Trouble on "The Endless Frontier"

Science, Invention and the Erosion of the Technological Commons

By Seth Shulman

NEW AMERICA FOUNDATION

PUBLIC KNOWLEDGE

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Washington, DC

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About the Author

Seth Shulman is a journalist specializing in science and technology. He is the author of several books including *Owning the Future*, which chronicles and analyzes fights over intellectual property in the emerging knowledge-based economy. He is a monthly columnist on intellectual property issues for *Technology Review* and has written hundreds of articles for publications including *The Atlantic*, *Discover*, *Nature*, *Parade* and *Smithsonian*. In 2001, he was honored as a finalist for a National Magazine Award in the public interest category. His forthcoming book, *Unlocking the Sky: The Race to Invent the Airplane* will be published in September 2002 by HarperCollins. He lives in Northampton, Massachusetts.

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Introduction

Basic research leads to new knowledge. It provides scientific capital. It creates the fund from which the practical applications of knowledge must be drawn. New products and new processes do not appear full-grown. They are founded on new principles and new conceptions, which in turn are painstakingly developed by research in the purest realms of science.

—Vannevar Bush, "Science: The Endless Frontier," 1945[1]

At the dawn of the 21st century in the United States, our culture and economy are so steeped in an unqualified belief in the power of entrepreneurial innovation that, ironically, we tend to disregard the enormous investment previous generations have made toward the nation's shared research infrastructure. We like to think that the inventions upon which we increasingly rely have sprung up like weeds. But the truth is that these inventions owe more than we often acknowledge to cultivation and the careful preparation of a seedbed.

A plan for farsighted investment in basic research is outlined in a 1945 report called "Science: The Endless Frontier" penned by wartime science advisor and Massachusetts Institute of Technology (M.I.T.) engineer Vannevar Bush at the request of then-President Franklin D. Roosevelt. The report, which paved the way for the National Science Foundation, may be the most important blueprint ever written for U.S. science policy. It argued forcefully for the U.S. Government to make a huge investment in the nation's research infrastructure in the aftermath of World War II to ensure scientific progress and economic health.

Today, more than six decades after it was written, Vannevar Bush's blueprint deserves our renewed scrutiny. Following its recommendation, the federal government continues to fund more than half of all scientific and technological research undertaken at U.S. universities,[2] primarily through open-ended basic research grants to independent scientists and engineers. As Bush's report predicted, scientific and technological innovation has proven to be a powerful engine of economic growth.

Yet despite the prescience of "Science: The Endless Frontier," much has changed since Vannevar Bush's day. It is one of the central ironies of our time that, while unprecedented advances in telecommunications have made possible more widespread, free and instantaneous sharing of information than ever before, we often find precisely the opposite effect taking hold: the privatization and suppression of knowledge. In fact, in many high-tech fields, freely shared knowledge seems increasingly like an endangered species. As ideas, concepts, blueprints and codes become the most desirable commodities in the knowledge-based economy, people are hoarding, fighting over and seeking to control them as never before.

In this survey, 73 percent of the geneticists said that the withholding of data slowed progress in their field and nearly half reported that their colleagues' refusals to share data or materials has adversely affected their own research and the education of their students.

Nowhere is the control of these desired commodities more evident than in the world of scientific and technological research. Consider a recent survey of some 1,240 geneticists published in the *Journal of the American Medical Association*.[3] In this survey, 73 percent of the geneticists said that the withholding of data slowed progress in their field and nearly half reported that their colleagues' refusals to share data or materials has adversely affected their own research and the education of their students. Notably, some 28 percent of these scientists reported that the decline in information sharing has actually prevented them from independently confirming published research—a key requisite for the advancement of any scientific field.

Especially in a field like genetics where barriers to the exchange of scientific knowledge can impede public health, many scientists are naturally outraged. "This runs completely against the scientific ethos," says Nelson Kiang, a professor emeritus of physiology at Massachusetts Institute of Technology (M.I.T.), responding to the survey results noted earlier. Some might want to treat scientific work as a competitive sport, Kiang says, "but our common enemy is ignorance and we should be helping each other as fast as possible."[4]

Unfortunately, the trend documented by the nation's geneticists is not an anomaly. Researchers in a variety of fields and at many different research institutions in the U.S. increasingly complain that open dialogue and exchange among their colleagues is being replaced by proprietary claims and secrecy. Anecdotally, administrators at libraries, museums, hospitals, photographic archives, universities and research institutes all report in growing numbers that they are confronting unprecedented commercial pressures from companies and individuals staking private claims to material formerly considered part of the public domain.

Such concerns are set against a backdrop in which corporations fund a growing share of research at universities and other research institutions.[5] Perhaps even more importantly, these enclosures on the public domain occur at a time when the rhetoric of the entrepreneurial marketplace holds sway as never before. There is no question that vital new industries have been spawned as technological developments have been brought to the marketplace. However, unprecedented proprietary pressures now seem to be encroaching upon research arenas, from medical research to software design, where knowledge has historically been shared. Powerful groups of technological titleholders are trying to significantly tighten control over knowledge assets, often creating troubling new monopolies that harm markets and research disciplines alike. In essence, the norms and values of the boardroom and the classroom are coming into direct and dramatic conflict within the nation's research and development (R&D) effort.

When we consider the status of the nation's scientific and technological research, it is customary to think of the economic paybacks. Yet we need to think of more than the short-term bottom line. Any schemes that foster the commercialization of knowledge at the expense of the free sharing of information and ideas deserve our closest scrutiny. Sharing knowledge, after all, is the basis for scientific progress and our educational system. And the open research environments in the United States and Western Europe are widely credited with contributing to their role as world technological leaders.

Charles Vest, president of M.I.T., noted several years ago in a speech at the National Press Club, that the country's research universities "are the foundation of our entire national research infrastructure." Vest explained that university research can be credited with a host of developments, from polio vaccines and cancer therapies to jet airliners and computers. Our broad-minded federal support for university research labs, Vest rightly observes, "is an investment in the future of our human capital—people and their ideas."[6]

This is true not just in a figurative sense, but in a literal one as well. In the United States, taxpayers contribute some $60 billion annually to underwrite the bulk of the nation's basic research and development at universities, research institutes and national laboratories.[7] Ultimately, the public deserves to know whether it is being well served by its significant investment in scientific and technological research.

The accumulating evidence is worrisome. Over the past several decades, a kind of private "land grab" on the high-tech frontier has taken place. In many important respects it undermines the core strategy for scientific and technological research laid out by Vannevar Bush: the idea that freely shared and open-ended basic research is the most important wellspring for new technologies. As Bush wisely put it, "Scientific progress on a broad front results from the free play of free intellects, working on subjects of their own choice, in the manner dictated by their curiosity for exploration of the unknown."[8]

This report is inspired by the belief that we should assiduously guard against an erosion of the "technological commons"—the ethos of sharing information, scientific data and even material that has served as a central foundation for the nation's research effort. To that end, this report presents a snapshot of some of the issues at stake while proprietary claims and entrepreneurial pressures place new strains on the nation's shared research infrastructure.

Among the issues to be considered are the erosion of the exchange of information and the new threats to unfettered access to data. This report also examines the effects of patents and secrecy on the "research ecosystem," especially on broad concepts "upstream" in the research environment. It also explores the often-corrosive effects of institutional liaisons between universities and private companies in the shared research environment.

Finally, this report offers a glimpse of some hopeful developments in which practitioners seek to remedy some of the worst market enclosure excesses of the technological commons. Far from a comprehensive list, the efforts presented are intended to illustrate the kinds of proactive initiatives that can help the technological commons to flourish and grow in the future.

I. The Changing Landscape of Scientific Research

What we accomplish stands atop a Gibraltar of technological inheritance. Seemingly contemporary transformations inevitably build on knowledge accumulated over generations.

—Gar Alperovitz, historian and political economist, 1994[9]

For a number of reasons, the landscape of scientific research has changed significantly over the past few decades as industrialized nations shift toward a knowledge-based economy. From U.S. Supreme Court rulings to international trade negotiations, the United States has led the rest of the world in moving swiftly to institutionalize the notion of knowledge as a commodity. Many of the key decisions that furthered this institutionalization have come about with little public debate and with remarkably little foresight about their potential long-term consequences.

An oft-cited example from a previous, revered generation of scientists illustrates the virtual sea change that has occurred in our notions about ownership and proprietary claims in high-tech research. In 1954, when Jonas Salk developed a polio vaccine, he never for a moment considered the idea of pursuing individual ownership rights to the discovery. Nor did Salk imagine the idea of licensing the vaccine in an effort to personally control the direction of future research in the field. In fact, Salk's funder, the March of Dimes, prohibited patenting or the receipt of royalties on the results of its research projects. When Edward R. Murrow, the renowned television commentator of the day, asked, "Who will control the new pharmaceutical?" Salk replied that, naturally, the discovery belonged to the public. "There is no patent," he said. "Could you patent the sun?"[10]

This story bears repeating for the contrast it offers to the contemporary research environment. In the 1990s, for example, a biochemist named Donald Young and his team at the University of Rochester conducted pioneering work to help understand the Cox-2 enzyme. Unlike Salk, however, this team sought—and, in April 2000 won—a patent on their research. The result: a bitter, ongoing, multi-million-dollar lawsuit involving Young, the University of Rochester, and two pharmaceutical companies that have brought to market a new class of painkillers—the Cox-2 inhibitors—that block the action of this enzyme. Officials at the University of Rochester contend that Young's seminal research should entitle them to billions of dollars in royalties on any drugs relating to the Cox-2 enzyme that result during the patent's 17-year term.

The fact is, however, that public information sharing is at least as important as private incentives in the successful conduct of scientific and technological research. It is a lesson we need to understand now more than ever.

When Gerald P. Dodson, a lawyer representing the University of Rochester, was interviewed by the press, he said the university was thrilled with the situation. "Imagine waking up in the morning and having a patent on aspirin," Dodson said. "Well, these people at Rochester woke up this morning and have a patent on a substitute for aspirin that is even better."[11]

Needless to say, the contrasting anecdotes bespeak a significant shift in priorities. The nation's research universities and national laboratories alike have increasingly come to be viewed by the public, industry and members of Congress as engines of economic growth fueled by the technological innovations they foster. In the absence of careful forethought about how to manage and preserve these research environments as a resource for the future, such a change in attitude has led to commercial pressures so intense that they frequently reduce the free exchange of information which has historically been a hallmark of these institutions' success.

Champions of entrepreneurialism argue that rewarding inventors with patents spurs innovation. The notion is a bedrock principle of our innovation system with deep roots in American history. In fact, Abraham Lincoln made much the same argument in favor of patenting when he lauded the nation's patent system for adding the "fuel of interest to the fire of genius."[12] The fact is, however, that public information sharing is at least as important as private incentives in the successful conduct of scientific and technological research. It is a lesson we need to understand now more than ever. A more appropriate balance between the two is the challenge for public policy.

The Commodification of Ideas

As an entrepreneurial, market-based approach to scientific research has come to predominate over the past several decades, one emergent problem is the fact that knowledge is intrinsically different from other kinds of tangible commodities. Traditional goods like oil, rice or running shoes, are finite resources that are depleted by use. Because their availability is limited, these goods cannot be easily shared among all who desire them. An allocation and distribution system, whether the free market or a commons-management regime, is needed. Knowledge, however—including the results of basic scientific and technological research—is not finite in the same sense. It is not depleted by use simply because of one person's consumption of a good. In other words, use of knowledge does not leave another person with any less knowledge (this concept is termed by economists as "nonrival consumption"). On the contrary, journal articles, software programs and medical procedures lose their value and utility when they are *not* used: when they are sequestered or (perhaps deservedly) neglected. In a fundamental sense, the utility of knowledge assets rests in their exchange and propagation.

This infinite, bountiful, nonrival quality of knowledge assets holds equally true for software, genetic information and virtually all formulas, techniques and languages that might be created, developed or discovered. This dynamic is the cornerstone of the enterprise we call education. When a doctor or biomedical researcher develops a lifesaving medical procedure, for instance, the world's inhabitants will benefit only to the extent that the knowledge is disseminated. Most notably, the original inventor can still perform the procedure effectively, even when the entire world's medical practitioners are apprised of it. A single, particular knowledge asset can, in essence, satisfy the needs of an infinite number of users.

The fundamentally nonrival nature of the burgeoning body of scientific and technological information presents special challenges to those who seek to treat knowledge exclusively as a commodity. In trying to "marketize" knowledge, entirely new and intractable problems arise. One problem is that it is inherently difficult to distinguish one idea from another. Knowledge is slippery, interwoven and often needs to be shared to be of any use. Unlike land or other forms of tangible property, it cannot easily be cordoned off and parceled into discrete packages. The result (already evident in many high-tech fields) is a growing number of internecine and unproductive lawsuits over proprietary rights to emerging scientific and technological know-how. In one well-publicized case, for instance, the conglomerate British Telecom is currently challenging Internet service provider Prodigy in court, claiming to own a patent on the "hyperlink" that facilitates easy access from one site to another on the Web.[13] Other bitter legal disputes have surfaced recently over the provenance of everything from screening tests for the breast cancer gene to the technology that made the Pentium computer chip possible.[14] By presuming that the new, knowledge-based regime can run on the same rules of private property that fueled the industrial age, we have created a legal tinderbox.

The viability of such a system is challenged by the conundrum concerning from where these ideas spring in the first place. What ownership rights, if any, should my specific, innovative scientific research earn for me? The critic Northrop Frye captured this dimension of the problem in 1957, when he noted famously that "poetry can only be made out of other poems; novels out of other novels."[15] Bruce Hartford, of the National Writers Union underscored the point emphatically in 1997 to an audience of computer professionals by observing, "All new knowledge, every single piece of new intellectual property, is built on the intellectual foundation of what has gone before. You cannot be a writer, or any other kind of creator, without also being a reader and a researcher."[16] This interdependence among creators applies as much to high-tech fields as it does to the arts and humanities.

The Impact of the Bayh-Dole Act

Practically speaking, the most significant single policy change, in recent history, to the nation's research infrastructure is surely the Bayh-Dole Act of 1980. With the support of the Carter administration, the Bayh-Dole Act sought to accelerate so-called "technology transfer" by allowing universities to retain private ownership rights over the discoveries of their faculty members—and thereby profit directly. This landmark legislation gave universities the right to seek patents for scientific discoveries made by their faculty and staff with support from federal funds. As such, it marked a fundamental policy shift toward the private, corporate exploitation of concepts and know-how that might otherwise be placed in the public domain.

At the time of the Bayh-Dole Act's passage, the U.S. Congress was preoccupied by competition from high-tech Japanese industry and fears over a sluggish domestic economy. As a remedy to both of these ailments, U.S. legislators sought to transfer the fruits of university research to the marketplace more speedily. In essence, the Bayh-Dole Act freed universities to launch for-profit entities to facilitate the transfer of technological developments to the market. In an era of federal belt tightening, proponents of the legislation portrayed it as an alternative funding source to compensate for the shortfall in federal grants to universities. By enacting the Bayh-Dole legislation, they hoped to attract corporate dollars to universities by offering the possibility of exclusive licensing agreements on discoveries made in campus laboratories.

At the time of its passage, opponents of the Bayh-Dole Act worried that it was a sellout to corporate interests and would have the undesired consequences of undermining academic independence and scientific integrity. Then-Congressman Al Gore, fretted publicly that the arrangement risked "selling the tree of knowledge to Wall Street."[17] Another critic at the time, Admiral Hyman G. Rickover, testified that he believed the Bayh-Dole Act represented one of the greatest giveaways in American history. "Based on 40 years' experience in technology and in dealing with various segments of American industry," Rickover warned, "I believe the bill would achieve exactly the opposite of what it purports," hurting small businesses and stifling competition while promoting "greater concentration of economic power in the hands of large corporations."[18]

Today, the Bayh-Dole Act is widely regarded as a success story for preventing publicly funded research from languishing in the ivory tower. The ownership rights of universities were further expanded under Public Law 98-620, passed in 1984. Since the enactment of these two laws, patenting by universities has risen sharply, especially in the life sciences. In tandem with this increase, licensing agreements and revenues have also jumped. Almost all large research universities now have special offices devoted to patenting and, frequently, to licensing and other forms of university-industry technology transfer.

And yet, nearly two decades into the Bayh-Dole regime, many of the concerns first raised by Gore and Rickover are being borne out. Scientists increasingly complain of secrecy agreements, ethical conflicts and other pressures brought upon the open, unfettered research environment. By placing such an emphasis on commercializing the fruits of the research infrastructure, many are coming to question whether we may have neglected to tend the garden in which these fruits grow.

Understanding the "Infostructure"

What is missing in the drive to institutionalize the commodification of scientific and technological research results is an appreciation of the role played by the "technological commons." One can think of this growing body of knowledge and the system through which it is shared as a kind of platform or framework (not unlike the network of roads that makes up the infrastructure of a city). In this sense, some types of knowledge constitute a shared infrastructure—or "infostructure"—that properly belongs to all who would use it. It exists in a gray area between the marketplace and the public square, between the boardroom and the classroom. As we build a global economy for the 21st century, we need a new way to think about this conceptual information commons.

As many are coming to realize, things work best in the knowledge-based economy when certain seminal information assets—particularly those needed by all players in a given high-tech sector to compete—are pooled and shared. In the realm of scientific and technological research, for instance, the principle of the "infostructure" can be seen to include both open source software and the open, non-proprietary hardware standards that have come to predominate in many high-tech sectors. It is present in the shared use of genetic sequence information; in the know-how that allows different engineers to design distinct machines that can plug into a single type of wall socket; and in software files that, because of common protocols, can travel seamlessly over the Internet. Like roads, public lands or public libraries, pooled knowledge assets must be freely accessible and protected within a framework that preserves their integrity.

Along these lines, the infostructure is undermined when data is withheld, when access to data or materials is hampered and when proprietary claims prohibit others from participating or accessing information. Nonetheless, most believe that inventors ought to be entitled to some assurance that they will be able to protect their rightful creations. They want to be able to recoup the risks they take and the investment of time, energy and resources that they expend to bring new and innovative products to the public.

When considering information flows in the scientific and technological research environment, there is a missing vocabulary. We do not have a conceptual framework that recognizes the value of shared knowledge assets as well as privately held knowledge.

How can a system support both the shared and private control of knowledge assets? Our extensive experience with land ownership can provide an answer. Most nations, such as the United States, that champion private property also venerate national, state and municipal park systems that preserve some special land for shared use. Similarly, we enact zoning restrictions that limit the uses of even privately held land. However, no analogous mechanisms yet exist in the realm of intellectual property law.

By placing such an emphasis on commercializing the fruits of the research infrastructure, many are coming to question whether we may have neglected to tend the garden in which these fruits grow.

Thus the first task before us, in high-tech sectors from software design to genomics, is to proactively identify the infostructure: to define when shared interests should override private claims on the knowledge frontier. Unless the issue is tackled head on, the escalating privatization of knowledge assets threatens to choke productivity, magnify inequalities and erode the vitality of our scientific research environment.

II. Current Threats to the Research Ecosystem

Although commerce is to be supported, there are signs of a culture being made sick by commercial interests to an extent that is unprecedented in science.

—Editorial in *Nature*, 1996.[19]

Few would argue that commercial interests have encroached dramatically upon scientific research in academia over the past two decades, especially in fields such as computer science and biomedical research. It is still too early to say conclusively what the long-term effects of this shift will be on productivity, but there are already strong indications of an impoverished research environment.

Absent a clear delineation of the infostructure as discussed briefly earlier, virtually everything in the research environment can come to be seen as a commodity to exploit. As the editors of the science journal *Nature* have put it: "Today's fundamental elucidation of a protein interaction can be (almost literally) tomorrow's profit-earning test kit. Today's gene sequence, if not applicable tomorrow, may be assumed to be replete with vast profits achievable the day after."[20]

Further confounding the picture is the growing realization on the part of corporations and universities alike that potentially lucrative discoveries are not always obvious at first. Lester Thurow has recounted, for instance, that the lawyers at Bell Laboratories were reluctant to patent the laser because they never believed it would become a commercially viable discovery. Today, as Thurow rightly notes, of course, "nothing is more ubiquitous than the laser—for correcting your eyesight, playing your music and transmitting your telephone calls."[21]

Today's companies are loathe to miss potential opportunities that might arise from the latest scientific and technological research. Ironically, the zeal to propertize scientific knowledge—as early and thoroughly as possible—now threatens the kind of open research environments that are most conducive to new discoveries. Intellectual ferment and cross pollination between many fertile minds requires an open, collegial environment; it is hampered by a closed, proprietary and legalistic regime.

Diminished Discourse

One of the most basic and subtle threats to research infrastructure is secrecy. Secrecy is anathema to progress in scientific and technological research because the endeavor depends on the robust exchange of information. As noted earlier, in science, knowledge quite literally grows by being shared.

Because the corporations that fund university research routinely do so in the hopes of gaining a competitive advantage, they invariably seek to control the dissemination of research results, at least until they can secure a patent on the research. This fact alone has led to widespread complaints among researchers in academia. In one 1998 study of university-industry collaboration, for instance, some 58 percent of respondents (drawn from a variety of fields in science) said they feared that close collaboration with industry disrupted their long-term basic research mission at the university; equally notable, more than 77 percent stated that those mixing research and business risked increased conflicts of interest.[22]

The shift toward increased secrecy usually shows up first in conferences and other forms of communication within a field. Russell Brand, the organizer of one well-known state-of-the-art computer industry conference, explained several years ago that more than half of the speakers he approached said they could not give talks because of patent-related restrictions placed upon them. As a result, Brand says, "It's going to be another two or three years to find out what they are doing, and so everyone working in that same field isn't going to be able to build on that research as quickly." Brand adds that the problem has increased dramatically since his conference series started in the mid-1980s.[23]

Excessive secrecy can also hurt the careers of students and junior faculty members who cannot publish or otherwise share their research findings. Jonathan King, a biologist at M.I.T., recalls, for example, that one of his graduate students recently made an important advance in the field but, in a break with longstanding tradition, opted to withhold the key piece of his thesis research even in an academic talk to his colleagues in the department of chemical engineering. The student, on the advice of one of his professors, decided to keep the information secret until he could secure a proprietary claim on it despite the fact that it would retard the work of his colleagues and his own progress toward his degree.

A growing body of data corroborates such anecdotal evidence. For instance, a 1997 study found secrecy to be particularly widespread among researchers in the life sciences. Out of some 2,000 academic life scientists surveyed, 79 percent acknowledged that they had delayed sharing new information in order to apply for patents or secure some other kind of intellectual property protection for their work. A fifth of those surveyed reported that, for commercial reasons, they delayed publication of their data for more than six months and in some cases, keeping it secret indefinitely. Even more troubling, nearly a third of those who delayed publishing research results admitted they had sought to "slow dissemination of undesired results," presumably because of the commercial stakes—such as the effect of the results on stock prices of companies to which they were related.[24]

Most researchers on university campuses decry the impediments that prevent them from sharing new ideas and developments in a given field. Recognizing the problem, many universities have adopted regulations limiting the amount of time that commercial sponsors can delay publication so that patents can be filed. Nonetheless, as industry funding replaces public research funding, the trend seems to be in the direction of increased secrecy.

As these scientists realize, the rise of secrecy is not just an unpleasant fact of life; it fundamentally undermines the entire research enterprise. Left unchecked, encroaching commercial interests threaten the open exchange of ideas that is largely responsible for the ferment and intellectual vigor of university research environments. As Paul Berg, professor of biochemistry at Stanford Medical Center, puts it, "We sit here and talk about feeding ideas into American industry, but we ignore the price we will pay." Berg goes so far as to claim that commercial incursions are already on the way to destroying pure, discovery-based science in U.S. universities.[25]

Hampered Access

The technological commons has been eroded not only by the withholding of data among scientific colleagues, but by legal and institutional barriers such as stiff database protections and nondisclosure agreements that also limits researchers' access to data and materials.

Jerome Reichman and Paul Uhlir point out that the privatization of formerly shared data can have dramatic effects that are often dependent on vast data sets, especially in fields like astrophysics and geology. As Reichman and Uhlir note, the federal government's decision in 1985 to privatize the Landsat program (jointly sponsored by the National Aeronautic and Space Association and the National Oceanic and Atmospheric Association) seriously undermined basic and applied research in environmental remote sensing in the United States for much of the next decade.

There are strong indications today, they report, of a similar threat in the data collection and dissemination activities of the U.S. Geological Survey. "There recently has been a great deal of pressure on the science agencies, particularly through Congress, to stop collecting or disseminating data and to obtain those data from the private sector instead."[26]

Meanwhile, academic biomedical fields have seen a proliferation in recent years of contracts governing the routine exchange of biological materials that serve as the basic building blocks of much biological research. Known as Material Transfer Agreements (MTAs), these increasingly elaborate contracts between research groups stipulate that in order to gain access to a given biological material—such as a proprietary gene sequence, microorganism or other genetic resource—recipients must agree to surrender their rights on discoveries that might be contingent upon the material's use. MTAs are essentially fences erected between research teams. These legal barriers appear to be steadily growing taller and more prevalent across the research landscape. Some MTAs demand the right to preview and comment on any articles that might arise from research involving the material that is to be exchanged. Some even stipulate so-called "reach-through rights" that stake a claim to next-generation inventions that might result from research; reach-through rights assert ownership in knowledge even before it is passed along to a colleague's laboratory or an invention is completed.

The proliferation of MTAs has drawn the ire of many researchers in academia who variously likened them to kudzu and to a "spreading virus" of restrictions. Kate Phillips, a staff member at the Council on Governmental Relations, a nonprofit group that represents

142 research universities, calls the increasing complexity of MTA contracts—and the time and effort devoted to negotiating them—"a horrendous problem." Julie Norris, director of the Sponsored Research Office at M.I.T., complains that "no amount of education" by university researchers and administrators has diminished companies' unceasing attempts to gain control or outright ownership of discoveries arising from the use of shared materials. According to Keith Yamamoto, a biologist at the University of California at San Francisco, the situation already "endangers the academic tradition of free and open publication."[27]

Of all the threats to basic scientific and technological research, perhaps none is as dramatic as the proliferation of increasingly broad, conceptual patents on basic research techniques.

Expanded Proprietary Claims

Of all the threats to basic scientific and technological research, perhaps none is as dramatic as the proliferation of increasingly broad, conceptual patents on basic research techniques. In the United States, the intellectual property system arguably thrived in the mechanical age, providing patent protection for tangible machines—like new toasters. In the 19th century, U.S. inventors were even required to make prototype models to receive a patent.

Today, however, the U.S. patent system has moved far up the ladder of abstraction. Instead of allotting protections on new toaster designs, today's patents more often afford exclusive rights on conceptual terrain akin to the idea of making toast. These broad new patent rights often function like needless tollbooths assessing royalty fees on everyone in an industry, or worse, like roadblocks that deter would-be competitors. Far from their original intent, these patents frequently deter innovation.

A large part of the problem is that, to receive a patent, an invention is expected to be "useful." Historically, courts in the United States have recognized that the system works best when a patent's so-called utility is defined narrowly to include only those inventions that benefit the public by introducing a new product into the marketplace. As the U.S. Supreme Court noted in a 1966 case, *Brenner v. Manson*, involving an allegedly novel process for making steroids, a definition of utility that is too expansive can undermine the patent system by creating a "monopoly of knowledge." A broad patent, the court wisely concluded in this case, "may confer power to block off whole areas of scientific development, without compensating benefit to the public."[28]

In today's knowledge-based economy, this seems to be precisely what is occurring. Legal scholars Michael Heller and Rebecca Eisenberg, for instance, have offered a helpful distinction between patent protection that falls "upstream" and "downstream" in the often-lengthy chain between research and product development. As these experts note, patents awarded too far upstream can, in fact, "lead paradoxically to fewer useful products."[29]

Take, for instance, the recent case of the protein receptor known as CCR5. Four years ago, several research teams pinned down the role of this CCR5 receptor as an entry point for the AIDS virus, making it a prime candidate for anti-AIDS drug development.

In 2001, the teams were chagrined to learn that, despite their breakthrough discovery, Human Genome Sciences (HGS), a major genomics player, had received U.S. Patent No. 6,025,154 granting the firm exclusive rights over the gene that codes for the CCR5 protein. Even before the HIV connection was made, HGS had applied for a broad and vague patent on the gene in June 1995—a so-called "composition of matter patent"—that simply claims ownership rights over a gene-based invention that produces a protein receptor. While the patent spells out the chemical building blocks that make up the gene and the protein, the rest of the application is highly speculative and general. It suggests that blocking or stimulating the gene or the protein could have an impact on diseases including cancer, blood disorders, allergies and arthritis. But there is no mention of AIDS or HIV in the patent and only a single passing reference to the fact that proteins related to CCR5 can be targets of viruses at all.

Nonetheless, in the current "winner-take-all" model, HGS is the technological title-holder for all research on CCR5. HGS profits both from the AIDS research of others and by determining who will be licensed to develop the research and medical products. Cases like the evolving story of the CCR5 protein offer only a glimpse of the types of disputes and problems ahead.

The result, of course, is a numbingly complicated situation that becomes nearly impossible for the legal system to sort out. As the patent system allows inventors to move continually "upstream" from one another along the river of generality in the concepts to which they lay claim, we can fully expect to see a surge of broad, contested, overlapping claims to valuable pieces of the knowledge-based economy. Indeed, the litigation boom has already begun. To make matters considerably worse, patent infringement cases are among the most costly type of litigation in the U.S. legal system. Even the average, run-of-the-mill patent infringement case that goes to trial now costs litigants $1.2 million in legal fees according to the Virginia-based American Intellectual Property Law Association.[30]

Academic researchers are often directly affected by these kinds of patent fights. For a powerful example, look no further than an astonishing patent issued in agricultural biotechnology to Monsanto in 2001. The patent—number 6,174,724—covers one of the most seminal technologies in the field: the use of so-called "chimeric" genes as a vector to shuttle new genetic traits into plants. The patent grants Monsanto exclusive rights to a key, widely used germ—*agrobacterium tumefaciens*. This was the very first "Trojan horse" scientists employed to get foreign genes into plants back in 1983. Some 18 years later, there is probably not a player in the field of transgenic plant research who has not made use of this technique. Armed with a 20-year monopoly on this fundamental technology, Monsanto managers can now lawfully choose whether they wish to license the technique to others and can demand whatever royalties they choose.

Monsanto has essentially grabbed a piece of the agricultural biotechnology "infostructure"—a technology to which everyone in the field needs access in order to compete. In the considered opinion of John Barton, a law professor at Stanford University, you can easily spot problematic patents like this one because they cover a technological tool that is likely to be used in many marketable products, but that is not directly marketable itself.[31] These upstream patents provide no incentive for innovation. On the contrary, they create powerful roadblocks to the commercialization of new products.

But what makes the Monsanto patent particularly egregious is the extent to which it represents the private capture of public investment. In this case, several of the teams that developed this powerful technology were made up of academic researchers operating, in part, with government grants. As Daniel Charles carefully chronicles in his book, *Lords of the Havest*, academic researchers developed the technique to use the germ over the course of a decade. And, in the good old days of collegial sharing of information, these academic researchers freely (and naively) passed along some of the most valuable pieces of the puzzle to Monsanto.[32]

It is clear that the rush to patent discoveries created by university scientists poses a threat not only to the research environment but to the credibility of the university as well.

Legal scholars Arti Rai and Rebecca Eisenberg, who have studied closely the tug of patents in the biomedical field, explain the problem succinctly: "Patents on research discoveries impose costs on R&D, and these costs may well exceed any social benefits that they offer in the form of motivating further private investment in product development."[33]

Academia, Inc.

If broad proprietary claims on basic research are eroding the technological commons, so are many of the policies that universities are adopting to govern their relationships with corporate research sponsors. It is not an exaggeration to say that many universities are becoming, in essence, extensions of corporate R&D programs. As early as 1987, for instance, Carnegie Mellon's Magnetic Technology Center, invited corporations to become "associate members." For a modest $750,000 minimum fee, such corporate powerhouses as IBM and Kodak were afforded the right to designate three topics each for academic researchers to pursue.[34] More recently, the University of California at Berkeley made a significantly larger sale of its research capacity to the life-sciences conglomerate Novartis (now Syngenta). In return for the company's $25 million investment, the university agreed to give the firm first rights to negotiate patent licenses on up to one third of the research produced by U.C. Berkeley's Department of Plant and Microbial Biology. As critics rightly charged, the deal could not help but alter research priorities at the university as well as privatize an increasing portion of the scientific knowledge generated in the university department. Arrangements such as these are hardly anomalous. One study, for instance, documents that more than 1,000 university-industry centers have already been established within the academic institutions.[35]

Many university faculty worry that their institutions are pressuring them to vest more and more of their intellectual capital into the private domain. Given that many public universities have an explicit mandate to facilitate the commercialization of research, the concern is largely justified. In addition, because almost all research universities are hungry for cash, they are, unfortunately, often willing to trade their faculty's independence for corporate research sponsorship. As Lita Nelsen, a technology licensing specialist at M.I.T. has put it, for these universities, "the way to hell is paved in small concessions."[36]

What makes the situation particularly problematic is that such concessions conflict with a time-honored tradition of research universities as an intellectual commons where the ideas and discoveries of scholars are made available for the use and benefit of all members of a democratic society.

Taken to its logical conclusion, in fact, one might predict that universities will forgo their public-spirited mission and go into business for themselves. In fact, such financial arrangements are already widespread. Many major research universities have established for-profit venture capital entities to commercialize the research of faculty members.

In his final annual report in 1991, Derek Bok, then-president of Harvard University, warned "it will take very strong leadership to keep the profit motive from gradually eroding the values on which the welfare and reputation of universities ultimately depend." As universities become more entrepreneurial, Bok declared, "they appear less and less as charitable institutions seeking the truth and serving students and more and more as huge commercial operations that differ from corporations only because there are no shareholders and no dividends."[37]

Concerns like Bok's have prompted some well-known observers—including Sir John Maddox, former editor of the science journal *Nature*—to publicly question whether the research university can even survive in such an emerging environment.[38]

It is clear that the rush to patent discoveries created by university scientists poses a threat not only to the research environment but to the credibility of the university as well. When university scientists are positioned to profit handsomely from licensing revenues, consulting fees and equity investments, and when outside firms play a disproportionate role in dictating research priorities, the very integrity of academic freedom and objective scientific inquiry is seriously undermined.

III. Restoring the Balance

The value of a piece of scientific work only appears to the full with its further application by many minds and with its free communication to other minds.

—Norbert Wiener, computer scientist, 1954.[39]

Like many other players in the emerging knowledge-based economy, today's research community is caught in a battle between a closed, proprietary mode of operation, and an open, shared one—a battle, in essence, between the boardroom and the classroom.

Investing in the Future

Perhaps the first step toward restoring the balance is to cultivate a more enlightened, long-term view of the research endeavor. Universities and corporations must understand that the fruits of the proverbial research garden cannot be picked indefinitely without tending to the trees and broader ecosystem from which they derive. Robert Cook-Deegan, director of the National Cancer Policy Board at the National Academy of Sciences, has noted that the pace of innovation is strongly influenced by two factors: the level of resource deployment and the speed of information flow.[40] As corporations invest more heavily in scientific and technological research at the nation's universities, they need to pay special attention to the latter—being careful not to hamper the flow of information unduly with overly onerous proprietary considerations. Ultimately, such closed systems will hinder development in their field and likely undermine their efforts altogether.

A crucial component of this effort comes through understanding the profound tensions between directed commercial R&D and the vitality of the broader scientific and technological research environment. The boardroom favors the former and the classroom needs the latter. From the perspective of a company, secrecy is normally desired to protect a firm's technological advantage. In academic research, however, the open exchange of information is paramount in order to test the veracity of new findings, to propagate new knowledge and to disseminate it to students and colleagues.

From the perspective of the boardroom, researchers are expected to be partial and partisan in how they manage information. Indeed, part of their duty as employees is to use research to champion the company's competitive advantage in the marketplace, while at the same time abiding by legal and ethical considerations. But in the classroom, the *disinterested* scientist is essential to the research enterprise. The scientific method requires a researcher to cultivate a clear-headed, fair-minded ability to formulate hypotheses and rigorously test them—and for colleagues to do the same.

The boardroom and the classroom have equally stark differences in how they develop a research agenda. In the boardroom, R&D is normally viewed as a key means to stay ahead of a company's competition. Enlightened, established corporations know that a loose rein on its R&D specialists is sometimes the most effective approach. But the bottom line is never far way. Invariably, commercially sponsored research must focus on how to develop a firm's existing product line or market performance. In academia, however, the independence of a university's faculty and researchers is a primary concern. The tenure process, for instance, is designed in large measure to free these individuals to pursue unpopular approaches and topics even if they show little immediate promise in the market.

Finally, some of the most stark distinctions between the boardroom and the classroom can be seen in the divergence of their missions. In the boardroom, the overarching mission is to maximize profits and reward the shareholders to whom corporate managers must answer. In academia, however, the mission is to disseminate and cultivate knowledge as an end in itself. The ultimate goal is to better the human condition, not just serve marketable needs.

Both of these value systems—those of the boardroom and the classroom—play an important role in the innovation process. These divergent value systems are often incompatible. This does not mean that businesses and universities cannot interact fruitfully, but rather that well thought out compromises will always need to be made. Given the fierce expansion of market norms in academic research, the values of the technological commons must be actively championed to prevent them from eroding beyond recognition.

Insisting on Openness

Several efforts are now underway to bolster the technological commons and ensure the open exchange of information. Each of the four initiatives reviewed briefly below tackles a different facet of the problem.

The OpenCourseWare Initiative

The OpenCourseWare initiative was pioneered at M.I.T. and is now being adopted, at least to some degree, by other eminent universities, including Harvard and Princeton. In these laudable efforts, the universities have begun to place all course information and materials on the Internet, making them freely available to the public. The effort stands in stark contrast to the prevailing trend. Most U.S. colleges and universities are currently investigating or actively pursuing strategies to profit from the online distribution of their courseware—often in conjunction with for-profit subsidiaries or outside contractors.

Announced by M.I.T. President Charles Vest in April 2001, the OpenCourseWare initiative plans to achieve its goal of making the materials for nearly all M.I.T. courses freely available on the Internet within the next ten years. As Vest put it in his remarks to the press: "OpenCourseWare looks counter-intuitive in a market driven world. It goes against the grain of current material values. But…it expresses our belief in the way education can be advanced—by constantly widening access to information and by inspiring others to participate."[41]

A large-scale pilot program, the OpenCourseWare project is now designing software and services as well as protocols to monitor and assess its utilization by faculty and students at M.I.T. and throughout the world. Within the next year or two, M.I.T. expects that materials for more than 500 courses will be available on the M.I.T. OpenCourseWare website.

The M.I.T. OpenCourseWare infrastructure could serve as a model for other institutions that choose to make similar content open and available. Over time, if other universities adopt this model, a vast collection of educational resources will develop, facilitating a widespread exchange of ideas and resources that promote innovative ways of teaching and learning. M.I.T. OpenCourseWare will serve as a common repository of information and will channel intellectual exchanges that can stimulate educational innovation and cross-disciplinary educational ventures.

Public Library of Science

Another ambitious, grassroots effort seeks to develop an alternative to private scientific publishers. In 2001, more than 29,000 researchers from 175 countries around the world—including several Nobel Laureates—joined a campaign to boycott publishers of scientific journals who refused to make research papers freely available on the Internet six months after their initial publication. When a molecular biologist or a biochemist has made a discovery—often after many months or even years of tedious experiments—they inform the rest of the world by publishing their results in a scientific journal. So far, these journals have controlled who can read them. The majority of scientific journals are privately owned, often by large publishing conglomerates who have complete discretion to charge exorbitant subscription prices, to limit online access and to restrict rights to article reprints or preprints.

M.I.T. OpenCourseWare will serve as a common repository of information and will channel intellectual exchanges that can stimulate educational innovation and cross-disciplinary educational ventures.

Email, Internet discussion groups and electronic databases have already transformed the way scientists exchange their research. In the life sciences, researchers are now demanding that their work be included in at least one free central electronic archive of published literature. These demands, which challenge the traditional prerogatives of publishers, have sparked widespread discussions among scientists, publishers, scientific societies and librarians about the future of scientific publishing. The confrontation between scientists and publishers is still in its early stages, but its eventual resolution promises to dramatically alter the world of scientific publishing.

Scientists who seek more control over their published works argue that they are the ones who supply the journals with a free and steady supply of their products—namely their scientific articles. Scientists also help journals by reviewing and judging the quality of each other's work through the normally unpaid process called "peer review."

To be sure, publishers edit the articles, organize the review process and provide news items and other content. Additionally, they produce, market and distribute a printed or electronic journal. Yet, in the eyes of Michael Eisen, one of the founders of the Public Library of Science initiative, the publishers' work does not justify that they then own the copyrights to the articles. "We think of the publishers as being like a midwife," he says. "They are paid for their role, and at the end of the day, they give the baby back to the parents."[42]

The founders of the Public Library of Science initiative were spurred into action by the woefully slow progress of a related effort called PubMed Central, a free electronic full-text archive of research articles started by the National Center for Biotechnology Information (NCBI) at the National Institutes of Health in early 2000. By storing articles in a common format on a single site, PubMed Central hopes to facilitate sophisticated literature searches. Ultimately, it also wants to link the literature to other online databases.

To facilitate their efforts, PubMed Central has asked journals to contribute their articles voluntarily as soon as possible after publication—within the period of a year—giving the journals time to make a profit by offering exclusive access. (Studies have shown that the demand for research papers decreases sharply after only a few months.) But most journals have been slow to sign on.

An online commons of scientific literature has worked effectively in other fields. In physics, for instance, scientists have been submitting their own research papers—both before and after publication—to the Los Alamos e-Print Archive since 1991; publishers have, in essence, been forced to go along with the practice. Despite the existence of the Los Alamos e-Print Archive, the American Physical Society continues brisk sales of subscriptions to three journals that publish more than 14,000 research articles a year.

Meanwhile, there are a number of researcher-led efforts to use licensing arrangements to ensure that works will be freely distributed, even following publication in privately held journals. Some researchers are even discussing the prospect of taking scientific publishing into their own hands.

Regardless of the outcome, the Public Library of Science initiative has prompted a much-needed discussion about how to bolster the technological commons by insuring the most open access possible to scientific literature.

IP.com and BountyQuest

Elsewhere in the research firmament, two related efforts seek to combat the perceived overreliance on patenting as a way in which proprietary claims are threatening to erode the technological commons.

The two intriguing Web-based ventures—IP.com and BountyQuest—are each taking steps to rein in bad patents—either by stopping them before they are granted or by challenging them after the fact. What makes these startups particularly interesting is that they are attracting support across a broad spectrum of intellectual property players—from patent system boosters to the most vehement open source programmers. In the highly polarized intellectual property field, that alone is no small feat.

The nub of the problem is that a U.S. patent affords the holder a 20-year monopoly on his or her idea, whether it is granted on valid grounds or not. This powerful monopoly right is presumed valid unless it is invalidated in court or unless the U.S. Patent Office can be persuaded to reexamine its decision. Both procedures take considerable time and money, however. The average patent case that goes to trial now costs millions, with notoriously unpredictable verdicts. The result: even when someone owning a blatantly invalid patent demands royalties, chances are good that lawyers for the "infringing" party will advise him or her to pony up rather than fight.

Of course, it is not supposed to work this way. If a concept is obvious to practitioners in a given field or has previously been published in almost any fashion, this should invalidate the patent application. Practically speaking, however, it's a tall order for the U.S. Patent and Trademark Office to scour publications to determine whether your particular software code or concept has already surfaced. So, inevitably, mistakes are made, eroding confidence in the system and feeding the problem by encouraging firms to apply for dubious and overly broad patents of their own.

Some new Web-based firms have arisen to help fight this patent pollution. IP.com, of West Henrietta, NY, offers a low-cost registration system that allows inventors to officially place their work into the public domain and prevent someone else from patenting it. A document submitted to IP.com becomes part of a database that both the U.S. and European Patent Offices have promised to search before issuing patents. And while it can only be used defensively—to protect against bogus claims and not as a means of collecting royalties—an impressive list of firms, from Abbott Laboratories to United Technologies, has begun using IP.com to guard against patent infringement lawsuits.

The standard fee for this insurance policy: just $109. However, IP.com provides a similar service to open source programmers for under $20. Especially at the discount rate, open sourcers can now gleefully thwart the excesses of a patent system they decry, preserving their work in the public domain in a form that is protected from proprietary claims.

Tom Colson, CEO of IP.com, says challenging the muddle of questionable patents reminds him of his work as a young lawyer on toxic contamination cases. Two separate campaigns are needed, he notes: stopping new pollution on the one hand, and clearing up the existing mess on the other.

If IP.com targets patent pollution, Boston-based BountyQuest is out to remediate the other half of the problem: patents of questionable validity that may already be wreaking havoc. Taking its cue from bounty hunters who track fugitive criminals for a fee, BountyQuest posts rewards of $10,000 and up that have been offered by threatened firms for "fugitive information" that can help bust invalid patents. Given today's high litigation costs, such bounties are a small price for threatened firms to pay for proof that could stop claimants of dubious patents.

In its most publicized bounty to date, BountyQuest investor Tim O'Reilly, who heads the computer publishing outfit O'Reilly & Associates, posted a $10,000 reward for information that would invalidate Amazon.com's "1-Click" online shopping patent. While the case drags on with unclear results, BountyQuest drew 25 submissions and ended up splitting the reward among three bounty hunters who provided information on various clicking patents related to making online purchases. Since its launch earlier this year, BountyQuest has paid out $60,000 in rewards. It now has roughly half a dozen open bounties posted on its website looking to bust patents involving everything from cascading computer-display windows to a drug treatment for osteoporosis.

With thousands of patents issued weekly, one cannot expect these two ventures to solve the problem of invalid patents. But by drawing their strength from the distributive power of the Internet rather than counting on an infallible patent system, they do offer important tools to combat the increasing use of proprietary claims to shut out others from whole areas of research.

Establishing Norms of Access

At the governmental and institutional level, a number of efforts are underway to try to establish norms of open exchange in scientific fields. The National Institutes of Health, for example, has tried to insist that its grantees abide by norms of open access to the research that results from their governmental funding. When researchers receive NIH funding to undertake large-scale gene sequencing, for example, the agency requires them to disclose their results rapidly.

Government leadership can be particularly effective in ensuring that research results remain open and accessible to all. As Eliot Marshall reports in *Science*, genetically altered mice are high on the list of "materials" that are causing bottlenecks among researchers. Scores of animals have been patented since Harvard University claimed the "Oncomouse" in 1988. In one now-notorious example in the mid-1990s, the Jackson Laboratory in Bar Harbor Maine (the nation's leading public source of genetically altered mouse strains) stopped handling mice created with one popular gene-insertion method known as Cre-loxP. The move came because DuPont obtained a patent on genetically altered mice incorporating this method and made itself unpopular by demanding that researchers not share the technology among themselves without the company's prior approval. DuPont also contacted scientists who had published data from Cre-loxP animals and asked them to sign an agreement stipulation that DuPont could review their scientific articles before publications. Furthermore, the company sought so-called "reach-through" rights, or rights to second-generation inventions that might arise from using these animals. As David Einhorn, legal counsel for the Jackson Laboratory put it, "It was a major problem. Nobody was able to exchange materials" freely any longer.[43]

In this instance Harold Varmus, then-head of NIH, intervened. In 1997, he refused to sign an agreement with DuPont concerning the Cre-loxP mice on behalf of NIH, making it impossible for thousands of intramural staffers at the NIH campus in Bethesda, Maryland to get access to the technology. It was a nuisance for them and an embarrassment for DuPont, but it produced a change. After a year of negotiation, Dupont made concessions: The company did away with demands for pre-publication review for research-only use of Cre-loxP mice, loosened up animal sharing provisions and dropped the reach-through property claims for NIH-based scientists.[44]

One lesson of this episode is that norms of scientific sharing can be established only when key players insist upon it. It is a model that might be successfully adopted in a wide variety of situations to ensure a robust technological commons.

The "Endless Frontier" Revisited

In his "Endless Frontier" report, Vannevar Bush took the notion of scientific and technological research as a frontier quite literally. "It has been basic United States policy that the government should foster the opening of new frontiers," he wrote. "It opened the seas to clipper ships and furnished land for pioneers. Although these frontiers have more or less disappeared, the frontier of science remains. It is in keeping with the American tradition—one which has distinguished the United States—that new frontiers shall be made accessible for development by all American citizens."[45]

After a technological "land grab" of unprecedented scope, especially over the past two decades, many now criticize Bush's frontier analogy as archaic. The real problem today, say critics, is preserving the scientific and technological commons. With an increasing number of private claims being made on information, techniques and scientific tools—and even whole areas of scientific inquiry—an increasing chorus of voices is suggesting that our scientific and technological research endeavor needs a new vision.

The current race in the human genome field is frequently likened to the Gold Rush, an analogy much like that of the frontier. But the savviest players recognize a fundamental difference this time around. Prospectors forever removed the gold when they panned it from rivers and mined it from the earth. But the information in the human genome is not depleted upon its discovery. The genome is a resource to which medical researchers will return again and again, helping solve the puzzles of human disease. It is a wellspring that will nurture a myriad of overlapping discoveries and inventions for many decades to come. In this sense, the human genome can—and must—be treated as a "public good" that supports nonrival consumption: a situation where multiple parties can profitably use the same resource without depleting it.

Unfortunately, the problem with the Frontier-Gold Rush analogy is that the land claims that helped tame the gold prospectors' free-for-all were a crude but necessary framework dividing rights to a tangible and decidedly finite resource. By carving up parcels of exclusive, private genomic real estate, the U.S. Patent & Trademark Office is needlessly replaying this history—but with a resource whose value comes from greater common sharing and use, not private control. Instead, an enlightened policy designed to govern the multiple and overlapping uses of the "genome commons" is needed: a policy that ensures unfettered access to the data and materials that are going to serve as the set of building blocks for countless drugs and treatments in the future.

As we have seen, knowledge assets like the human genome differ from the finite tangible goods that made up the old economy. The sooner we develop enlightened intellectual property policy that reflects this fact, the better. Rather than taking our cues from the Gold Rush, we would do well to remember the 1799 discovery of the Rosetta Stone, the remarkable tablet that offered the same long passage of text sequentially in three ancient languages. The Rosetta Stone provided linguists over many ensuing years the seminal key with which to finally unlock the previously undecipherable hieroglyphics of ancient Egypt. Imagine how that job would have been hampered if someone had proposed to chop the stone tablet into separate proprietary chunks; such a plan would clearly have diminished—if not destroyed—the central value of the resource.

Sadly this is exactly what is happening now with the human genome. Companies are forced to think about their firms' short-term bottom line. For today's crop of genomic companies, especially given today's absence of clear rules, this means obtaining as many patents as possible under the broadest claims they can imagine. And just as fast as the human gene sequences can be identified.

The tens of thousands of human gene-related patents pending have polarized an already divisive situation. On the one hand, companies investing millions of research dollars argue that they need to protect their intellectual property. Without patents, the private sector will not ante up the billions of dollars needed to stimulate the rapid development of genome-based health-care products. On the other hand, the patenting frenzy is kindling understandable fears that a few corporations will end up controlling a resource of priceless value to humanity. As a result, many are looking anew at the notion of how to strengthen the technological commons.

Within the scientific and technological research environment, we need to try to strike a kind of ecological balance: providing financial incentives for people to innovate by protecting the fruits of their labor, but also supporting enough sustainable cross pollination and ferment to spur innovation in the future.

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James Boyle has proposed that the concept of "the environment" has much to offer the intellectual property arena.[46] Like Boyle, a growing assemblage of thinkers is subscribing to the notion that it is appropriate to consider the sphere of information and ideas we call the "public domain" as a kind of ecosystem. As such, it can remain healthy only if its relationship with the market—as embodied in intellectual property law, technology and social practice—is kept in balance.

Back in the 1970s, once it caught on, there was little question that a broad conception of "the environment" helped to galvanize a dramatic change in public perceptions about the appropriate use of natural resources. Of course, it is far too early to know the extent to which the disparate critics of the current intellectual property regime will be able to coalesce under anything like a similar banner. Nonetheless, in beginning to think of the scientific research infrastructure less as a frontier and more as an ecosystem, an important conceptual hurdle may have already been overcome. Within the scientific and technological research environment, we need to try to strike a kind of ecological balance: providing financial incentives for people to innovate by protecting the fruits of their labor, but also supporting enough sustainable cross pollination and ferment to spur innovation in the future. The powerful realization that we must actively work to stem the erosion of the technological commons is, itself, no small feat.

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