12 The Age of Transitions

Newt Gingrich

I have spent the last year at the American Enterprise Institute and the Hoover Institution thinking about the direction we are going as a nation and what the implications are for the nature of the scientific endeavor in the next generation. I would like to share with you some of my observations.

I believe we are experiencing an explosion of knowledge of such scale that it is hard to describe. If you think of an S-curve of technological development (slow when discovered and then rapidly ascends before it slows down), I believe the S-curve we have been experiencing opened with computers and communications. Most people think we are in the middle of this change. We are probably about one-fifth of the way into it at most.

As we accelerate up the rest of the computer-communications S-curve, I believe we are simultaneously starting up a second S-curve of change. This curve is the triangle of nanoscience, biology, and information interacting in a way that creates capabilities that were unimaginable 45 or 50 years ago.

The nano world may be the most powerful new area of understanding in the triangle. "Nano" is the space between one atom and about 400 atoms. It is the space in which quantum behavior begins to replace the Newtonian physics. In this world of atoms and molecules, new tools and new techniques are enabling scientists to create entirely new approaches to manufacturing and to health. Nanotechnology "grows" materials by adding the right atoms and molecules. Although years away, nanotechnology may be at least as powerful as space or computing in its implications for new tools and new capabilities.

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The nano world also opens up our understanding of biology and biology teaches us about the nano world because virtually all biological activities are at a molecular level. Thus our growing capabilities in nano tools will expand dramatically our understanding of biology. Our growing knowledge about molecular biology will expand our understanding of the nano world.

Beyond the implications of the nano world for biology, in the next decade the Human Genome project will teach us more about humans than our total knowledge to this point. The development of new technologies will increase our understanding of the human brain in ways previously unimaginable. From Alzheimer's to Parkinson's to schizophrenia, there will be virtually no aspect of our understanding of the human brain and human nervous system which can not be transformed in the next two decades.

Steven E. Hyman, Director of the National Institute of Mental Health, made the point that the revolution in brain science was largely driven by physics and mathematics, not biological science. This revolution created opportunities to begin to understand how the brain works at levels unimaginable 15 years ago. As a result, we are beginning to realize that the human brain itself may be one of the most complex aspects of our intellectual universe. The mathematics that may ultimately be required to understand what is going on in the brain may be far denser than we ever thought. These are the kinds of things that may be telling us that we are on the edge of another new frontier.

Finally, the information revolution will give us vastly better capabilities to deal with the nano world and with biology. It will give us the technology and equipment to use this kind of knowledge and to create these kinds of breakthroughs in biology, material science, and quantum computing (as well as many areas that are only beginning to be plausible in the last ten years). As an historian, I believe that if we do get those kinds of breakthroughs, they could be larger in their impact than all of the developments of the 20th century.

It is the synergistic effect of these three systems intersecting (nano world, biology, information) intersecting with the computer/communications S-curve that will lead to an explosion of new knowledge and new capabilities. We will simultaneously be experiencing the computer/communications revolution and the nano world/biology/information revolution. The period of intersection of these two curves will be a constant age of transitions.

Every area of science is affected by the age of transitions. For example, in astronomy, the weekly and monthly breakthroughs in new knowledge are just a hint of the potential information new space-based and ground-based systems will unveil in the next decade. In quantum mechanics, the simple reality is that we can predict certain results fairly well but remain far from a full understanding of complex systems. In biology we have unlocked the alphabet of the human genome but are only beginning to approach the mysteries of protein folding. In microbiology we have identified about three to five percent of single-cell organisms in the most studied water (from waste treatment facilities) and well under one per cent of the single-cell organisms in the ocean. The list could go on.

An Opportunities-based Science Budget

Policymakers need to rethink the responsible level of commitment necessary to continue advancing at this rate. Even advocating (which I have done) for a doubling of all government scientific funding, not just the National Institutes of Health, is shortsighted. We need a bold assertion of *all* the opportunities that are made possible by modern instrumentation, computation and the Internet. We need an opportunities-based science budget.

My proposal is simple. The National Academy of Sciences, AAAS, a Congressional Commission, or an *ad hoc* group, should produce an opportunities-based budget rather than an incremental one. If the right number to save lives, to stop Alzheimer's disease, to cure diabetes, to have national security, to launch the economic growth of the next 50 years is 11 billion or 14 billion or 7 billion, so be it. We need an opportunity-driven number, not a politically or accidentally driven number. And we ought to have it across the board. One way or another, we should get the debate on an opportunities-based approach to science started.

The idea for an opportunities-based science budget was born out of a meeting initiated by John Porter (R-IL) when I was Speaker. When we in Congress decided to balance the budget, John came to me to suggest that we should bring in every senior research vice president of every pharmaceutical company in the country. About 35 people came to the meeting. Every one of them said that free enterprise only begins immediately after scientific discovery. If we do not make the investment in the initial discovery, our capacity to create growth industries, to lead the world in these products, and to save more lives could all disintegrate within a decade. They made a very compelling case. I think this meeting was a major step in the right direction. One of our weaknesses was getting other industries to understand that they have an equal obligation. Many of our industries indirectly depend on these breakthroughs and should also be actively making the economic case for this kind of budget.

For example, an opportunities-based budget would find out how much the Defense Advanced Research Projects Agency (DARPA) can use. In many ways DARPA is one of the unsung heroes of the Internet and the computer age. The fact is that there are times when peer-reviewed research is too incremental, too narrow, and too small to create large-systems architecture. Both the National Aeronautics and Space Administration (NASA) and DARPA did a great job by convincing us that we needed this next big breakthrough and we needed this large amount of money to do it. The country then invested in ways that probably would not have survived if the investment had not been done in these kinds of programs.

Another example of why an opportunities-based science budget is needed was illustrated on front page of the *Washington Post* last year. One story was about a sudden, unexpected snowstorm that hit Washington. Next to that story was one about the discovery of weather patterns in the Pacific Ocean that may change weather all the way from China to the Sahara. This involved an effect that we did not know existed three years ago. Before we spend trillions of dollars on a Kyoto policy decision, we should spend a billion or two on a ten-year project with systems architecture similar to the International Geophysical Year in 1957–58. This effort should be aimed at optimizing our understanding of the planet's climate. This is not an irrational decision. Investing a billion dollars first to decide whether or not it is right to spend a trillion is what every business leader would consider a sound economic decision. It is important to come from the larger world to the smaller world of science and say this is the amount we can now spend intelligently.

With an opportunities based science budget, we can identify the opportunities we have to dramatically decrease human pain and death and allow the financial savings to be reapplied to other research areas. For example, the scientists who work with juvenile diabetes say they believe within a decade we can either totally mitigate the impact or potentially eliminate the disease. They think there is practical reason to say this because the system's architecture of knowledge is there. What is the return on investment if diabetes is eliminated? This disease is the largest single cost factor in Medicare. Every seventh dollar of Medicare is spent treating the side effects of diabetes, which are blindness, heart disease, kidney disease, and loss of feet. We can, as a nation, justify a very high investment to get such a solution. Using arguments like this can be a much more aggressive way of asserting that these breakthroughs are real, this new knowledge is real, and this opportunity is real.

Areas of Funding Emphasis

I believe an opportunities-based science budget should emphasize the following five funding areas:

- There should be an increase in peer-reviewed money allocations to enable more high-quality proposals to get full funding. The scale of shortfall was highlighted when the Director of the National Science Foundation (NSF), Rita Colwell, stated that funding existing first-class research proposals would require more than twice as much funding as the $4.7 billion currently appropriated. Yet even her testimony understates the potential shortfall in science. Dr. Colwell is describing the current shortfall within the current system. The psychology of a budget-constrained science community minimizes proposals of appropriate large-scale research projects.

- We must begin to fund a new generation of large projects that could create great breakthroughs. The Defense Advanced Research Projects Agency invested millions of dollars without peer review, which made possible the creation of the Internet. In astronomy, the terabytes of data that will be produced daily ought to be captured in an open, Internet-based, archived, virtual observatory. The current plans will capture only a tiny percentage of the data. In weather and climatology, we are drifting toward spending trillions of dollars under the Kyoto Global Warming protocol. Yet we fail to increase the current budget by less than one-tenth of one percent as much for a worldwide climatology project. The National Oceanic and Atmospheric Administration is so strapped for money to keep its current systems operating that it legitimately shies away from this grandiose scale of investment in knowledge and research, which actually should be the minimum investment.

- Money needs to be available for highly innovative, “out of the box” science. Peer review is ultimately a culturally conservative and risk-avoidance model. Each institution’s director should have a small amount of discretionary money, possibly three to five percent of their budget, to spend on outliers. The history of plate tectonics should remind all of us that accepted wisdom could be wrong.

- We need a new commitment to integrate the hobbies and funnel the interests of amateur scientists into real discovery. Significant recent findings by amateur scientists include animal tracks in New Mexico older than dinosaurs, and discovering supernovae in distant galaxies. It is important to remember that Darwin the amateur beetle collector nurtured Darwin the evolutionary theorist. There is plenty to be discovered and explored by amateurs, and the Internet combined with new instrumentation can harness and focus the work that amateurs already do.

Shawn Carlson recognized the untapped resource of amateur scientists and in 1994, founded the Society for Amateur Scientists. He and others guide amateur scientists in their research and enlist their help in gathering data for professional scientists. The society’s Web site sends out calls for assistance on projects at universities and laboratories around the country. The potential is massive but the funds are lacking.

The Ames Research Center hosts a program that is another excellent example of amateurs, in this case students, helping professionals with research. National Aeronautic and Space Administration funds a collaborative project between Ames and the nonprofit Marine Sciences Institute, a science education organization that runs educational cruises for teachers and students in the San Francisco Bay area. The program’s director, Lynn Rothschild, has utilized the samples and physical data (temperature, UV radiation, water clarity, etc.) collected by students on the cruise to help her identify UV-absorbing pigments in plankton and to measure DNA damage experienced by plankton in the Bay at different times of the year. This information could help scientists understand more about environmental effects on coastal communities. Students are being immersed in research by giving them part-ownership in scientific data. This program not only nurtures the next generation of scientists but also has allowed Ames to provide useful data that would otherwise have an economically prohibitive price tag. We need federal funding to support more programs like this one.

- We must have new approaches to learning that combine the discovery process, virtual reality, and a 24-hour/7-day-a-week Internet-based opportunity for the committed learner. In particular, we need an immersion approach to virtual learning about the quantum world, which is so counterintuitive to our daily experience of the classical Newtonian world.

This investment will also require a dramatic overhaul of science and math education. This is a national security issue of the first order. Barely half of our computer science graduate students working in the United States were born in the United States, in large part because our own high schools are not graduating enough students with the math and science capabilities to sustain American society in the 21st century. While we benefit from being an educational beacon for the world, it should alarm us that our own society is not producing enough math and science students for us to remain a world leader. We cannot assume that we can import people from India, China, Germany, and Japan to substitute for the collapse of the American capacity to educate its young. We should think through from the ground up about rebuilding science and math education. In my judgment learning science and math is harder than most other kinds of learning. There is a reason in a highly wealthy society that people at the margin do not go into these areas. Part of the reason has to do with the way we now teach these subjects, especially science. We teach science as facts to be memorized rather than science as a great adventure to be pursued. I suggest that we look at this issue in a very broad way.

I think we must be very bold, as bold as necessary. For example, I would pay high school students to learn calculus. Look at the National Defense Education Act of the 1950s. I would consider the notion that a major in math and science as an undergraduate you would pay no interest on student loans. If we do not do something that bold, do not give all the theoretical process and philosophical arguments, do not produce enough students who can do math and science, we are out of the game. We have had 15 years of dealing with these problems and, in my judgment, we have gotten nowhere. The relative improvement in science is trivial compared to the requirements of entry-level courses. The number of Americans who continue to invest their minds and their lives in science and math is clearly too small, with the result that our graduate schools cannot find enough qualified applicants.

This is a national security issue of the first order, and I do not believe we can survive as a major power if we do not solve it. I do not believe we can continue to buy the rest of the planet's children to do our science. At some point their quality of life in their homelands will be good enough that they won't stay in the United States. When that happens we will have a precipitous decay in the conduct of our science. The British problem of 1870, and the reason they could not compete in the end with Germany and America, was that they could not convince their elite that it had to learn to be technical and managerial in its functioning.

The Digital Opportunity

One step in the direction toward the overhaul of math and science education and the involvement of amateur scientists in the process of discovery would be to digitally connect the entire country. I believe that every four-year-old child ought to be given a personal computer funded by the government. As soon as they learn to read and write, they ought to get an Internet connection (with screening for pedophiles and pornography). Our public policy should stipulate that every family will have access to the Internet. The City of LaGrange, Georgia, is the first city to do this. They have announced that they are going to connect everybody through their cable system. Already 85 percent of the population is connected to cable. The city will cross-subsidize to get the other 15 percent connected. This is not complicated. If we decided to give every four-year-old child a computer, computer companies would figure out a way to make a remarkably inexpensive base computer because production runs would be so high.

The endless frontier of discovery needs both scientists and nonscientists to push its limits. The implications of the opportunity for young people to be real scientists at the discovery level on a worldwide basis are astonishing. We have the technology that can involve everyone in the excitement of scientific discovery. It may be worth our while to look at how to mass-produce the tools needed so that every science student could be involved in the discovery process. They could be on the Internet and could be connected locally to an institution such as a university or federal laboratory so they could learn real things in a real way. This is totally different from the current mind-numbing, fact-oriented, explanation of things that are 40 years out-of-date, which passes for much of today's science education in America.

This country achieved 98 or 99 percent penetration on the telephone because we insisted as a nation that is what we want. We invented the Rural Electrification Administration so everybody could have electricity. In light of this success, arguments about the feasibility of providing computers ought to be over. In 1800, universal public education was a radical idea; it did not start until 1844, in Massachusetts. In 1900, in the South, suggesting free textbooks was a radical idea. In 1928, Huey Long won the Governor's race in Louisiana by advocating free public textbooks. Today, we take both for granted.

There is not going to be a digital divide in this country. This country does not live with divides. They are wrong; they are not American. We have the resources, the intelligence, and the capability to unite this country with technology. It is cheaper than remedial education and it is cheaper than prison. It is doable.

Scientists As Citizens

Without active participation of scientists in the public policy process neither the opportunities-based science budget, nor significant progress on the five focus areas can be achieved. Scientists must act as citizens. It is ridiculous to say that because what they are doing is noble and interesting these should not also function actively as part of our society. Scientists have as much an obligation to attend their representative's town hall meetings, write letters to the editor, or come to Washington to visit their congressional representative as do dairy farmers, sugar planters, coal miners, or any other legitimate group who represent their own concerns. If scientists truly believe that they are on the cutting edge of the future, they have a double burden because not only do they have self-interest, they also have the moral obligation of educating our democracy into creating a better future. Yes, citizenship is frustrating, but it is a privilege we must exercise. Yes, it means occasionally scientists will be involved in controversy. Yes, they have to learn communication skills such as speaking in a language everyone else in the room can understand. But these are doable things. They also are vital not only to the survival of this country, but also to the future of the human race. The answer to poverty in the developing world is vastly greater productivity. The answer to health in the developing world is a dramatically better system of delivering health and preventive care. These all grow out of science.

Most of the great breakthroughs in the last 200 years have at their base an expanded scientific knowledge. Scientists have a moral obligation to be good citizens. I urge every scientist to at least once a year talk to your elected official. Do not complain about Washington not understanding scientific research if scientists in this country are not willing to take on the burden of talking to people in positions of authority. That is a simple challenge. I do not mean to sound so harsh, but I am fed up with brilliant people explaining that they are too busy to be part of our democracy.

Scientific Investment's Affect on National Security

At the end of the enormous zones of new opportunity, serious national security implications exist. I serve on a study committee that reports to the Secretary of Defense, a committee that President Clinton and I created when I was Speaker of the House. This committee is charged with looking out to the year 2025. I think we could easily not be the leading power in the world in 25 years. That could happen if we fail to adequately invest in research and development and do not massively overhaul math and science education in this country. If the world of knowledge is in fact on the edge of very substantial breakthroughs, we must make them or someone else will.

We could be launching another quarter of a century of American progress. Or we could be like Britain between 1870 and 1900, which failed to modernize and, as a result, it fell behind Germany and America for the first time in almost two hundred years. It is absolutely imperative that we understand the extraordinary national security implications of making (or not making) a full-scale investment in research and development.

Conclusion

I am a fiscal conservative and support a lean, effective government. But the economy of today is based on the science of the past two generations. The economy of tomorrow is going to be based on the science of today. Anyone who wants to maintain a healthy American economy in the future had better support a very substantial science investment in 2000 and 2001 or it will not be there. Responsible investing in scientific research is not only the right thing to do for America, but will vital for our society's health and survival.