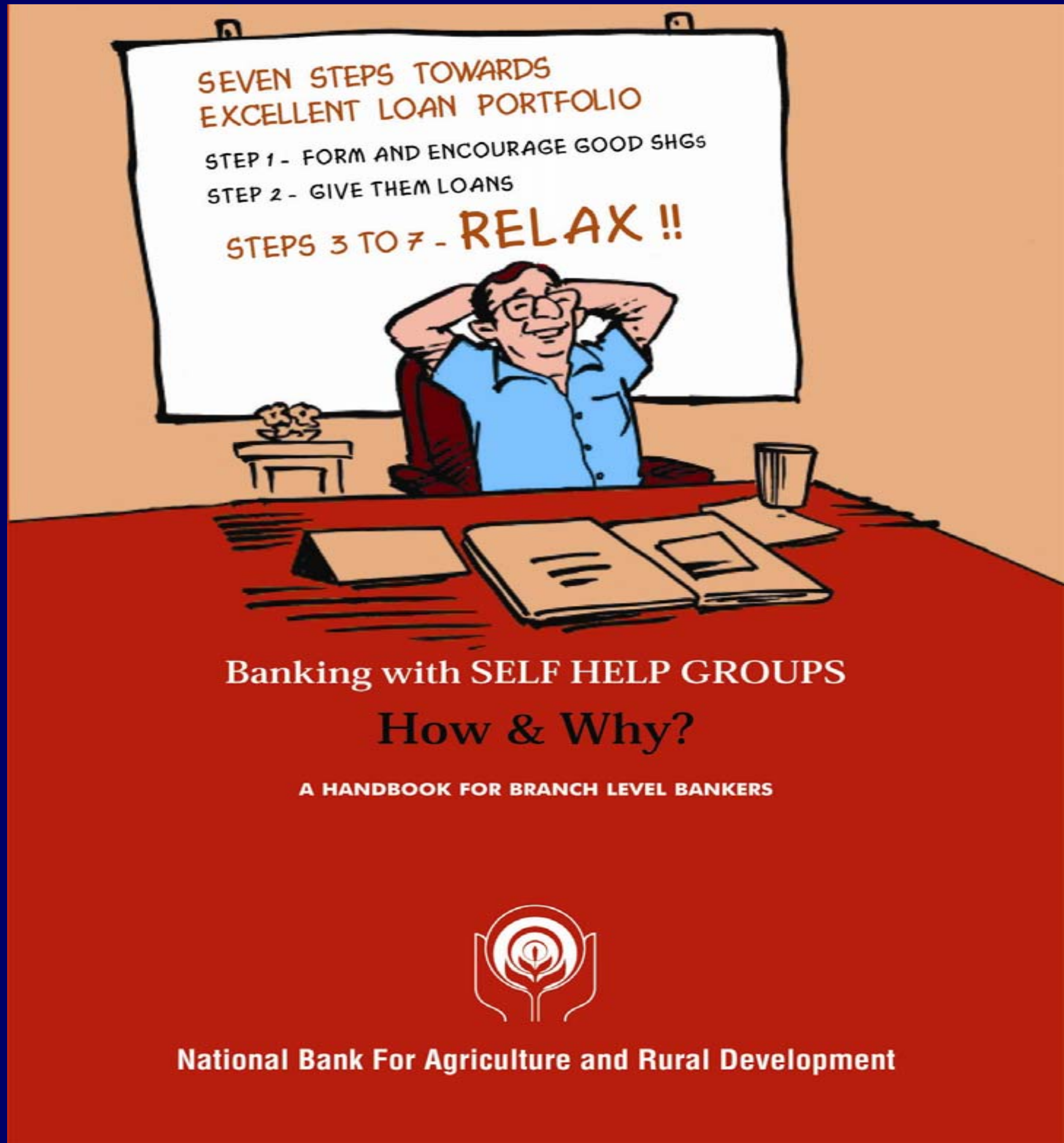
A “science franchise” that produces parasitic moths

2004: bringing in the bankers


M.S.SWAMINATHAN RESEARCH FOUNDATION
STATE BANK OF INDIA
SELF HELP GROUPS OF
FUNCTION OF ECO ENTERPRISES RURAL
KIOSKS.
16-1-2004.

www.nabard.org

“Self-Help Groups” — each composed of 10 to 20 villagers who have learned to work together — are among the bank’s best-performing customers, with 95 percent of repayments being made on time!



What I learned

Science and technology can make a major difference for national development through a myriad of interventions, but most of these are much too fine-grained for outsiders to expect to be able to solve other nation's problems.

Instead, our focus should be on helping to build the local capacities that each nation will need to solve their problems themselves.

More specifically:

It is critically important that science, and scientists, achieve a **much** higher degree of influence throughout both their nations and the world.

- This is important for the success of each nation.
- It is also important for building a better world.

In particular, we need much more of the creativity, rationality, openness, and tolerance that are inherent to science --- what Indian Prime Minister Nehru called a "**scientific temper**" -- for both the US and all other nations

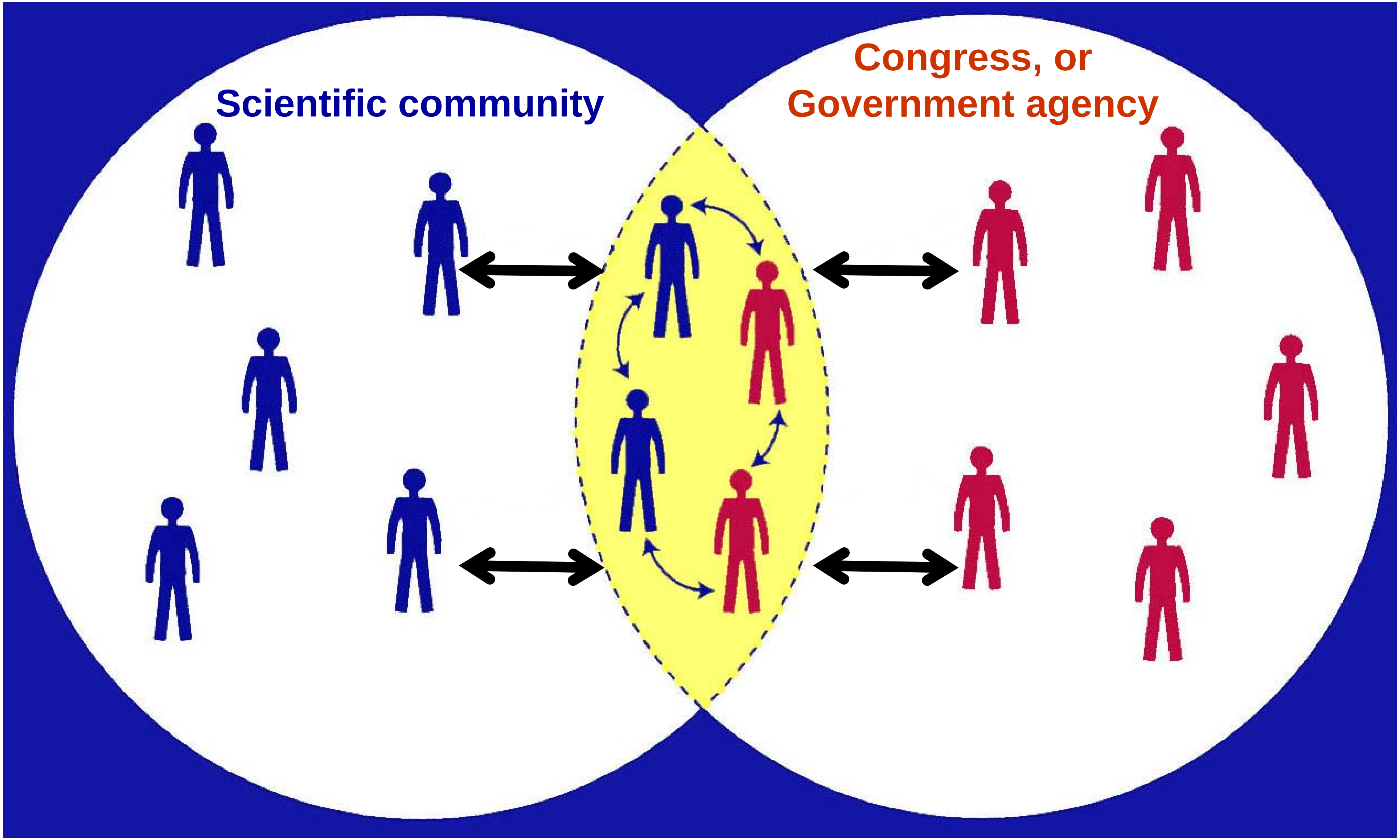
Ambitious goals: some strategies

Strategy 1, people:

To spread science, we must spread scientists

To generate a scientific temper for our nations, we will need scientifically trained people in all professions

- These individuals are invaluable for connecting our scientific community to the very different cultures of government, pre-college education, law, the media, business, etc.

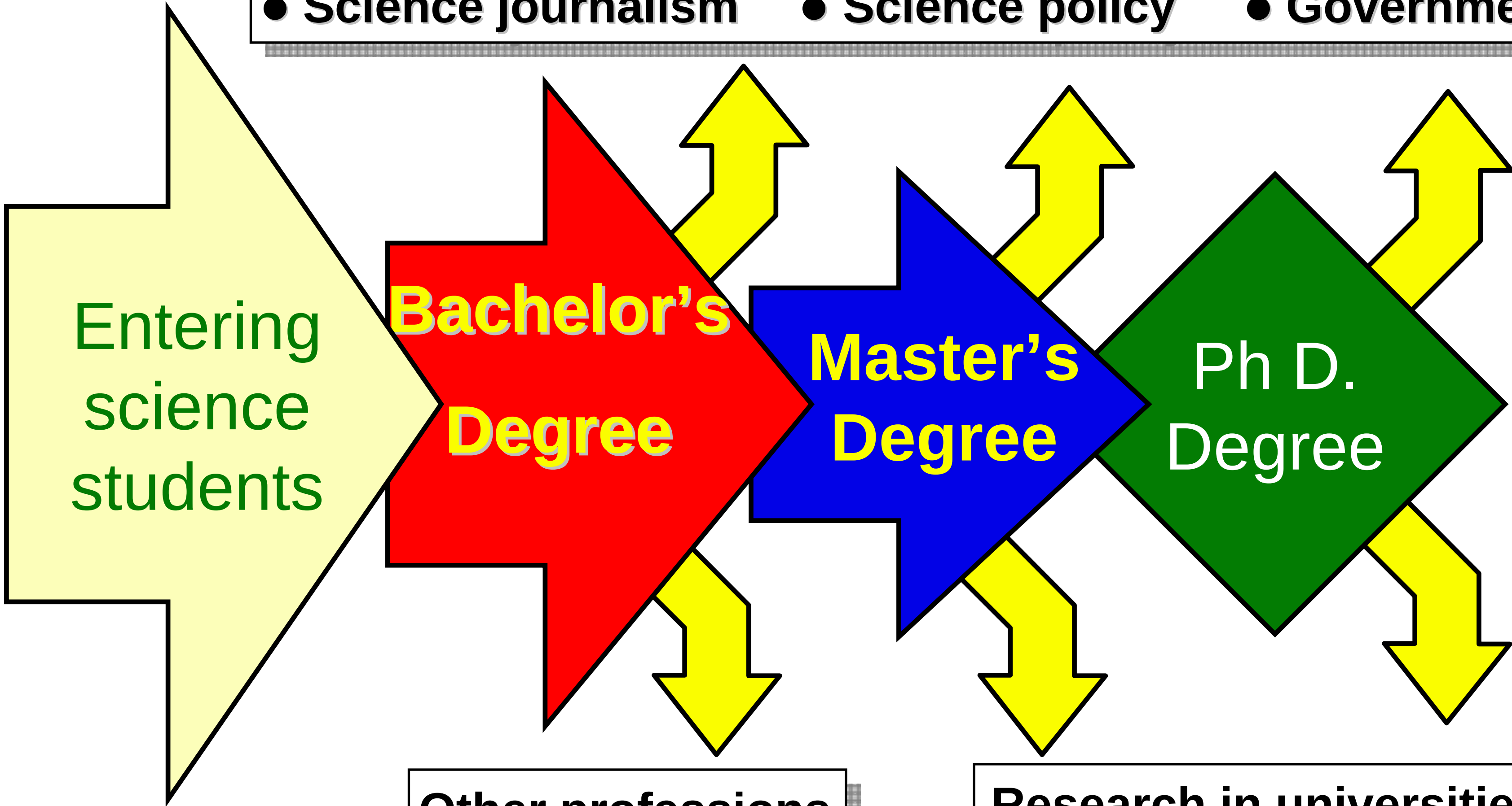


What I saw in Washington: strong interactions between individuals with a science background can bridge cultures

Encouraging a broader pipeline from college and university science departments

MANY PROFESSIONS NEEDING SCIENCE EXPERTISE

- Precollege teaching
- Curriculum development
- Science journalism
- Science policy
- Government



Other professions

Research in universities and Industry

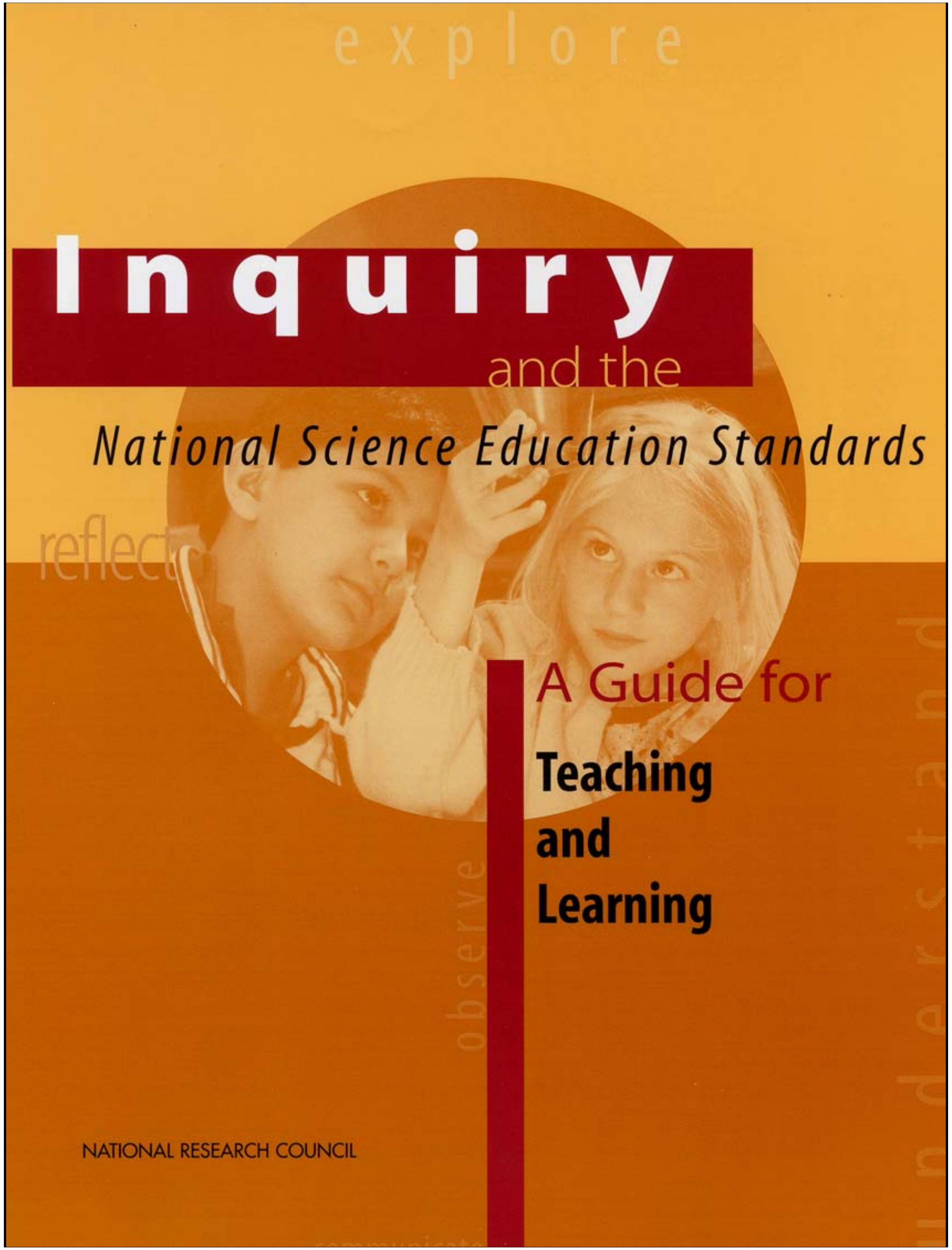
California Legislature's new Science and Technology Policy Fellows

Strategy 2, education:

A focus on science education at all levels

What science should look like in school

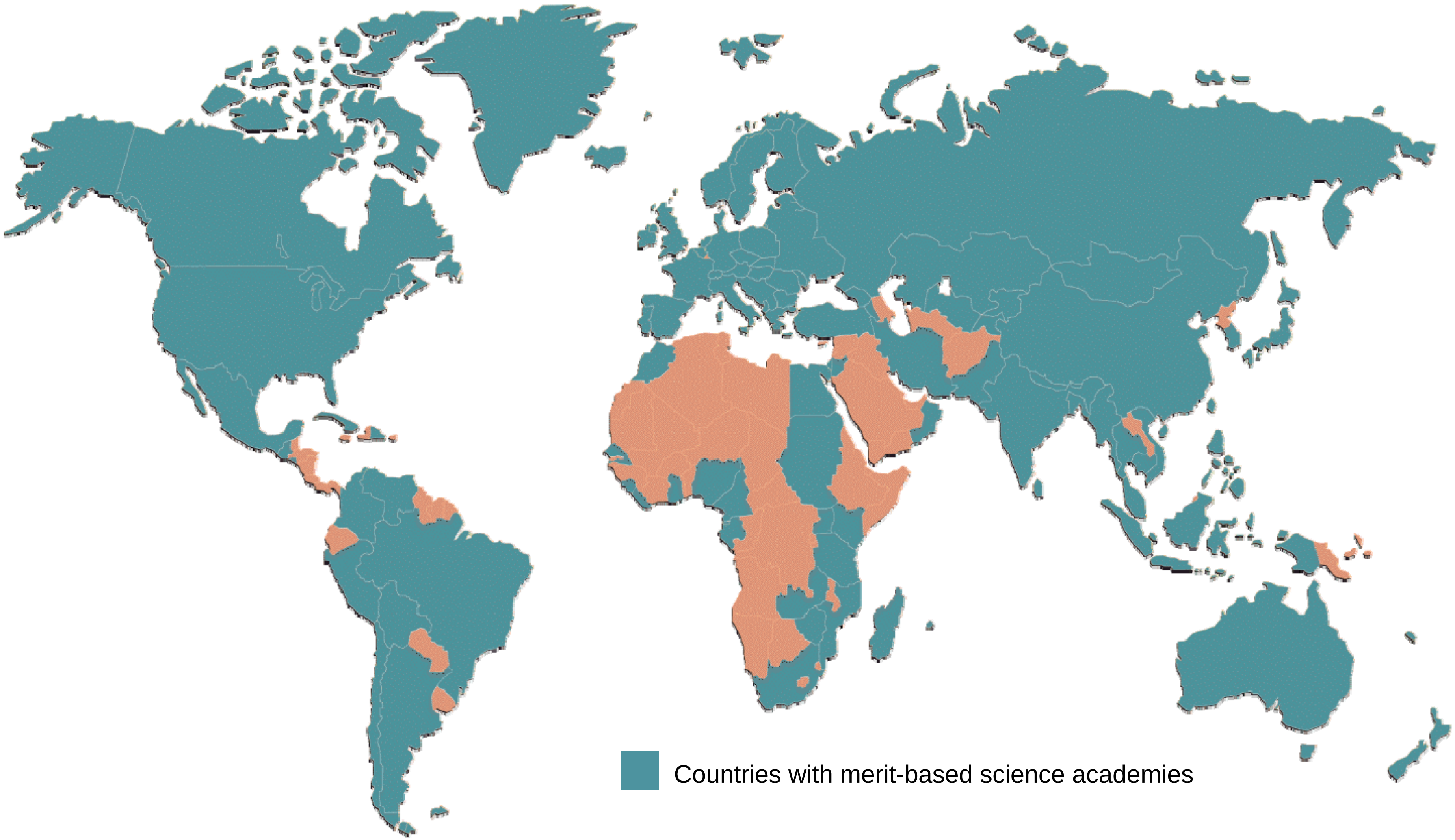
An emphasis on active inquiry



Strategy 3, scientists need to get organized!

The InterAcademy Panel (IAP) and the InterAcademy Council (IAC), two new international organizations for science

The InterAcademy Panel on International Issues (IAP) is now a network of 100 science academies Initiated in New Delhi in 1993



The support of “sustainability science” by the InterAcademy Panel

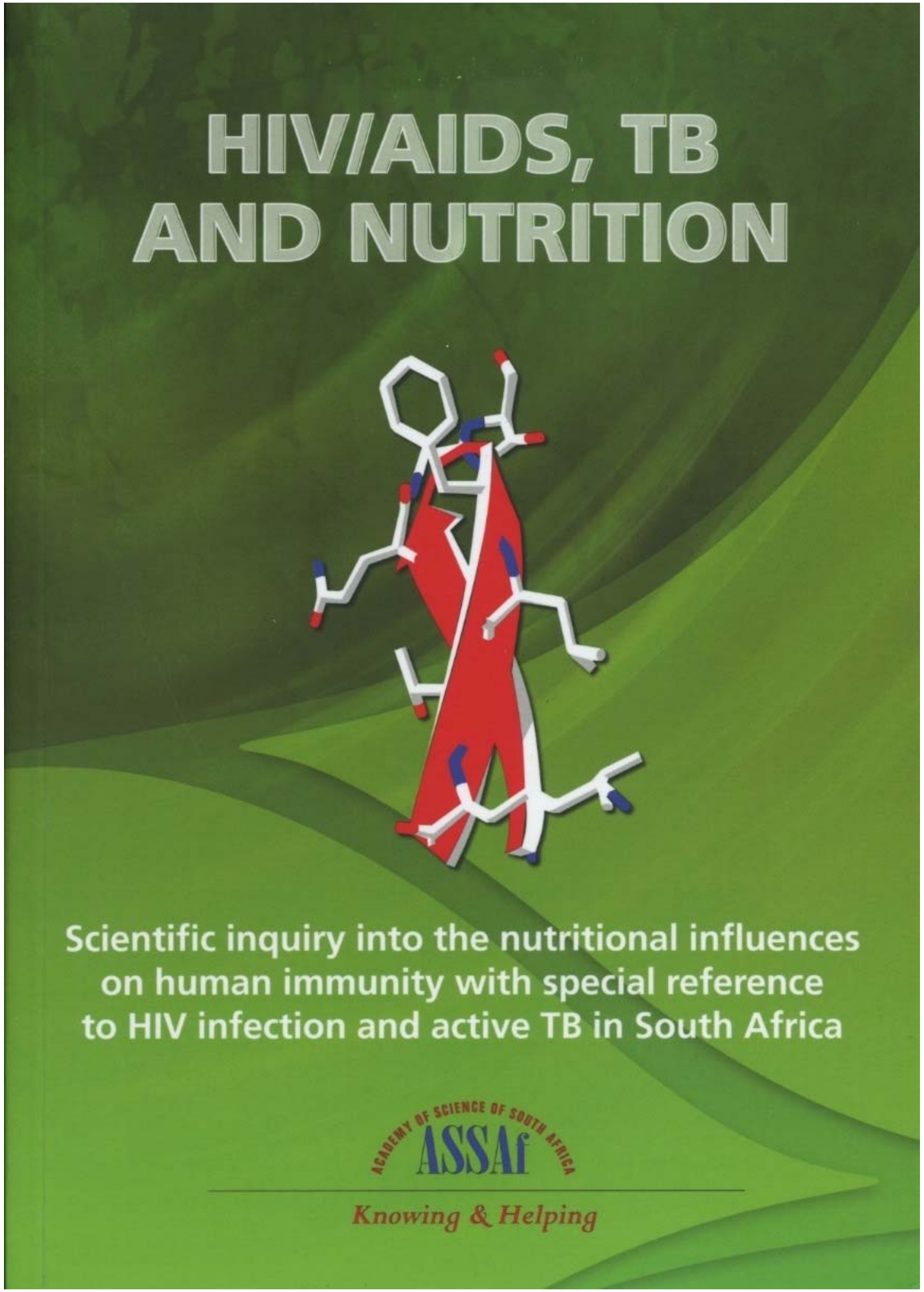
- Helping the science academies in each nation develop a larger role in their own societies, including becoming a respected advisor to their own governments
- Sharing information and resources as “public goods” to strengthen world science (e.g., electronic journals and other Web publications, programs and resources for science education, ages 5 to 25)

Often, only local scientists will have the credibility required to rescue a nation from misguided local policies and beliefs

Some recent examples:

- **Fear of polio vaccination in Nigeria**
- **Fear of GM crops in many nations**
- **Myths about HIV in South Africa**

Important recent report from the South African Academy of Sciences



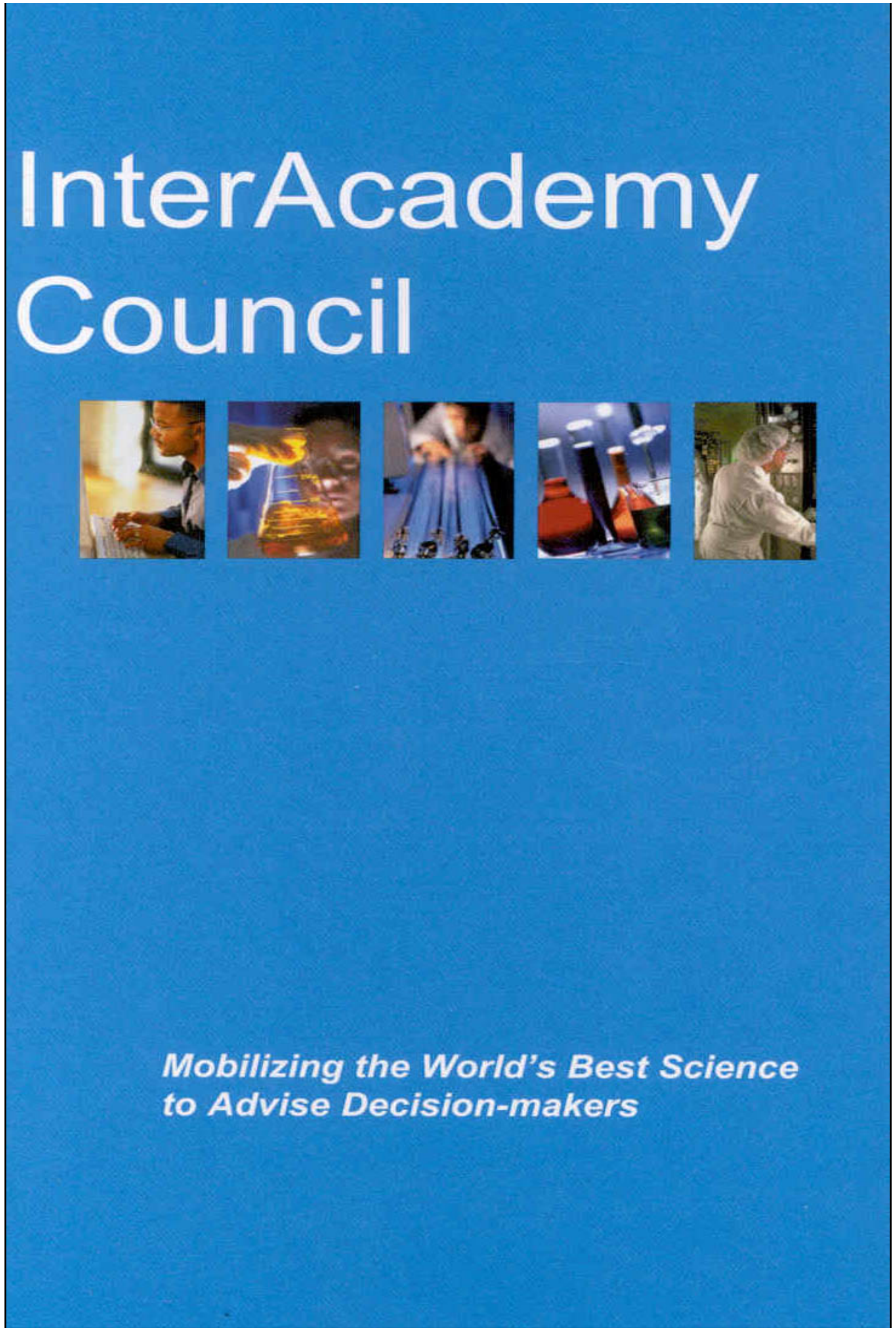
Through the IAP, the academy presidents recognized that scientists need to have a much larger presence in world affairs.

In particular, how can the world's scientists more effectively communicate their agreement on central issues?

The answer:

The IAC was established by the IAP in 2000, with a secretariat at KNAW in Amsterdam

Governed by 15 academy presidents

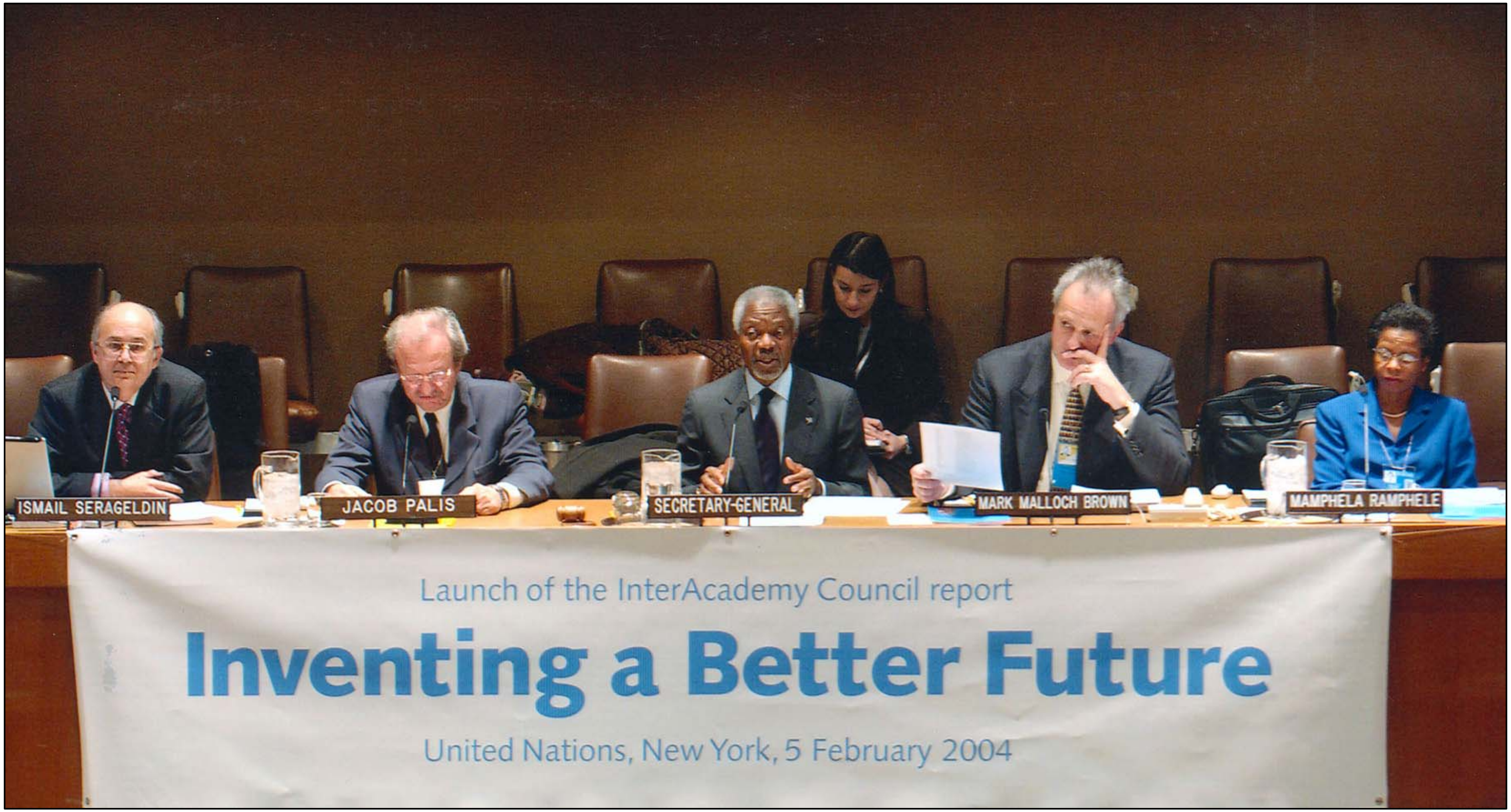


The first report of the InterAcademy Council was released at the UN General Assembly in February, 2004

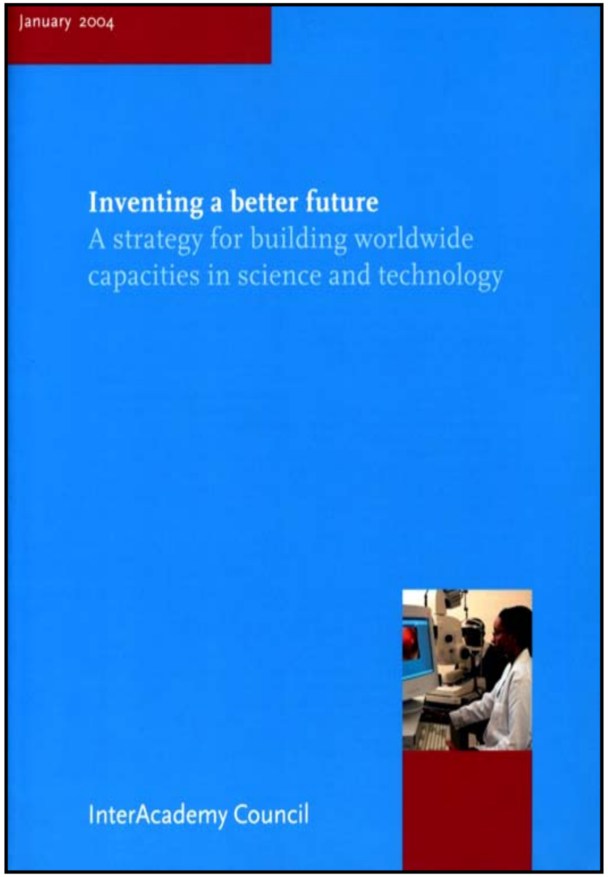
Inventing a Better Future: A Strategy for Building Worldwide Capacities in Science and Technology.

- A guide for building high quality institutions for science and technology in every nation.
- Committee co-chairs from Brazil and Egypt, plus scientists from 10 other nations.

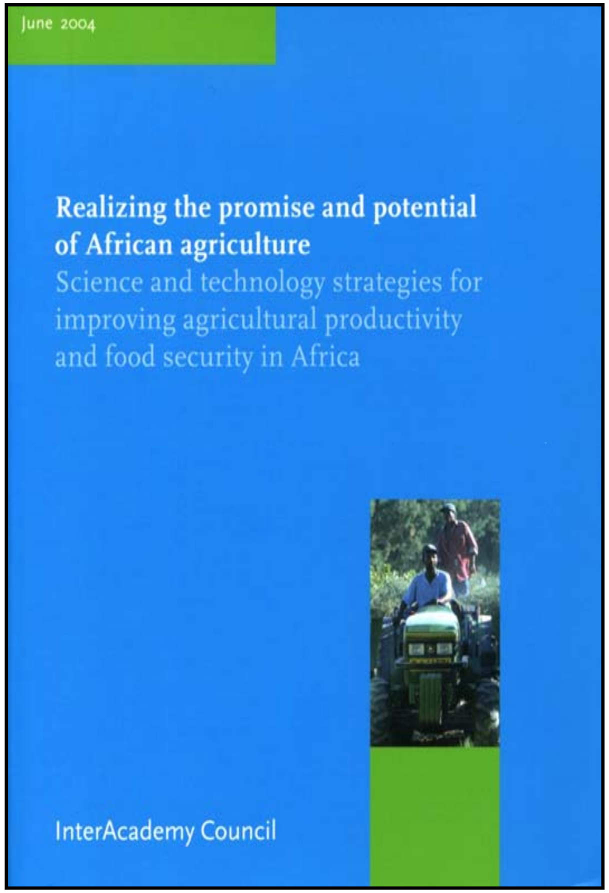

Inventing a Better Future


ISMAIL SERAGELDIN
JACOB PALIS
SECRETARY-GENERAL
MARK MALLOCH BROWN
MAMPHELA RAMPHELE
Launch of the InterAcademy Council report
Inventing a Better Future
United Nations, New York, 5 February 2004

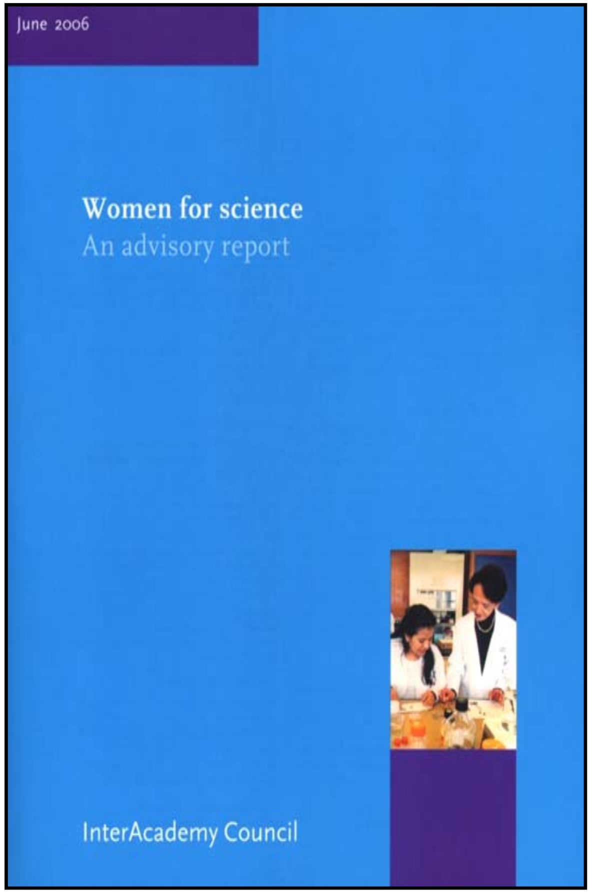
The first three IAC reports, 2004 to 2006



capacity building



agriculture



women

4th IAC report released October 2007

Lighting the Way: Toward a Sustainable Energy Future

Co-chairs:

Steve Chu (USA) and Jose Goldemberg (Brazil)

Chu (Nobel Prize Physics) is now the Secretary of Energy for the US

For every nation, strong institutions for science and technology are key

Scientists are unlikely to be effective in either their work or in guiding the decisions made by their nations without strong institutions to support and harness their efforts.

To develop, harness, and retain the talent needed in every nation, building and supporting effective merit-based institutions for science and technology must become a key goal for development.

The urgent need for capacity building

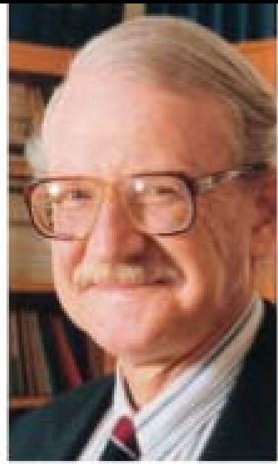
- Those of us in more scientifically advanced nations must help less advanced nations develop a greater capacity in science and technology, as appropriate to their national needs.

- This in our own interest, as well as being critical for the rest of the world.

The promise of world science collaboration

Science magazine as a tool for improving the scientific enterprise

EDITORIAL

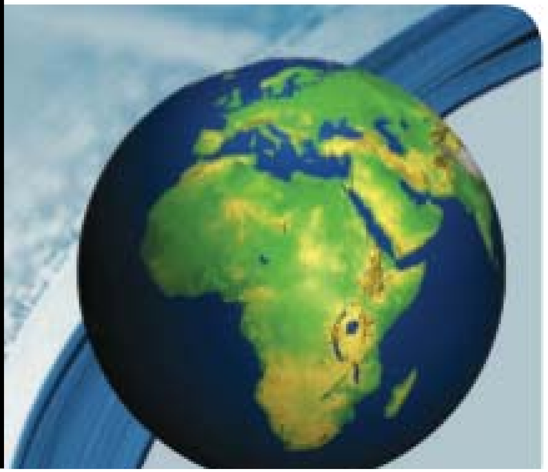


Globalizing Science Publishing

Wieland Gevers is Emeritus Professor of Medical Biochemistry at the University of Cape Town in South Africa; he was President of the Academy of Science of South Africa from 1998 to 2004.

PUBLISHING IN SCIENTIFIC JOURNALS IS THE MOST COMMON AND POWERFUL MEANS TO DISSEMINATE new research findings. Visibility and credibility in the scientific world require publishing in journals that are included in global indexing databases such as those of the Institute for Scientific Information (ISI). Most scientists in developing countries remain at the periphery of this critical communication process, exacerbating the low international recognition and impact of their accomplishments. For science to become maximally influential and productive across the globe, this needs to change.

The economy of electronic publication, open access, and property rights fuel current academic and policy debates about scientific publishing in the industrialized world. The concerns in the developing world (with few ISI-indexed journals) focus on more fundamental questions, such as sustaining local research activity and achieving the appropriate global reach of its science activities.



The essence of the African situation is captured by R. J. W. Tijssen's analysis of publications by African authors,* which was based not only on data from ISI indexing databases, but also on publications not indexed in this system. Surprisingly, half of the South African citations in the indexed ISI literature are to articles in nonindexed, locally published journals. Also, several nonindexed local journals are cited in the ISI system at about the same rate as are indexed journals. The share of indexed articles with at least one author with an African address remains steady at about 1%. About half of the ISI-indexed papers with at least one author with an African address have non-African partners outside of the continent. These figures vary, country by country, sometimes in surprising ways. For example, 85% of the papers published from Mali or Gabon involve

Calestous Juma is a professor of the Practice of International Development at the Kennedy School of Government, Harvard University, Cambridge, MA. E-mail: calestous_juma@harvard.edu.

Elisabeth Moyer is an assistant professor in the

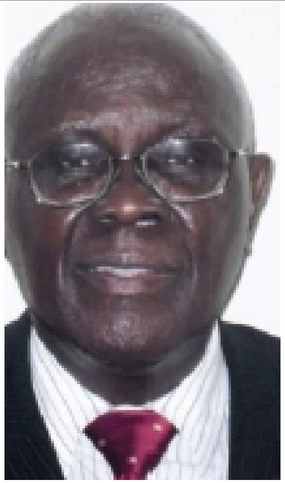
Broadband Internet for Africa

IMAGINE A MAJOR RESEARCH UNIVERSITY WITH TENS OF THOUSANDS OF STUDENTS TRYING to access the Internet through a single U.S. household connection. That is the present situation in most African universities. Students there theoretically have access to *Science* through several journal archives for the developing world. In practice, most could never download it.

Sub-Saharan Africa is the most digitally isolated region in the world, with a bandwidth per capita that is only 1% of the world average and 0.2% of that in the United States. Not surprisingly, sub-Saharan Africa also has among the highest connectivity costs in the world. Its universities pay some 50 times more for bandwidth than do similar institutions in the United States, and connectivity cost per gross domestic product is almost 2000 times higher than in the United States. The resulting isolation of Africa's students from the remainder of the world is a serious impediment to both education and economic development.

The challenges the continent faces—meeting human needs, participating in the global economy, managing the environment, and improving governance, all outlined in the 2007 report *Freedom to Innovate*, commissioned by African presidents—require engineers, doctors, scientists, and businesspeople, all products of Africa's universities. For years, strategies to address these challenges centered on providing direct assistance for combating disease and poverty and for providing food and water. But living conditions in Africa cannot be improved without sustained long-term economic growth. That goal in turn requires connecting Africa to the rest of the world. The 3 million college students in sub-Saharan Africa need the same resources and access to knowledge as students anywhere. Next month, when the G8 summit opens in Japan, this aspect of African development should be a priority.

Africa's isolation is the result of both lack of infrastructure and lack of competition in telecommunications. West Africa is connected to the

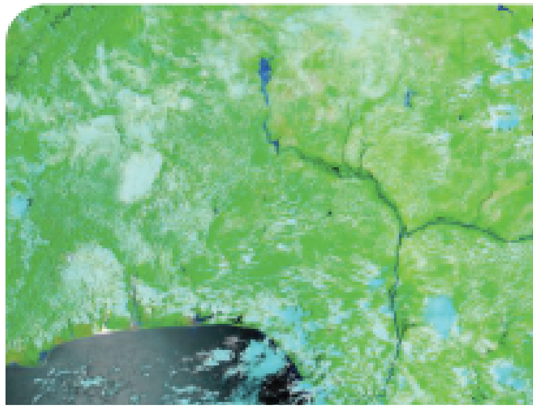


Akin L. Mabogunje is chairman of the Foundation for Development and Environmental Initiatives, Ibadan, Nigeria. E-mail: mabogun@skannet.com

New Land Reform in Nigeria

IN AN INTERVIEW FOR ALLAFRICA.COM THAT WAS CONNECTED TO HIS VISIT LAST MONTH TO GHANA, U.S. President Obama noted that progress was being made in the rule of law, anti-corruption efforts, and the protection of property rights in Africa. Success in these endeavors requires that Africa faces squarely several fundamental impediments to progress. In doing so, it must access the best available science and technologies not only from the natural sciences and engineering, but also from the social sciences. A critical example that combines all of these elements relates to property rights and land tenure reform, which is an issue at the heart of reducing poverty, promoting wide-ranging development, and ensuring the basic rights of African citizens.

The World Bank estimates that about 70% of the population of my country, Nigeria, lives on less than U.S.$1 to $2 a day. In discussions of poverty here and throughout Africa, far too little emphasis is placed on the economic incapacitation of the population due to their having no recognizable property rights. Nigerian citizens thereby miss out on many economically empowering possibilities that such rights confer, including access to the collateral that is required to acquire credit from financial institutions. This ability could bring them into the mainstream of the growing market economy



For several decades, many African countries have engaged in programs aimed at realigning their largely kinship-based, communal land tenure to the demands of an increasingly free-market economy. Initially, in the 1970s and 1980s, such land reform attempts devolved into legislating custodial rights of communal land to governments in a manner reminiscent of land nationalization. The growing inequi-

EDITORIAL

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Science in the Future of India

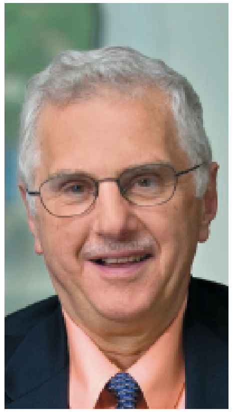
INDIA HAS VOTED FOR SCIENCE. IN MAY, HALF A BILLION PEOPLE CAST THEIR BALLOTS, AND THEY decisively favored spurring the development of the world's second most populous nation. The reelected Prime Minister Manmohan Singh and his new coalition government have made a commitment to reduce poverty and disease, create employment, and stimulate rural and industrial development. Attaining these goals will require substantial new investments in science and technology (S&T) plus much greater investments in human capital.

Since achieving freedom in 1947, India has established many institutions devoted to science and higher education. Most notably, five Indian Institutes of Technology (IITs) were established between 1951 and 1963, and by 2008 there were 13 IITs: national degree-granting institutions devoted to the training of high-quality engineers and scientists. Despite the gap in infrastructure between advanced countries and India, there have been critical successes in areas such as space, atomic energy, and agriculture. In fundamental research too, India has made progress. Because of the innumerable demands on the economy, however, the higher-education sector has not received adequate support. Part of the reason for the decline in India's university science education system in the past decades has been the preferential funding for R&D activities in national research laboratories.

Prime Minister Singh has recently announced an increase in government investment in S&T from the present 1% of gross domestic product (GDP) to 2% of GDP over the next year or two, an increase of unprecedented magnitude. The contribution of industry has also increased significantly in the past few years, now amounting to approximately 20% of the nation's total investment in science R&D. And the government has begun appropriate administrative reforms as well. For example, two

My current obsession

Using science and *Science* to create more coherence in the field of education



Bruce Alberts is Editor-in-Chief of *Science*.

EDITORIAL

Redefining Science Education

THERE IS A MAJOR MISMATCH BETWEEN OPPORTUNITY AND ACTION IN MOST EDUCATION SYSTEMS today. It revolves around what is meant by "science education," a term that is incorrectly defined in current usage. Rather than learning how to think scientifically, students are generally being told about science and asked to remember facts. This disturbing situation must be corrected if science education is to have any hope of taking its proper place as an essential part of the education of students everywhere.

Scientists may tend to blame others for the problem, but—strange as it may seem—we have done more than anyone else to create it. Any objective analysis of a typical introductory science course taught today in colleges and universities around the world, whether it be biology, chemistry, physics, or earth sciences, would probably conclude that its purpose is to prepare students to "know, use, and interpret scientific explanations of the natural world" (strongly emphasizing the "know"). This is but one of four goals recommended for science education by the distinguished committee of scientists and science education experts convened by the U.S. National Academies that produced *Taking Science to School: Learning and Teaching Science in Grades K-8*. And yet college courses set the model for the teaching of science in earlier years.

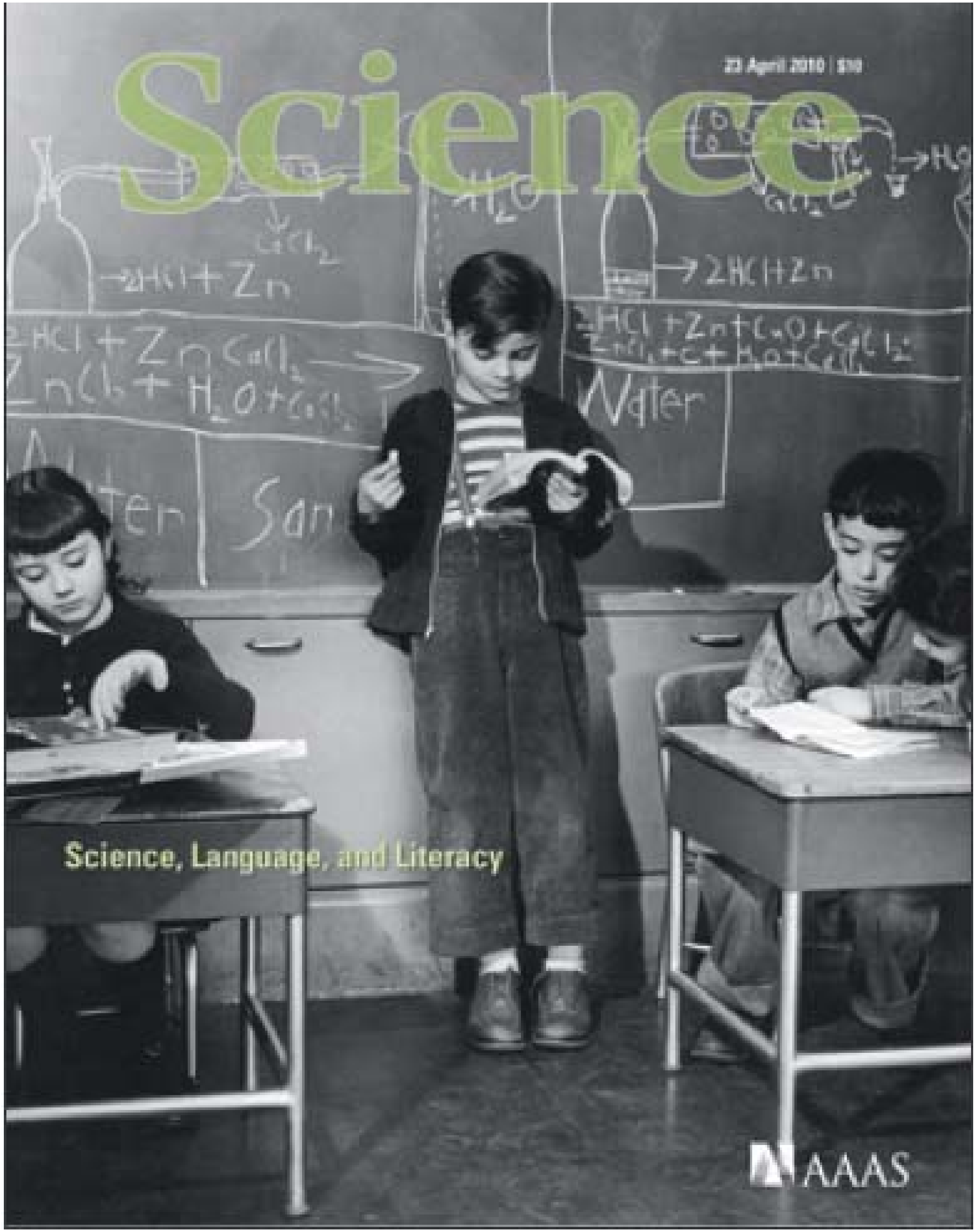
The three other goals of equal merit and importance are to prepare students to generate and evaluate scientific evidence and explanations, to understand the nature and development of scientific knowledge, and to participate productively in scientific practices and discourse (summarized in the Academies' *Ready, Set, Science!*). Scientists would generally agree that all four types of science understanding are critical not only to a good science education but also to the basic education of everyone in the modern world. Why then do most science professors teach only the first one?

As the scientist and educator John A. Moore emphasized in his pro-

April 23, 2010

Special issue:

Connecting science to language and literacy



Most recent issue

Also critical to work to improve the scientific enterprise itself!

Collaborating with the chief editors of *Nature* and the *Proceedings of the National Academy of Sciences*:

1. To establish an **“author ID” system”** so that each author can be specifically identified in databases like PubMed.

2. To discourage “honorary authorships,” require that the **contribution of each author be published** with a paper.

Also critical to work to improve the scientific enterprise itself!

Collaborating with the chief editors of *Nature* and the *Proceedings of the National Academy of Sciences*:

3. To **insure data quality**, require that a senior author take responsibility for having seen the original data for each type of method used in a publication.

4. To **encourage mentoring** by senior scientists, establish a separate mentoring search feature in PubMed and other databases.

My favorite quote

“The society of scientists is simple because it has a directing purpose: to explore the truth. Nevertheless, it has to solve the problem of every society, which is to find a compromise between the individual and the group. It must encourage the single scientist to be independent, and the body of scientists to be tolerant. From these basic conditions, which form the prime values, there follows step by step a range of values: dissent, freedom of thought and speech, justice, honor, human dignity and self respect.

Science has humanized our values. Men have asked for freedom, justice and respect precisely as the scientific spirit has spread among them.”

Jacob Bronowski, Science and Human Values, 1956