DR. WILLIAM R. BRODY became the 13th President of The Johns Hopkins University in September 1996. Immediately prior to assuming that position, he was the Provost of the Academic Health Center at the University of Minnesota. From 1987 to 1994, Dr. Brody was the Martin Donner Professor and Director of the Department of Radiology, Professor of Electrical and Computer Engineering, and Professor of Biomedical Engineering at JHU, and Radiologist-in-Chief of the Johns Hopkins Hospital.

Dr. Brody received his B.S. and M.S. degrees in electrical engineering from the Massachusetts Institute of Technology, and his M.D. and Ph.D., also in electrical engineering, from Stanford University. Following post-graduate training in cardiovascular surgery and radiology at Stanford, the National Institutes of Health, and the University of California, San Francisco, Dr. Brody was Professor of Radiology and Electrical Engineering at Stanford University (1977–1986). He has been a co-founder of three medical device companies, and served as the President and Chief Executive Officer of Resonex, Inc., from 1984 to 1987. He has over 100 publications and 1 U.S. patent in the field of medical imaging, and has made contributions in medical acoustics, computed tomography, digital radiography, and magnetic resonance imaging.

Dr. Brody serves on the executive committee of the Council on Competitiveness. He is a member of the Institute of Medicine, and a fellow of the Institute of Electrical and Electronic Engineers, the American College of Cardiology, and the American Institute of Biomedical Engineering.

Dr. Brody spoke at the Millennial Challenges Colloquium series on 14 January 2000. The text of "The Quantum Physics Model of the University in the New Millennium: The University Without Walls" follows.

The Quantum Physics Model of the University in the New Millennium: The University Without Walls

William R. Brody

People often ask me what exactly I do. The common impression is that university presidents live in big houses and beg for a living. That may be part of the job, but only part. At Johns Hopkins we have a unique model for the university: a highly decentralized structure with extraordinary leadership at the various divisions. Because of that, the known problems are being worked on and solved at the divisional level. What I really get paid to do is to anticipate the problems people are *not* thinking about at this time.

This is exciting but difficult, since we cannot predict the future. In fact, it is hard enough knowing what is going on at present. But I have been thinking about education and research, and particularly research universities, a great deal. I've come to believe that our research universities are already undergoing tremendous changes that most people fail to recognize. Those of us within the university are looking outward and are therefore not paying attention to the day-to-day changes. People outside the university community don't know enough about the changes to think about them. But it's extraordinary to see what is really happening.

A little over a decade ago, gloom and doom prevailed. U.S. quality was terrible, productivity was in the bucket, and Japan was set to take over the entire world. When the Japanese bought the Pebble Beach golf course, that was it. It seemed we were all going to be working for "Japan, Inc."

Nobody thinks about that today; in fact, the Japanese overpaid for Pebble Beach and other high-profile properties and basically had to bail out. Certainly a lot has changed. A tremendous revolution in quality and productivity in the United States has affected many sectors of our economy. It started with the automobile manufacturing sector and then moved into the services sector. Now it's everywhere. Yet one sector that has escaped the quality revolution has been education.

But not for long. I think education, and research as its counterpart, are next. And these changes are likely to have a huge impact on us, just as they have on other industries. So one of the things we need to do is to look at how the world outside the university has changed.

I highly recommend four books, all of which have informed my talk today. One is by Peter Drucker, of whom I am in awe. Mr. Drucker, now an octogenarian, has been incredibly successful at predicting the future. His *Post-Capitalist Society*,[1] written a number of years ago, is about the change in the United States after the Cold War, but it is really about the

new economy. Drucker, as many of you know, coined the terms "knowledge worker" and "knowledge economy" 25 years ago, when he predicted many of the changes we see today. Thomas Friedman, a columnist for the *New York Times*, has authored a book called *The Lexus and the Olive Tree*,[2] which is a fascinating account of globalism. Shapiro and Varian are economists who have written *Information Rules*,[3] which posits that the rules for the Internet economy are not new; rather, they are old rules that we need to revisit and understand. Clayton Christensen's book, *The Innovator's Dilemma*,[4] talks about why it is difficult for well-run organizations to adapt to innovative, new technology.

DRIVERS OF CHANGE

We all know that changes are occurring in our digital economy. I view the Internet as just another step in the communications revolution that began with telegraphy and the telephone. These are technologies (even including jet travel) which allow people to connect. Will the Internet have a greater impact than other forms of communication? Who knows? We can say that it is growing a lot faster, its adoption rate is a lot faster, and in some sense its pace of change is much faster. Just on that basis alone it is probably a more important phenomenon. But it's just part of a series of events that started well over a century ago.

I just got back from a trip to China where Johns Hopkins has had a campus in Nanjing for more than a decade. The changes in China are unbelievable. While I was in Nanjing, the center hosted a symposium and invited Jim Jarrett, the president of Intel-China, who talked about "China Meets the Internet." Two days previously I had breakfast with three Chinese Internet entrepreneurs in Shanghai, but I could just as well have been sitting in Silicon Valley. Basically, Jarrett noted that although Internet adoption rates are slower in China, the same things are occurring there as in Silicon Valley. He talked about new business rules for e-commerce and how the competition is just a mouse-click away. His message was strong: "Embrace the Internet or die."

To some extent, this may be hyperbole. But fundamentally, it really is true: for many businesses, the entire way they manage their processes, from start to finish, is being turned topsy-turvy. They recognize that if they don't adopt the Internet rules they will not make it. Now let me be clear: this is a very different discussion than the fate of the Amazon.coms and the eBays of the world. They may or may not make it. But what is going on in the business and services sector in terms of business-to-business commerce, or b-to-b, is phenomenal, and of course the b-to-b part is really behind the speedy growth of Internet commerce. Although b-to-b is going to be about the same size as Internet commerce, in my view it will have a much greater importance.

Let's talk a little about the next 10 years. There are a series of issues and themes. The first is the speed of communication. Everybody talks about 24-7-365 nonstop. People who work in Internet companies talk about dog years—1 year in an Internet company is worth 8 years in a regular company. You form an Internet company, 7 months later you have a product, and 14 months later (if you are slow) you take the company public.

Although we don't know which of the Internet companies will survive, it is clear that there is a tremendous ferment and creativity going on in the Internet sector, something that we have not seen on that scale before. We have seen it in other industries before, but the number of people and the amount of capital fueling it are really quite new.

So speed drives everything. You used to turn on the television and see somebody peddling records or tapes of famous singers, and the ad would say to call a number and your order would be processed within 6 weeks. Nobody will stand for that anymore. You order something and if it doesn't come in a day or two you're wondering where it is. Basically a different tempo has been created—we've gone from *andante* or *legato* to *allegro* and *vivace*.

Another force of change is globalism, which implies a single set of rules for a global economy, intense competition, and the disappearance of geographic and political borders. One has to adopt a uniform standard of business systems, what Tom Friedman[2] calls software: every country has to have the same software systems to adopt to this global economy and to the ubiquitous access to information. All this is driven by Moore's law. I don't need to tell technical people about Moore's law, particularly since Moore had his first job after graduate school at APL. In Drucker's *Post-Capitalist Society*,[1] he talks about ubiquitous access to information and how this phenomenon has driven down geographic and political barriers. It was responsible, in Drucker's view, for the fall of the Iron Curtain and the Eastern Block countries since they could no longer keep the citizens in Russia or East Berlin in the dark about what was occurring on the other side of the wall.

Access to information has had another effect, a rather serious one that is reducing the sovereignty of nations. Friedman[2] notes that no two countries that both have McDonalds have ever gone to war with one another because, in some sense, information and the economy become more important to the citizens than what their local politicians have to say about geographic boundaries.

So it is a very profound effect. Once a country reaches a certain economic point it is more interested in joining the global economy than worrying about shooting its neighbors. That may or may not hold true in the long run, but because of this, the superpowers have lost tremendous influence.

As you lose your sense of belonging to a particular geographic entity, you have to fill the void. You fall back, as Friedman says, to the local olive tree, and that local olive tree comes to represent your tribal roots. Even if you are no longer necessarily a member of the USSR, you become a member of Uzbekistan or Chechnya, or even yet, one of the tribal cultures that exist within those countries. And so we're going to see a significant rise in tribal conflicts, which is something Drucker predicted.

And multinational companies will begin to dominate. Again, if you go to Shanghai or Bejing and you look at the list of companies, you might as well be in Silicon Valley or the Washington–Baltimore area.

Two decades ago, Drucker predicted that knowledge would replace capital as the major driver of economic success. In other words, economic success is determined not by the amount of financial capital but by the intellectual capital which resides in the knowledge workers. In regard to universities, Drucker also said recently that in 25 years universities will no longer exist as we know them. The changes our society will undergo will be far more profound than when the printing press was invented. Drucker thinks we are "history," but does not suggest what will replace universities.

Regional economics is another driver of change. A very active organization in this area is the Council on Competitiveness in Washington, DC. It was started in the face of the threat of a Japanese takeover of the world economy. Recently, economist Michael Porter from Harvard spoke to the council about several interesting studies on what it takes to be competitive. His own study on regional competitiveness concludes that the two most important drivers of regional economics around the world, as well as within a country, are the annual increase in the number of R&D personnel educated each year and the level of spending on research and development—the two major functions of a research university, and particularly a research university like Johns Hopkins.

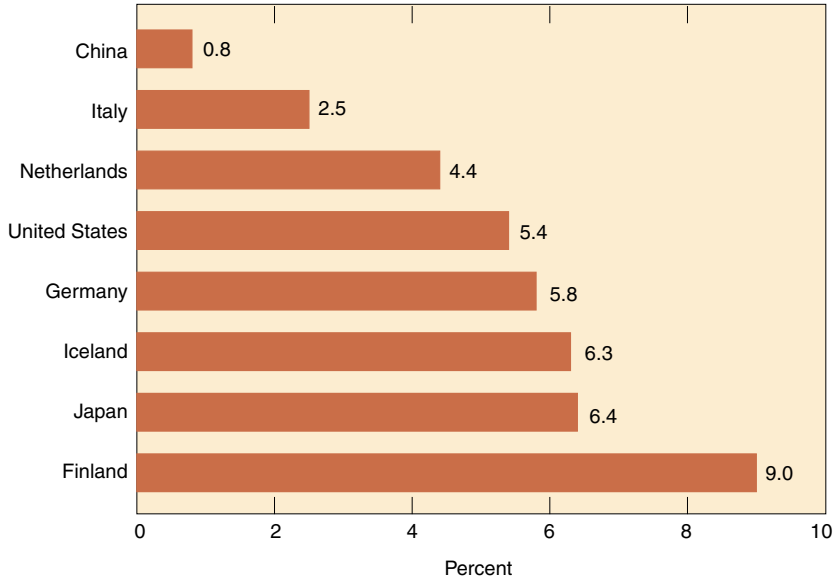

Figure 1. Science and engineering degree recipients worldwide (source: NSF).

We at Hopkins are therefore responsible for driving local economic development. Just look at the numbers of science and engineering degree recipients worldwide (Fig. 1). You can see that some countries like Finland, which is dominating in cell phones (maybe *all* Finns are making cell phones), have a very high percentage of their graduates going into science and engineering.

If you look at R&D expenditures by source, it's apparent that government funding in laboratories is decreasing while university expenditures are increasing (Fig. 2). According to Porter, this is desirable because funds spent in an entirely government-owned laboratory do not act as regional

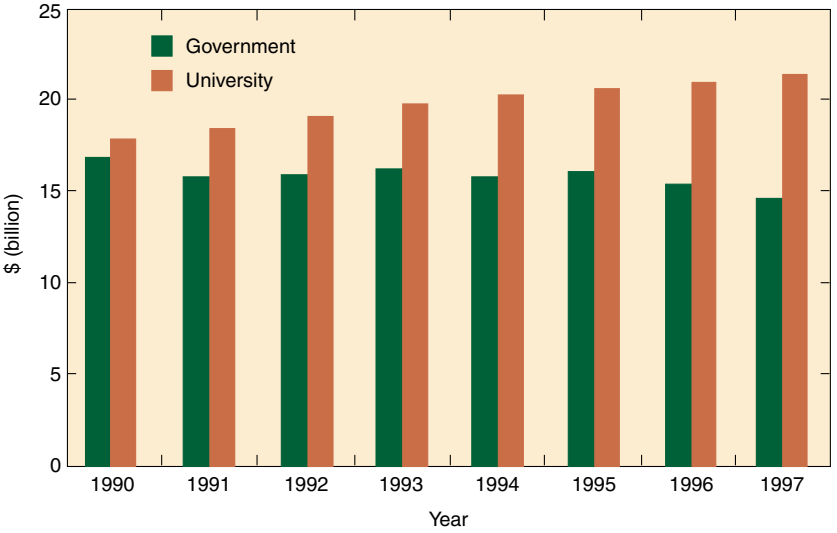

Figure 2. Research and development expenditures by source in constant 1992 dollars (source: NSF).

economic drivers. The research funding needs to occur, even when it comes from the government, *outside* government laboratories.

For example, Friedman talks about the Cold War verses the global economy. If a nation joins the global economy, it has to adopt a single set of rules, and these rules are palatable to some nations but unpalatable to others. We saw this in the recent currency crisis in Southeast Asia when Malaysia was unwilling to adopt the rules. What Friedman says is that you either adopt the rules or get left behind. It will be interesting to see what happens with Malaysia over the long term since they refuse to keep their currency open.

TURNING INFORMATION INTO EXPERTISE

Getting back to the university, it is important to distinguish between information, knowledge, and understanding. We have lots of information; none of us is lacking in information crossing our desks. Information can be "signal" or "noise," depending on the context. Knowledge is the process of collating, validating, assembling, and filtering information so that it becomes relevant for solving a specific problem or set of problems. In going from information to knowledge, the next step is understanding, which leads to insight and an ability to make relationships based on an accumulation and application of knowledge. That is what we try to do—not only generate knowledge but also take it and apply it to specific problems in order to gain understanding.

The paradox for the present is that we are inundated with information but starved for knowledge. People who can transform information into knowledge are experts and, in this society, it is they who become the most valuable. Singapore, for example, has concluded that their economy, which has grown at 8% a year since 1965, cannot sustain that rate in the next decade because they do not have sufficient population growth to generate the necessary expertise. So they are creating in Singapore a world-class city with cultural, educational, and health care institutions—like MIT, Johns Hopkins, and the Wharton School—to try to attract more people to study and live there. They need knowledge workers to transform their economy.

Toyota builds cars all around the world. They don't care where they build the cars or who builds them. Instead they value the knowledge of how to build the cars and how to put the manufacturing system together. We see a similar situation with Intel-China. When I asked them if they were there because of the inexpensive labor force, they said no—labor represented only 8% of the cost of assembling their flash memory chips. They were in China because of the *quality* of labor, that is, because the people were highly knowledgeable, highly skilled, and highly reliable.

When we look at education versus training, the two require different processes. What we do in universities like Johns Hopkins is try to teach people to learn how to learn. This is a highly interactive process and is not content-specific. I believe that you can teach students to learn how to learn whether they are studying the Greek classics, quantum physics, or anything in between. Education is about reasoning and about problem solving, as opposed to training, which is the acquisition of specific skills and is content-specific to performing a job. Training may not require the same degree of interactivity as education, and may be more suited for distance learning.

Looking at research expenditures at Hopkins, we continue to grow. We are the largest research university in the country in terms of amount of research grants. This year we will do over a billion dollars of government-funded research and development. But what has happened as we continue to do research and education is that we are becoming subjected to the same kinds of factors as businesses: globalism, speed, ubiquitous access to information, and technology.

The globalization of education and research has profound implications. It used to be that if you were an expert in Chinese history and politics and you were at Johns Hopkins, you only had to be better than someone within probably a 200-mile radius. As long as you knew more than any other scholar in a local geographical area you were in a pretty good position and certainly would warrant a tenured professorship at Hopkins. But today if you are an expert in Chinese history and politics, you have to be the world expert. Since knowledge and communication are freely transportable, the expertise is also mobile, so we place a much higher value on expertise today than we did a century ago.

It's very much the Michael Jordan phenomenon. He was making $6 to 10 million a year with the Chicago Bulls, while the person sitting on the bench next to him was probably a very good player but making $500,000 a year. That is because Michael Jordan was the world authority at basketball and able to command a global presence. The journeyman guard playing next to him may have been fine for the local crowds in Chicago but was not going to have the drawing power on an ESPN broadcast. Even in China and Japan they mourned the retirement of Michael Jordan.

It's the same thing with expertise. We demand and require world-class expertise among researchers. There is going to be a premium on knowledge generation, and no country, no university, no state, no region can have a monopoly on intellectual capital. Expertise will seek its own level. This has profound implications for the university. Similarly, the student population is global. We need access to students around the world, and students need access to universities around the world. Universities have to develop global partnerships for accessing both expertise and customers (students).

Speed is important because the half-life of new knowledge is decreasing rapidly in many fields and the pace of innovation is increasing. Time is money—we're back to the Internet time frame of dog years. Coupling knowledge and skills to opportunities requires a rapid response—it means we must have the ability to put teams of people with the expertise together very quickly.

Universities will also have to become more nimble to respond to rapid changes in knowledge generation. We all know about information overload. The interesting thing is that the more information out there, the more job security we have in the university environment, since we are the people who can take raw information, generate signal, and remove noise when it is becoming harder and harder to do so. Anybody who doesn't believe that can surf the Internet and see the difficulty of getting good information. Despite the fact that I can get news from several sites on the Internet, I still go to one or two different newspapers every day. For instance, I believe the *New York Times* has the best ability to sort through, weigh, and report the most important information. This winnowing process is critical. At the same time, we will have to make larger investments in information technology to access and store all this information, which brings me to the concept of libraries.

A few years ago, when I assumed the presidency at Johns Hopkins, I was frequently asked about plans to close the libraries since everything would soon be available electronically. Quite the contrary! The more information we have, the more we need libraries, since it is there that the information is collated and sorted; it is filtered and validated in order to meet the needs of people who not only want access to information but particularly want to gain *knowledge*.

In 1995 we had the "just in case" library, where we stored as much information as possible in case somebody from APL or from the English or Biochemistry departments wanted access to a particular piece of published information. Today we are moving to the "just in time" library. There is so much information out there that we cannot hold on to it all ourselves. But much of it can be retrieved from archives. So we will have a library that tries to get the information to you "just in time."

I have, not facetiously, suggested partnering with Federal Express and locating our library in Memphis, Tennessee. If you think about it, Federal Express has a phenomenal database to track parcels and packages, and they also have the ability to deliver on time. So you could store in your local library only materials like journals and periodicals for the last year or two that people want to reference quickly. In Memphis, you would have all the hard copies. If you wanted a book, you would simply generate a requisition and the next morning that book would appear. It would probably be very cost-effective if you got enough universities to do the same. So far we haven't gotten any takers.

Beyond that, though, will be the "just for you" library—a library that knows what information interests you in your field of expertise and searches for it electronically, collates it, and delivers it to you even before you know it exists. This is, of course, a promise for the future, and perhaps we will actually be able to deliver on it one day soon.

Technology is another factor that is very important in education. It can certainly remove barriers to education, whether they are geographic (the student and university are in different places), temporal (classes are available during the day but the student works), cultural, linguistic, or financial. Technology can and will improve the quality of education and reduce cost, although it is often difficult to define quality, figure out how to measure change, and quantify precisely what the implications of technology are. But it *will* ultimately make education more cost-effective.

If you look at the cost of higher education (Fig. 3) and just focus on private universities, it has grown enormously. Basically, since 1975, relative to median family income, the cost of a four-year university education has doubled. At Johns Hopkins, it has risen from $18,000 in 1995 to $22,000 in 1999. The important fact is that 60% of our undergraduate students rely on scholarships and loans to finance their education. For every dollar increase in tuition, this number goes up, because many students find the cost to be at the margin of affordability.

Why is education so expensive today? Lack of increased productivity increases higher education costs compared to other industries. If you compare the bank of the early 1900s to one today, you almost would not recognize that the two were the same industry. Even more dramatic is the difference between an early

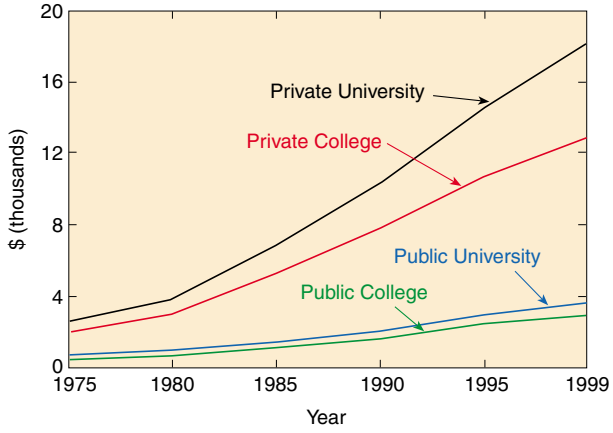

Figure 3. Average tuition and fees by type of institution (source: *Digest of Education Statistics*, 2000).

automobile manufacturing plant and one today. Many other sectors of our economy have used technology and quality improvement techniques in order to get tremendous productivity increases. But if you compare the Harvard or Hopkins of 1900 to what you see in 2000, you will recognize them as being the same; the only difference is that the chalkboard is white instead of black, and maybe a viewgraph machine or a computerized slide projector has been added. But the *mode* of delivery is the same. Improving productivity is not just a question of getting faculty to teach more; it is figuring out how to teach differently. We don't really know how to do that yet, and that will be one of the challenges we face in the years ahead.

The research university without walls has a global orientation. It will need partnerships for assembling expertise because research now is multidisciplinary. APL has been doing this for years because you have been dealing with system problems. But even problems in relatively narrow fields like biochemistry can no longer be dealt with by a biochemist alone. You also need a molecular biologist, a biophysicist, and a physiologist. We increasingly find that research is conducted in multidisciplinary teams. We continue to try to outsource our noncritical functions. But one of the things that is happening—and this is where we begin to get into the quantum physics model—is that the students and faculty are much more mobile today than ever before.

If you looked at research grants in a typical Hopkins department in 1985 (we would exclude APL because of the kinds of problems tackled here), most of them probably involved a single faculty member and/or a single faculty or discipline. Five or 10 years later, grants were often going to groups of faculty members from multiple disciplines, but most of them were still at Hopkins. Today, very few grants are given to just a single faculty investigator, and probably 20% of our grants involve a faculty investigator who is *not* at Hopkins.

For example, we received a prestigious National Science Foundation grant for robotic surgery that involved a number of divisions at Hopkins, including APL and the School of Engineering, but also included faculty members from Carnegie-Melon, MIT, and Harvard Medical School. This is the way of the future.

With the availability of transportable curricula and faculty, one can collect world-class expertise to put together a grant. You might say that we need the Michael Jordans of the academic world to assemble all-star teams, not just Hopkins franchises, in order to compete. It's more like putting an Olympic team together than a single state or local team. One needs to draw on expertise as widely as one can. On my recent trip to Singapore, I was accompanied by three other Hopkins faculty members: one teaches mathematics during the winter semester in Singapore, and the other two were doing collaborative research with faculty at the National University of Singapore. This is the way of the world.

THE QUANTUM PHYSICS MODEL

Which leads me to the quantum physics model of the university. The classical model of the atom is a central sphere with electrons orbiting around it. You can also think of the classical model of the university as this well-defined nucleus—the campus—with faculty and students acting as tightly coupled electrons rotating around the nucleus. The faculty and university were held together by commitment and tenure. Students were there full time and physically present, and everything was good, except when the students rioted every spring. But the students also felt a lot of loyalty to the university. Again, the faculty members, although loyal to their discipline, only needed to be *local* experts, so in some sense they had a lot more commitment to their institution.

Today we have multiple campuses, in fact, more like a cloud-like collection of sites. Hopkins has more than a dozen sites, and that number will probably increase in the next 10 years. The faculty are loosely bound and they obey the uncertainly principle: the more you try to pin down where they are, both physically and in terms of loyalty, the harder it is to find them. The faculty has to be a collection of international world-class experts. Their loyalty in some sense is not only to their discipline but to their subfield, and they need to work with others with the same focus. This association is natural and is made possible through electronic connections or physical moves. Faculty somehow "tunnel" between organizations in some quantum mechanical sense. We may have a faculty member teaching at Harvard in the fall, Singapore in the winter, and Hopkins in the summer. Or we may have faculty members doing collaborative research.

The students are wave-like as well because they've gotten older and have different expectations. They will pick and choose between institutions because they also need access to world-class expertise for their education. If you don't believe me, look at what is happening in higher education for undergraduate enrollments; full-time enrollments are going down while part-time enrollments are going up, and the average age of students is in the mid-20s. That average is heavily biased to state and community colleges, of course, but even if you look at Hopkins, our students are getting older, many more are working, and many drop out to pursue careers.

One of my friends at Stanford called me in great distress because his son, a junior at Stanford in computer science, told him he was dropping out to take a job programming at a start-up company for $55,000 a year plus options. I told him to stop lamenting and just

ask his son for 10% of his options. We're going to see more and more students moving in and out of universities. The idea that you have to get educated in a linear sequence and spend time for so many years like you do in a prison is going to fall from favor for educational cost reasons, for curriculum reasons, and because of the availability of other opportunities. Students will come into and go out of the university at their own pace. After all, Bill Gates was only at Harvard for a year, and he didn't do badly.

CHALLENGES

Making education more affordable is one of our biggest challenges. One way to do this is to make the delivery of content more cost-effective, while another is to leverage the investment that we make in course content and in our faculty by delivering that material to a larger audience. So, for example, if we prepare material for a neuroscience course for our undergraduates and if we invest more money to make it better, we could also market the material nationally to other schools or provide it through distance education. This is part of the strategy that Varian and Shapiro outline in *Information Rules*.[3] I think it's a very interesting idea because the cost of developing course content is quite high.

Various educational segments exist. If we look at delivering education to the highly interactive segment, which we think of as undergraduate and graduate students, the Hopkins hand-tooled education is the most expensive, but the most value-added education. Or we can look at delivery to the moderately interactive segment, like those at some state colleges, which provide more group-tailored education. It also has value added, but not as much perhaps, and it doesn't cost as much. And we can think of distance education or correspondence courses, which involve minimal interactivity. Education at this level has the lowest value added, but the fees are also much lower. So if one could develop a curriculum to be used across all of these segments, but delivered in different ways, one could recoup the large investment required to develop the much better curriculum.

Teleducation is primarily a way to deliver remotely a standard lecture format. It has been used in closed-circuit video teleconferencing and does not require any change in our standard format. It is costly, but with broadband video over the Internet just around the corner, it will hopefully become less expensive. Multimedia content can be delivered either through distance education over the Internet or by using CD-ROMs, but this requires changing the teaching paradigm. It is more interactive and allows user control on demand, but it is much more expensive to develop. We developed an interactive CD-ROM for our Hopkins Center for Talented Youth for 12- to 14-year-old children. The program, designed to teach the Pythagorean theorem, is called Descartes' Cove. The cost for developing one CD-ROM was between $1 and 1.5 million. In the absence of a broad market, a program like this cannot recoup the investment necessary.

Simulation tools certainly offer lots of opportunities beyond flight simulators. We are beginning to see laboratory simulators in the physical sciences, mathematics, and engineering. But one can look at simulation for the social sciences, game theory, financial modeling, and ultimately even for training physicians (without having to kill patients in the process). So I think there is a broad applicability. But again, the challenge with simulation tools is that they are extraordinarily expensive to develop and one has to figure out how to develop them for applications to a broad market.

Finally, asynchronous learning is being used in a number of universities to allow faculty and students to communicate without the need to be on-line at the same time. The advantage is that feedback is accelerated between student and faculty; it doesn't need to be done in "batch mode" as we do currently, and the quality of learning goes up dramatically. Faculty that have participated in this model actually like it.

The limitation of computer-based instruction is that it is more costly to develop, but the advantage is that it is less costly to deliver. It is repeatable, which ensures that all students have a uniform educational experience. We professors do not like to think of the latter as an advantage, but in fact, especially for K–12 education, more uniform standards in teaching delivery would be a tremendous gain. It makes it more difficult to tailor course content to the individual needs of the student, but we are making progress in this area. Information on demand and rapid feedback are shown to maximize learning. It is always more difficult to make education interactive, although I have seen people attempt it even for courses like creative writing, where it is tremendously challenging.

There are major issues confronting us in Internet-based education. One is sharing course content. One company has gone on the Internet to provide class lecture notes. They pay a student to sit in on a lecture and take notes, and then they publish the notes on the Internet. At first sight, this doesn't sound like such a bad idea. After all, students would not have to be so diligent in taking notes in class, and if they miss a class they can get access to the information. But of course all other students across the country can also get access to it. There are some questions as to whether we are guarding the information content. Thus far, universities haven't figured out how to do that.

But there's a much more insidious problem, particularly for those of us in research universities, where you would like to give students access to your latest research results. In fact, you would like to give them problems from your research and have them solve those problems

for you. But if the material is going to end up on the Internet, you have a dilemma. You don't want to put your latest research out on the Internet, and you don't want to give your students preprints of a book you may be writing and find it on the Internet.

The University of California, Berkeley, is suing the company I just mentioned because, rather than making the material more readily accessible to their students, it had the unintended consequence of restricting the amount of communication between faculty member and class because faculty cannot copyright the material. In other words, no one has found a way to copyright material if a student sits and takes notes and then puts them on the Web.

Another issue is the ownership of the course content. We provide our faculty with a long-term contract through tenure, but it's not clear that we own the intellectual content of their work. In fact, most universities, including Hopkins, have allowed faculty to publish books and collect royalties. Recently, a Harvard law professor developed course content for a distance education firm, and Harvard is now suing the faculty member for violating his commitment. This will be a tremendous challenge because we haven't really clarified in our contract with faculty members who owns their intellectual output. We believe the university does. But that could precipitate some real obstacles at a time when the relationship between the faculty and the university is already being challenged because of the issue of global expertise.

The third issue, which is related but different, is the ownership of intellectual property. As you may know, we have the "Fair Use Provision" of the Copyright Act, which lets us make a limited number of copies of articles for students for use in teaching or research. The Disneys and the Microsofts of the world want more stringent copyright rules that would eliminate fair use laws and make it very difficult or expensive to distribute copyrighted materials for teaching.

Finally, we have the for-profits. Can the Phoenix universities or the Strayer colleges of the world adopt the Walmart or Home Depot model of discount education and come in and take over our business? Currently they are looking at a different segment of the market, the continuing education market. But I am concerned that in the long run they could find a model that really works. So for-profit companies are certainly a concern. Their advantages are access to capital, lower cost structure, and nimble organization. They can invent new paradigms without being tied to the past, something that is more difficult for higher education.

So is the American university obsolete? In my view we are in a market where there are far too many colleges and universities, and there has to be consolidation or some of us will not survive. The survivors will have to mutate significantly, and probably the education paradigm will shift. You already see the strains of this in that a few liberal arts colleges are having problems. Unless they have a large endowment or a unique niche, they cannot afford to support their infrastructure.

There has to be partnering, mergers, acquisitions, or closures in order to deal with this issue. Two years ago I proposed to Jim Neal, our director of the Sheridan Libraries, that he approach all the colleges and universities in the Baltimore area with the idea of managing their libraries—they would outsource their libraries to us, and we would manage them. You spread the cost of managing—the cost of managing five libraries is not five times the cost of managing one—and we have the expertise to do that. Jim said he has tried, but no one was sympathetic.

But I guarantee that when the economics get strong enough, or negative enough, people will become much more sympathetic. And those kinds of things will create opportunities for the universities as well as significant change. I cannot predict whether the for-profits will come in and take over our business or whether the Internet will destroy us. I don't think so. But what you see happening with the Amazon.coms is that they are adopting the Internet and using it as well as conventional businesses. So our strategy is to try to figure out how to embrace the technology and use it to our advantage.

I am more concerned that the quantum physics model has already begun to transform the American research university, and it will have profound cultural implications. We are a community of scholars and will continue to be a community of scholars, but maybe not in the same way as we were in the past. As our geographic and national boundaries have been destroyed by globalism, so, in some sense, have the university boundaries. In the push to acquire expertise, we are seeing enormous bidding wars for faculty in certain disciplines. The drivers of this change are access to global expertise, speed of knowledge generation, changing demographics, the different needs of students, and the imperative of increased productivity.

We have software systems, to use Tom Friedman's term, like tenure promotions, that are suited for the Cold War, but not for the new global economy. How we adapt to these challenges will determine who is going to survive in this new quantum world of ours.

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