

UNIVERSITY of MINNESOTA – HAYES LECTURES:
"SETTING AN AGENDA FOR 21st CENTURY SCIENCE"

Martin Apple, PhD May 1, 1997

ALL SCIENCE IS FOUNDATIONAL

All science has a common direction: find out what we want to know but do not know. The paradigm of most frontier scientific and technology practice is

Conceive--> Believe-->Achieve.

What we achieve is understanding about the way Nature really works. We use powerful methods of defining and solving problems. We use the method of multiple working hypotheses to ferret out the truth about how Nature is and operates. Ours is a system of self-correcting development of truth. Scientists have the exhilarating opportunity and experience of being able to routinely walk each day where no footprints have ever existed before. We extend that paradigm to additional utility by using that sequence from conceive-->believe-->achieve to not only enlarge our understandings and build our knowledge but to provide amenity in the form of new technology. Thus all science in our world is not, as often falsely dichotomized, either basic or applied, but is instead all foundational. Scientists in any lab mixing test tubes of substances, or fusing atoms, or dissecting how groups of neurons learn, or measuring mutant gene behaviors or cloning an animal or even creating an entirely new species are doing research. We cannot tell by observing the experiment if it is basic or applied, so we have created an arbitrary distinction by asking the performers their motives, and then label the research, even though their answers may change day by day.

All science can be properly described as foundational because it serves as the foundation for more new discovery and/or more new utility. This foundation is indeed the foundation of our future.

We have begun to recognize that the driving force of American foundational science during most of the lifetimes of those here has been driven by the federal funding of the Cold War. The government, enamored by the quick end to WWII that grew out of the work of one team of researchers, and encouraged by the American belief in new frontiers, redirected resources into science, the endless frontier. Federally funded foundational scientific research grew at a 2-digit percent annually until in occupied \$40 billion/yr in a federal budget of \$1700 billion/yr. All it took to get an increased federal appropriation for research was to wave the flag and whisper "we must beat the USSR".

Of that amount about \$13 billion went into universities last year to perform foundational research. **That foundational research in universities also had a unique effect of developing a specialized workforce able to handle both the future of research and a foundational part of the future of national economic development.** There was a national good that could be achieved by this tiny piece of the federal budget and it grew into an important social contract for half a century. When the Cold War was over about 5 years ago, the Nation rethought its priorities and shut down much of its Cold War effort. Suddenly the growth in research funding that we had taken for granted stopped growing altogether. Over the 1990s it didn't even keep pace with inflation. This transition, for lack of foresight, has traveled a very bumpy road and because of this and many other intersecting forces, research intensive universities have been required to rethink their own future and rejustify their use of resources to a certainly more skeptical public.

From Galileo to the cellular shepherd in Scotland, **scientists make social change occur abruptly, often inadvertently.** As new knowledge is discovered, and foundational research impacts others around us, we create and alter the future and how everyone around us perceives it. Our research regularly leads to changes unimagined by our institutions struggling to adjust to them.

SCIENCE CREATES MEASURABLE VALUE

During the time of this social contract of the last half of the 21st century we

- *developed polio vaccine,
- *discovered antibiotics,
- *walked on the moon,
- *conceived a baby in a test tube
- *verified the theory of continental drift,
- *defined every gene in an animal,
- *watched the decay of monarchy and fall of empires on live TV in color from around the world in real time,
- *developed lasers & magnetic resonance and turned them into medical lifesavers,
- *first synthesized effective new medicines for treating mental illness,
- *first synthesized hormones,
- *cracked a "universal" genetic code,
- *cloned an adult animal,
- *saw an atom for the first time,
- *conducted electricity without resistance,
- *stored an encyclopedia on a credit card,

*produced human insulin in a bacterium, *flew a jet plane across the ocean in 2 hrs,
 *found evidence of extraterrestrial life, *transplanted genes into food plants and animals
 *understood the organization of units that construct subatomic particles,
 *discovered a new kingdom of living creatures, *duplicated the sun with a sustained fusion reaction,
 *discovered the principle of the transistor, *invented modern computers and the worldwide Internet,
 *transplanted hearts from the dead to the living, *grew live creatures in boiling water,
 *saw humans live far from earth in a constructed space station.
 *and thousands of other revolutions that changed our lives forever.

What is more remarkable, is that only one human lifespan ago none of these were conceivable. They are not simple projections from the past. They are not forecasts from prior events and trends. They were each revolutions.

Science and scientists, by intention or not, are the most important catalytic change agents of our time. **We all recognize that much of the present is the future that was created by scientific research of decades past.**

Most of this future in which we now live stemmed from that social contract. That social contract in the 1990s seems to have suffered the fate of Humpty Dumpty.

As we evolve to the new social contract, we need now to clearly communicate:

- * how research saves lives and
- * how research creates jobs and
- * how important to the nation it is to increase its research-trained workforce

This workforce serves not only as the foundational researchers of the future but as often serve as leaders of effective & creative problem solving in every type of institution and enterprise.

Many of us are unaware that 2/3 or more of the patents that our US companies receive and use as cornerstones of their national and international competitive advantage, **(that means jobs for us)**, stem directly from federally funded and university based foundational research.

Many of us are unaware that for each dollar the federal government has invested in foundational agricultural research we have received a direct internal rate of return of 40% or more year after year for decades. Such high returns to the economy suggest that the federal government is actually UNDER-investing in foundational research!

The high tech and highest growth Industries in America that generate \$700 billion/yr of our GDP are just part of the return on our \$13 billion invested in university based research. We need to reconceive our federal budget into investments and consumption categories and then first ensure that our key investments in the future, that is education and research, are robustly supported, before our Congress is allowed to expend our resources on consumptive items. This is not a trivial pursuit, but is one that is necessary to promote the national interest of the 21st century.

LEADERSHIP ENVISIONS THE FUTURE

The national science community leadership has an obligation to set down some of its millions of ideas into some patterns so that those we will affect, and those who will affect us, continue the confidence in us. In the midst of national turmoil on many fronts, we find in many nationwide surveys that 4 / 5 of the public supports federal funding for our research even though they cannot immediately see its payoff, and that a similar proportion believe it has made their lives better off.

What will the year 2097 be like? How will it change? What will have happened? The answer is that we don't know, of course. But we can safely forecast that science will change our future. Because science has become or is becoming the major change agent of our future, we as scientists have an important responsibility to explain where we are leading the world. It was in many respects unwise for us to have accepted the Cold War rationale as so high a priority for 20th century science, but that is now history.

We have the opportunity and power to answer now to address the questions historians will ask in 2097-- what was the agenda of 21st century science and where was it going? What revolutions did it create?.

We can begin to see where we are going over the next few decades with some higher degree of probability. Using modern forecasting, we can see:

- * telecommuting employees flattening city skylines of the future,
- * star teachers giving major parts of courses to >50,000 students at one time,
- * neglect destroying our priceless world Agricultural Seed Bank germplasm,
- * that Beijing may need to be abandoned after draining its water table dry,
- * Asia's demand for seafood exceeding the productivity of the entire world now,
- * fuel cells dominating electromechanical energy markets,
- * just-in-time temporary personnel becoming the majority of those in R&D,
- * surgeons trained to be better surgeons than now through virtual reality simulations,
- * biological weapons used in a war by rogue states
- * new biomaterials able to replace/repair most types of medical injury,
- * pocket size movie players that play full length color movies,
- * nations becoming economically specialized and squeezing out inefficient rivals,
- * software-filtered cyber-malls succeeding mega-malls as places to socialize/shop,
- * robots on the moon being controlled by persons on earth,
- * spacecraft having mapped the entire solar system,
- * bridges, highways and machines made of never-before seen new materials,
- * infectious agent diagnosis will take only a minute
- * preventive medicine replacing treatment-prioritized medicine,
- * chemical pesticides disappear, displaced by newer technologies
- * the environmental mess of the 20th century reversed by bioremediation,
- * children playing in cyber neighborhoods to the detriment of their social development,
- * many types of new ultramicromachines conquering fast growing manufactured goods and medical markets,
- * and many, many others

AND A CENTURY FROM NOW ?

It doesn't take much thinking to see some of the major problems we will face in the next century and possibilities for remarkable discoveries. Much more as a provocation for your own creative ideas than as my own best forecasts, I present here some ideas with the strong confidence that none of you will be able to pounce on any that are in error 100 years from now. These sample provocations include these views from the end of the next century:

- * photo-expeditions mapped every planet around the hundred nearest stars,
- * schoolchildren, having unlimited and instant access to all the world's information, had to learn how to think and define/solve problems instead; information textbooks were consigned to the dustbin of history as schools became thinking institutes that required attendance, not from K-12, but from pre-K to 99.
- * expansion of the understanding of the neurobiology of learning forced redesign of all education systems in the nation into ones very dissimilar to those of 2000.
- * the virtual university displaced the last 19th-20th century style university only half way into the 21st century.
- * microorganisms and plants were genetically designed and created for numerous tasks & product production (materials-e.g: biomacromolecules, plastics, new medicines)
- * the growth of new knowledge, published and available on internet-5 (i.e., 10^5 times faster than the Internet of the year 2000) created such information overload, that simply getting our attention had become the key business problem of 21st century marketing.
- * not having enough information to make a decision, the 20th century problem, was replaced by having too much information to make a timely decision; it required a spectacular growth in decision science effectiveness and executive development strategies to just keep our institutions functioning.
- * quantum computing, faster than any ever conceived before, was miniaturized.
- * atomic scale machines, that replicate themselves when instructed, replaced most manufacturing as we know it now.
- * insect farms, using genetically redesigned species that were nutritionally improved, became major new food sources worldwide,
- * genetically modified food plants were grown in immense yield in the major world deserts using ocean water irrigation.
- * learning acceleration genes and brain repair enhancing genes will be routinely introduced into human embryos before birth.
- * all medical therapies were based on an individual's unique gene sequence and most mental illness was prevented in susceptible individuals.

- * novel same day cure antibiotics were used only when the agent causing the problem was certain to be sensitive, a diagnostic process that took as long as 5 min. Most disease control was pre-emptive.
- * new sources of commercially viable and safer energy arose from discoveries not made until 2050 in subatomic physics and solar energy capture efficiency.
- * drive-in gene repair shops performed this routine outpatient medical procedure.
- * life was discovered on other planets and moons
- * a new perfect human diet was developed for 7 billion persons using less than half the planetary resources used in the year 2000.
- * polyvalent vaccines that stop over 50 diseases each become universally adopted
- * disclosure that a supercomputer alone turned a stake of \$100,000 into \$1 billion led to worldwide financial panic, then admiration.
- "Lingua-Infotech" evolved to displace all other 20th century languages for communications on the Internet, becoming the first universal language.
- * a human-inhabited space station was built on a near-earth asteroid and the planet Mars. Mars underwent 50 years of terra-forming by 2097.

I can only hope that this will set you to thinking for yourself what contribution to improving the future of humankind you can conceive---believe---achieve as you research into the frontiers of knowledge. It is a worthy exercise for you, for your department, your university, and for your professional association to think in these terms and try this futuring exercise.

The whole nation would welcome your hopes and dreams for the future.

During the 21st Century we can be sure that not only some sciences became collaboratively integrated, but new journals routinely arose as new sciences arose, and could well have included these:

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| J. Interplanetary Microbiology | J. Planetary Linguistics |
| J. Fusion Physics | J. Failure-Proof Software Systems |
| J. CNS-Brain Trauma Repair | J. Human Memory Replication |
| J. History of Extinct 20th Century Diseases | J. Species Design Technology |
| J. Robotic Surgery | J. Precise Weather Control |
| J. Atomic Manufacturing Technology | J. Self-Cleansing Aquifers |
| J. Human Organ Culture | J. Cures of Blindness |
| J. Neurobiology of Learning | J. Bone Repair Sciences |
| J. Intelligent Computing | J. Species Gene Banks |
| J. TransWarp Transportation | J. Ecosystem Health and Therapy |
| J. Extraterrestrial Intelligence | J. Biomolecular Computing |
| J. Virtual Education | J. Applied Gravity Waves |
| J. Planetary Terraforming | J. Intelligent Materials |
| J. Molecular Neurobiology of Consciousness | J. Unified Field Theory |
| | J. Negative Population Growth Economics |

SUSTAINABILITY IS 21st CENTURY PRIORITY CHALLENGE

No one of us can propose the whole science agenda for the 21st century. It is however clear that many of us can agree on some overarching goals that serve the future and that give us pause for reflection as we expand the frontiers of knowledge and uniquely see our own opportunity for discovery.

It is likely that the whole scientific community across all fields will join into establishing **SUSTAINABLE SYSTEMS** as one of the overarching scientific goals of the 21st Century. No discussion of this goal can ignore the root causes of the problems, the uncontrolled growth of the human population and the demands that stem from that.

From the beginning of human history until 2 centuries ago the world human population had grown to reach the first 1 billion people. A person born in 1930 will probably live to see the arrival of the 3rd, 4th, 5th, 6th and 7th billion human inhabitants of earth. To achieve the 20-fold increase in economic production demanded

by the 7 billion could tear apart the fabric of world sustainability for the future generations. Life on Earth is contained in a thin film about 2-3 miles in each direction (up and down) from the surface of the Earth. It is a fragile film, an ecosystem of immense complexity with many interacting systems of all kinds. Yet growth will likely continue so that there will be an 8th, 9th, 10th and even more billion people on earth. Our future has a fork in the road of environmental health of that whole film of life. One road declines slowly downward and is labeled "deterioration", the other is inclined upward and labeled "enhancement". One is easier to travel, the other is an effort to travel. During the 20th Century we took the easy choice. We must for the 21st century make the right choice, not the easy choice, for the future.

The highest priority of all science and social, economic and political institutions on this planet is to develop and establish a morally acceptable, politically stable and economically feasible decrease in the world human population of 1 billion persons during the 21st century and to continue that decrease by another 1 billion during each of the succeeding 2 centuries.

This is a daunting challenge, but one from which we cannot turn aside. All our institutions are driven by growth. I am devoted to competition and capitalism. Opposition to this population decrease will develop from the world capitalist systems whose only mantra is growth. The immense power wielded by that economic mantra and its leaders may draw the battle lines for the soul of the 21st century.

In contrast, think of the dehumanizing devaluation of life that will accompany the reaching of an excessive world population of 10 billion, and the slow rise in the valuation of people that will accompany even a slight perceived scarcity over a long time. Instead of 10 billion, most starving and illiterate, think of 7 billion most of whom are productive, healthy and happy, and self actualizing people, sharing the resources that once sustained 10 billion, and improved much since then. Such smaller but more asset rich markets should attract all thoughtful capitalists.

Since 90% of the growth expected in the 21st century will be in the least developed countries, it would cost only 5-7 cents/day/person for us to move the family planning process the first giant steps to Zero Population Growth in those areas over the first third of the next century (according to data from Population Action International).

Sustainable aquatic and land based agricultural production systems, sustainable energy production systems, sustainable industrial and post industrial production systems, sustainable habitation systems and others are areas of major needs for research that ultimately establishes a sustainable world.

All economic systems of the future will be driven by science into biodegradable and recyclable systems and pollution free processes. Even noise pollution will be abated by quiet technologies.

We owe our children no less than our best efforts to ensure the world in which they will live out their lives will not have been used up or despoiled. Ecosystems, like new ideas, are not contained within commercial or national borders. The understanding of, and ensuring of, healthy ecosystems will arise as the major world scientific underpinning of our sustainable future.

DEVELOPMENT OF HUMAN CAPABILITIES is the second goal that most scientists across all fields seem to advocate as an important overarching goal for the 21st century. The key areas of this research include the development of human capital, creativity, prevention of behavioral pathology on both an individual & national scale, understandings developed from future neurobiology, and the elements of effective education.

As much of what we formerly thought of as work will be performed by intelligent robotics and computer systems, we will shift into a post industrial age that co-exists uneasily with its waves of predecessor ages.

The 21st century will require our population to think for a living. Thinking skills have become the most important skills for the workplace. The employers and nations of the future will rise and fall in their competitive effectiveness based on their skill as learning organizations and the rate limiting factors for their future success will be the rate of learning of the populations engaged in productive work.

Our education systems must be understood as whole systems and changed even revolutionized to accept and optimize what we learn about learning in the first five years of life, our teaching adapted to the neurobiology of learning, **our curriculum redesigned around creative problem solving as its core**

curriculum, ensuring lifelong learning becomes a societal norm, our cyber schools and virtual universities designed around how we learn and for no other primary convenience.

HEALTHIER LIVES is the third overarching goal that seems to be a consensus among leaders of all the scientific disciplines as important for the 21st century to make great strides. Since infectious diseases are once again a worldwide scourge, we must provide worldwide treatment and preventive medicine successfully.

We can already see the rapid rise of fast sensors as automated diagnostics for all types of health problems. Health education by virtual simulation both for the health practitioners and their patients may become routine and more effective than current learning systems. As each incurable malady falls to our never ending search for understanding, the cures of the incurable will extend not only to replacement therapy for all genetic diseases, healing and reconstruction of every kind of trauma, and reversal and finally prevention of mental health disorders, but ideal nutrition and preventive environmental medicine. Preventive health practice will emerge as the primary shift in medical practice in the coming half century.

Experimental food animals, food plants, and unconventional food sources will dominate the innovation of our next century agriculture. The nutrition of disease resistant genetically engineered food plants will easily reach that of animals and include photosynthetic efficiency for much higher food productivity per hectare of arable land. Animals as a necessary food source can be succeeded by the end of the 21st century if population demands on food production exceed the best productivity of overstrained arable land, or a serious epidemic of animal borne disease becomes a temporary scourge of human populations. It may well be cultural habit, not necessity for good nutrition, that retains animals as a food source.

Animal and human genes can be successfully expressed in plants. Harvesting novel value-added crops utilizing this discovery is already becoming economically important. Gene banks will be the most valuable of all economic banking systems as their importance becomes more appreciated.

A national goal to which science will not only contribute, but form most of the foundation for, will certainly be **ECONOMIC LEADERSHIP**.

The 20th century saw most industrial development come from the continuing innovation that stemmed from scientists learning how Nature works. All indications are that this is accelerating at an incredible rate. The economic engine of the nation has shifted into high technology industries over a very short time span. Over the last decade, most new jobs were created in the small to midsize companies driven by innovation; many of these companies only started in recent years. America's 2+ million businesses, only 15,000 are now larger than 500 employees. The desktop computer with a memory storage component, is still an adolescent, and has yet to see its 15th anniversary, yet already it sits astride the world as a Colossus. Combinatorial chemistry accomplishes in days what took years with our advanced technology of the 1980s and 1990s. New materials achieve the unachievable in every realm of our economic endeavors.

Ideas we here have not yet thought of will become multibillion dollar enterprises in the 21st century. This requires us to foster entrepreneurial education to ensure there is a sufficient population of business adventurers to ensure the public who supported our research sees ongoing benefits flowing from it that they can understand, and new jobs are a benefit that is readily understood. We who shun all involvement with business or politics or public education through the mass media will do so at our peril in the coming decades. It is one of the changes in our attitudes that is required to meet the new emerging social contract for support of science.

NATIONAL AND WORLD SECURITY have been the most important drivers of the old social contract with science. We have still the need to defend the free from the rogues who have the power to take away freedom. As we see that military superiority is no longer the driver for the scientific future, we should reassess our need to be involved in its destructive exterminations. We prosper because we are free and we should support freedom and help construct free institutions everywhere.

The USA has a unique opportunity to use its current position as the only world superpower to build, over the next generation of time, situations that diminish the need for a security establishment that can annihilate all life on earth many times over. It will require the kind of international military and international political leadership

that is unique in history. Yet it has become a necessity and the window of opportunity is the first in our whole lifetimes.

My personal view is that it is unethical for any scientist to ever again participate in the design or development of weapons of mass destruction. Our energies and intellect should be channeled into the most constructive future building we can conceive. We can do so much more for the future of the world and its people and environment with all the challenges that I have just discussed and many others, that it becomes a corrupt perversion of our skill and knowledge to seek such goals. Our role should be to support the very strong leadership and creative problem solving needed by the military and political institutions and durable new institutions that would lead to highly certain world stability. The rise of the concept of the nation-state requires it to defend its borders and culture. Competitive zeal requires that it impose it on neighbors. Evolving that thinking into newer concepts that enhance cooperation more than pathologic competition may become worthwhile at some point in the next century.

We can indeed contribute our science to preventing the need to use such weapons. We can do everything to provide for a world of well-fed, healthier and fewer people, to provide that populations are economically secure and stable, to provide for our great-grandchildren an environment with as durable a future as our great-grandparents received when they were born, and to ensure the lifelong learning that provides all the self-actualization and inner peace we can want.

ROLE OF SCIENCE & SCIENTISTS IN POLITICAL DECISION MAKING

Since we can be sure the world of the future will differ greatly from the present as the present does from a century ago, we must now lead the effort to recognize and capitalize on the differences.

Our own future now depends on effective development of appreciation for science by the political decision making institutions and the generally science illiterate general population. We cannot leave it to others to do what needs to be done. It is our future. It is our obligation. Ours has never been the role of watching the future happen. We make it happen.

Every political institution deals with constituencies. The constituencies declare and support avowed purposes. The political decision-makers trade off the power of constituencies and the significance of their cause. Almost every constituency asks the political forces to provide largesse to them at the expense of others.

What is our constituency? Is it research laboratories and centers? Is it universities? Is it university professors? Is it research scientists' jobs? Is it my discipline at the expense of yours? Is it my research grants? To all of these I say NO! It is all these selfish apprehensions that help discredit us in the public eye. We then become just another arrogant self-interest group and are no better than any other.

What unites us is more important than these.

We are the nation's most consistent and vigorous Constituency for the Future. We are almost the only such constituency. We recognize that deployment of national resources into education and research is what creates our future. Our role is to explain that understanding as often and as forcefully as we can whenever the opportunity arises. We are united in our desire to create a better future and we know how we have done it for the nation for the last human lifespan and will do it again over the next human lifespan. We must ourselves come to believe how much more important it is for us to act for the national future where science is serving the national interest than to act as just another special interest group only concerned with its own paycheck.

As that future forms, the major value creations for science that could become **the engines driving future US investment for science** in the first half of the coming century are perhaps these six:

21st CENTURY VALUE CREATION

- 1) **new understandings**, enlightenments and sciences from scientific discovery
- 2) ensuring the **biosphere is sustainable** and all human interventions are within sustainable systems
- 3) entirely new models of **lifelong learning systems**, not K-12 but pre-K to 99.

- 4) **engines of economic development** and leadership, many of which may not even be conceivable yet, as those that we created the last century were not conceivable a hundred years ago.
- 5) **healthy populations** worldwide, both physically and mentally, via accessible and affordable preventive care systems, new science and new technology.
- 6) worldwide **energy autonomy** of individual family units that is safe, affordable and readily accessible, and as the rising tide, can raise all boats, around the world.

This is not just a laundry list. It is the potential framework for our future.

OUR COMPETITIVE ADVANTAGE IS ELECTRONIC NETWORKING

Our role as scientists is to lead the political system, not follow it, and do this via a long range vision that we develop, conceive & believe, so that it becomes compelling to the public and future resource allocators.

Because most of us have at least a decade of familiarity with Internet communications and routinely participate in and encourage others to participate in virtual communities with shared interests, and cyber-conferencing, we have developed a competitive advantage in building political will for the constituency for the future.

As just one example of how to utilize this advantage, we can see the following: We can readily:

- * organize all our professional scientific groups into issue communities that coincide with the boundaries of Congressional Districts,
- * ensure that all those persons communicate regularly with each other on the Internet about the issues confronting the Constituency of the Future,
- * communicate regularly with a coordinating center that helps alert you to issues that will be highly important to the Constituency for the Future,
- * at a few specific and important times act upon those issues in concert both within the individual Congressional District and across all the 435 Congressional Districts.
- * make these actions as communications from voting constituents of the Member of Congress on your views on the identified issue that will affect the Constituency for the Future and how it will help or harm that future.

I hypothesize that if every Member of Congress heard from 1000 voting constituents in that district during a given month on a single issue, and each of the communications was independent (dissimilar, brief, thoughtful personal letters from your own home to Congress, etc) and 90% of them agreed on what to do about the issue, the voting behavior of the Member of Congress would be influenced considerably, maybe permanently. Each Member would recognize a "hot issue" and shy away from making it controversial again, and each Member would be pleased to report to 1000 voting constituents that he/she took such action that would please the voting constituents.

NEEDED: SCIENTIST STRATEGISTS AND SCIENTIST HEROES

Science as an enterprise can not face the future with confidence unless it has some degree of organization and utilizes that organizational system(s) to plan its future strategically. Common interests of scientists are brought together in the professional societies with which most active scientists affiliate. While our disciplinary groups wrestle with all the issues of the day, the impacts of cyberspace publishing, the shrinking supply of academic research opportunities, fewer research resources, and many others, they do not adequately develop the next generation of strategists for the whole scientific community who are able to ensure the ongoing robustness of the whole scientific enterprise. This narrow perspective will become even more self defeating in the future. We are all parts of a scientific ecosystem, not just part of world no bigger than our knowledge discipline. We do not operate independently of each other. We cannot in the changing world around us survive working only in our own narrow interests. We all now share a shrinking pie of resources. The wrong response is to circle the wagons and shoot inward as we compete for fewer resources. A deliberate and strong program to develop our future strategic leadership is an imperative during the 1990s to ensure improving our possibilities and opportunities into the next century.

Avoiding talking to the public about our research has risen in the last decades to the level of a taboo. With only 5% of the general public considered science literate based on surveys by NSF, and our schools in

turmoil educating the lowest achieving science students in the industrial world according to international math and science studies, we can no longer shun this responsibility.

In the past our petty jealousies led us to hold those Professor Carl Sagan-like scientists up to ridicule as violators of the unwritten taboo. They did not deserve so much public appreciation when they did not do the best science in the world, we said to ourselves. Yet much of what literacy the public does have and a huge amount of the appreciation for science comes from such persons. They are heroes to the public and raise the esteem of all science to a nation now deciding how to shape its next century and how to allocate its future resources. Until we are wise enough to follow Sagan's example, we will continue to struggle for survival.

Our conscious effort should rise to the level of encouraging, supporting, developing, even training our next generation of hundreds of science heroes in an unselfish way for the betterment of the whole scientific enterprise. Learning how to be an active part of the mass media and staying actively involved in your own city is an obligation. Skill in communicating science to the public in the way the public best receives that communication is a learned skill, and many scientists do not have any inclination to do so. Those who do need our strong support.

A university of this size deserves science stories every day on both TV and in the newspapers. There are such stories here. Let us bring them out of hiding and actively build public appreciation for what we do in science. Each of us must allocate our time and other resources to do so. Science journalists should be our heroes.

CONCLUSIONS

- Science is Foundational
- Scientists create much change
- Scientists have generated considerable value to the society
- Science saves lives, creates jobs, provides a unique workforce
- Scientists are the constituency for the future
- We can envision the future we would like to create and it is exciting
- We will make important new discoveries that benefit humankind
- We will create new sciences never thought of before
- Scientists are ready to accept the challenges of the 21st century
- Some overarching goals for our future are
 - Sustainable Systems
 - Developing Human Capabilities
 - Healthier Lives
 - Fueling Our Economic Engines
- Scientists Need to Effectively Communicate to Our Decision-Makers
- Scientists Need to Communicate to the Public Through the Mass Media.

Today is tomorrow's greatest labor saving device.