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WIKINOMICS

How Mass Collaboration Changes Everything

EXPANDED EDITION

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and Anthony D. Williams

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PORTFOLIO

6. THE NEW ALEXANDRIANS

Sharing for Science and the Science of Sharing

The Alexandrian Greeks were inspired by a simple but powerful idea. Collect all of the books, all of the histories, all of the great literature, all of the plays, all of the mathematical and scientific treatises of the age and store them in one building. In other words, take the sum of mankind's knowledge and share it for the betterment of science, the arts, wealth, and the economy. The Alexandrians came very, very close to achieving that goal. At its crowning glory, estimates suggest that they had accumulated more than half a million volumes.

Certainly the works of great thinkers such as Aristotle, Plato, and Socrates could be found there. It was also the place where Archimedes invented the screw-shaped water pump, Eratosthenes measured the diameter of the earth, and Euclid discovered the rules of geometry. Ptolemy wrote the Almagest at Alexandria; it was the most influential scientific book about the nature of the universe for the better part of 1,500 years. And for those reasons the Great Library of Alexandria is regarded by many as the world's first major seat of learning, perhaps even the first university, and the birthplace of modern science.

When the library was destroyed in the fifth century it was a major setback for the arts and sciences. Five hundred years later, the largest library had less than one thousand volumes. With forty-two million items today the New York Public Library is larger than the Alexandria library, but there are still very few libraries that rival the collection at Alexandria nearly two thousand years ago. This despite the fact that the stock of human knowledge is now infinitely wealthier than it was in the fifth century.

Indeed, we are fortunate to be living through the fastest and broadest accumulation of human knowledge and culture ever. *Wired* cofounder

Kevin Kelly recently reported that humans have "published" at least 32 million books; 750 million articles and essays; 25 million songs; 500 million images; 500,000 movies; 3 million videos, TV shows, and short films; and 100 billion public Web pages—and most of this knowledge explosion took place in the last half century.[1] Now add the constant stream of new knowledge created every day; so much, in fact, that the stock of human knowledge now doubles every five years.

Thanks to a new generation of Alexandrians this fountain of knowledge, past and present, will soon be accessible in ways our ancestors could only dream of. Companies such as Google, and librarians at esteemed institutions such as Harvard, Oxford, and Stanford, are hastily scanning books by the thousands and turning them into bits. Along with media of all varieties, these digitized books will be sewn together into a universal library of knowledge and human culture. When the new virtual library of Alexandria comes to fruition it will provide a shared foundation for collaboration, learning, and innovation that will make the present Internet look like a secondhand bookshop.

Digital libraries, and the Herculean efforts to build them, are impressive and important. However, they are only one aspect of a much deeper transformation in science and invention that we describe in this chapter. Indeed, the Alexandrian revolution extends far beyond the way we archive knowledge, to the way we create and harness knowledge to drive economic and technological progress.

A new age of collaborative science is emerging that will accelerate scientific discovery and learning. The emergence of open-access publishing and new Web services will place infinite reams of knowledge in the hands of individuals and help weave globally distributed communities of peers. The rise of large-scale collaborations in domains such as earth sciences and biology, meanwhile, will help scientific communities launch an unprecedented attack on problems such as global warming and HIV/AIDS. All considered, leading scientific observers expect more change in the next fifty years of science than in the last four hundred years of inquiry.[2]

As new forms of mass collaboration take root in the scientific community, smart companies have an opportunity to completely rethink how they do science, and even how they compete. Companies can scale and speed up their early-stage R&D activities dramatically, for example, by collaborating with scientific communities to aggregate and analyze precompetitive knowledge in the public domain. In fact, the efforts described in this chapter, including the SNP Consortium and Intel's open university network, suggest that even competitive rivals are seeing the benefits of collaborating on initiatives that will establish and grow a market for new products and services. Depending on the type of venture, firms can identify and act on discoveries more quickly, focus on their area of competence, facilitate mutual learning, and spread the costs and risks of research.

If this plays out the way we predict, the new scientific paradigm holds a more than modest potential to improve human health rapidly, turn the tide on environmental damage, advance human culture, develop breakthrough technologies, and explore outer space—not to mention help companies grow wealth for shareholders. That's a bold statement. But there is growing evidence to support it. Companies and scientific communities can harness mass collaboration to fundamentally change the world we live in. Read on to find out how.

THE SCIENCE OF SHARING

Humanity's capacity to generate new ideas and knowledge is the source of art, science, innovation, and economic development. Without it, individuals, industries, and societies stagnate.

In the past, firms have relied heavily on closed, hierarchical approaches to producing and harnessing knowledge. Increasingly, though, knowledge is the product of networked people and organizations looking for new solutions to specific problems. This peer-oriented approach to producing knowledge and sharing information is nothing new in academia: Research in the sciences has been circulating and building on discoveries for centuries. But it's new territory for firms.

Collaboration, publication, peer review, and exchange of precompetitive information are now becoming keys to success in the knowledge-based economy. As we have explained in previous chapters, the driving force behind this shift is the digitization of information and communications. Whether we look at art, science, commerce, or culture, we see that these forces are changing the way value is created throughout society. Digitization means information can be shared, cross-referenced, and repurposed like never before. Knowledge can build more quickly within networks of firms and institutions that cross seamlessly over disciplinary boundaries.

Conventional economic wisdom says companies should hoard their knowledge and technology. Most companies get prickly when people outside the firm start sharing or remixing their intellectual property. "I can't move into your backyard and just decide what to do with your landscaping," says Carla Michelotti, senior vice president and general counsel of Leo Burnett. "It's trespassing. It's taking somebody else's property."[3]

But in today's networked economy, proprietary knowledge creates a vacuum. Companies that don't share are finding themselves ever more isolated—bypassed by the networks that are sharing, adapting, and updating knowledge to create value. Conversely, evidence is mounting that sharing and collaborating, if done right, creates opportunities to hitch a ride on public goods and lift all boats in the industry. But first we must recognize that the modes of interaction in science (i.e., openness, peering, and sharing) have commercial viability, productive capability, and the ability to be drivers for private companies.

This is a considerable leap of faith for many managers who think the realm of science and the world of private enterprise operate under completely different principles. But it's not such a stretch when we recognize that just like science, the creative engine of capitalism requires access to the ideas, learning, and culture of others past and present. Indeed, the history of capitalism is replete with examples of how the material success we enjoy today is directly attributable to the evolution of openness in science and private enterprise and the rapid technological progress this unleashed. To see how this works in practice, it's worth taking a short detour into the history books.[4]

The Industrial Enlightenment

Starting as early as the seventeenth century—as the ideas of the Enlightenment took hold—we began to create, accumulate, and harness knowledge in new ways.[5] Engineers, mechanics, chemists, physicians, and natural philosophers formed circles in which access to knowledge was the primary objective. They exchanged letters, met in Masonic lodges, attended coffeehouse lectures, and debated in scientific academies. Some of these personal exchanges were confined to the realm of science. But a growing number helped smooth the path of knowledge from scientists and engineers to those who applied this knowledge to solve practical problems and build new cottage industries.

Buoyed by improved literacy rates, universal schooling, and the invention of movable type—and paired with the appreciation that such knowledge could be the base of ever-expanding productivity and prosperity—these nascent knowledge networks soon became indispensable to technological progress. For the first time in history, knowledge about the natural world became increasingly nonproprietary. Scientific advances were shared freely within informal scholarly communities and with the public at large. Science became a public good rather than the exclusive property of a privileged few.

The knowledge revolution continued into the eighteenth and nineteenth centuries, driving not just new knowledge and new ideals, but also better and cheaper access to knowledge and scientific tools. Improvements in our ability to publish and distribute knowledge, for example, dramatically lowered access costs, particularly for rank-and-file practitioners. It made the process of learning and economic change more efficient. Superior techniques spread faster. New technologies were more widely deployed and improved. More minds were trained in science, and more skills were brought to bear on practical problems.[6]

As time went on, the interplay between open science and private enterprise initiated a virtuous circle of knowledge creation and application that unleashed a period of sustained growth, prosperity, and technical improvement. Feedback from knowledge to technology—and from technology back to knowledge—made the continued evolution of science and learning the norm rather than the exception.

Eventually the wholesale pursuit of science radically improved our understanding of the natural world and enabled us to manipulate nature in previously unimaginable ways. Corporations arose as a vehicle to channel investment capital into entities capable of harnessing this new knowledge by turning it into products and services that the market desired. Further improvements in information technologies meant that knowledge was readily available for others to build on and improve. Over time, we honed the positive feedback loops between science and private enterprise to provide a sustained basis for economic growth.

The Age of Collaborative Science

Though the industrial enlightenment gave us much to be thankful for, it's fair to say that we still haven't seen anything yet. The advances in our capacity to generate and apply new knowledge in the industrial era pale in comparison to capabilities within reach today. Plummeting computing and collaboration costs are widening the distribution of knowledge and power. At the same time, our ability to self-organize into large-scale networks is enhancing our ability to find, retrieve, sort, evaluate, and filter the wealth of human knowledge and, of course, to continue to enlarge and improve it.

That's where we stand today. But as we spoke to colleagues and people out in the field we became convinced that we are only at the beginning of an exciting new scientific paradigm—call it the age of collaborative science. Just as the Enlightenment ushered in a new organizational model of knowledge creation, the new Web is helping to transform the realm of science into an increasingly open and collaborative endeavor characterized by:

- the rapid diffusion of best-practice techniques and standards;
- the stimulation of new technological hybrids and recombinations;
- the availability of "just-in-time" expertise and increasingly powerful tools for conducting research;
- faster positive feedback cycles from public knowledge to private enterprise, enabled by more nimble industry-university networks; and
- increasingly horizontal and distributed models of research and innovation, including greater openness of scientific knowledge, tools, and networks.

Above all, the new scientific paradigm will be truly global, swelled by the participation of millions of budding scientists from across Asia, South America, and Eastern Europe.

These are the characteristics that define collaborative science. And this new scientific paradigm is a key reason why we believe the rate of innovation in the coming decades will eclipse anything that we, or previous generations, have ever experienced. It's also the reason why the New Alexandrians we discuss in this chapter are so central to a robust economic future. To reiterate: The New Alexandrians are individuals, companies, and organizations that recognize the power and importance of openness in today's economy. They are doing more than building a modern equivalent of the world's greatest library. They are building rich collaborative environments and open knowledge infrastructures of all kinds, including open standards, open-content initiatives, open scientific networks, and open research-and-development consortiums.

These are the pillars on which new forms of private enterprises and new twenty-first-century industries will be built. Just as they are the foundation on which a society rich with art, culture, and ideas will flourish.

THE SHARING OF SCIENCE

Call it collaborative science, or even Science 2.0. The Enlightenment accomplished real alchemy, turning research into knowledge by spawning the practice of open scientific publishing. But a centuries-long trend toward openness did not stop there. Today a new scientific paradigm of comparable significance is on the verge of ignition, inspired by the same technological forces that are turning the Web into a massive collaborative work space.

Just as collaborative tools and applications are reshaping enterprises, the new Web will forever change the way scientists publish, manage data, and collaborate across institutional boundaries. The walls dividing institutions will crumble, and open scientific networks will emerge in their place. All of the world's scientific data and research will at last be available to every single researcher—gratis—without prejudice or burden.

Unrealistic you say? Not really, when you consider that conventional scientific publishing is both slow and expensive for users, and that these issues, in turn, are increasingly big problems in science. Visit any campus today and you'll hear ever louder vocal cries for the old paradigm to be swept aside. As new forms of peer collaboration and open-access publishing emerge, this looks more likely by the day. Before we describe this new paradigm, however, let's briefly review the problems.

Traditional journals aggregate academic papers by subject and deploy highly structured systems for evaluating and storing the accumulated knowledge of a scientific community. Each paper is peer reviewed by two or more experts, and can go through numerous revisions before it is accepted for publishing. Frustrated authors can find their cutting-edge discoveries less cutting edge after a lumbering review process has delayed final publication by up to a year, and in some cases longer. With the pace of science increasing today, that's just not fast enough.

The other problem is that the vast majority of published research today is only available to paid subscribers. Ever increasing subscription fees, meanwhile, have made this research less accessible. What's worse is that these impediments to access persist despite the availability of much cheaper electronic publishing methods. Though an unlimited number of additional readers could access digital copies of research at virtually no additional cost, publishers hold back for fear of creating a Napster-like phenomenon.

No doubt these problems are hangovers from a world of physical distribution and a much more limited volume of publishing. The current publishing regime emerged in seventeenth-century Europe, when the pace of discovery was glacial by twenty-first-century standards. Scientific journals provided the primary infrastructure for scholarly communication and collaboration. Apart from annual academic symposiums, journals were *the* place where scientists could find out about, engage with, and carefully critique each other's work. Publishing journals was expensive, entailing significant capital and operational costs.

As the scientific endeavor swells in scale and speed, however, a growing number of participants in the scientific ecosystem are questioning whether the antiquated journal system is adequate to satisfy their needs. New communication technologies render paper-based publishing obsolete. The traditional peer-reviewed journal system is already being augmented, if not superseded, by increasing amounts of peer-to-peer collaboration.

Science Goes Large Scale

Organizing the pursuit of knowledge in a peer-to-peer fashion is certainly nothing new in science. But recent research suggests that collaboration is exploding. One study conducted by the Santa Fe Institute found that the average high-energy physicist now has around 173 collaborators. The same study found that the average number of authors per scientific paper has doubled and tripled in a number of fields. A growing number of papers have between two hundred and five hundred authors, and the highest-ranking paper in the study had an astonishing 1,681 authors.[7]

Knowledge aggregators need to accommodate new realities, such as the growing use of massive online databanks and the rise of large-scale Internet-mediated collaborations. Take the Large Hadron Collider (LHC) experiment at the European Council for Nuclear Research (CERN) for example. Starting in 2007, the world's largest particle accelerator is expected to begin producing petabytes of raw data each year—data that will be preprocessed, stored, and analyzed by teams of thousands of physicists around the world (note: a petabyte is one quadrillion bytes—in other words, quite a lot of data!). In this process, even more data will be produced. There will be a need to manage hundreds of millions of files, and storage at hundreds of institutions will be involved.

Then there is the Earth System Grid (ESG), an experimental data grid that integrates supercomputing power with large-scale data-and-analysis servers for scientists collaborating on climate studies. Once the first of its kind, the project is building a virtual collaborative environment that links distributed centers, users, models, and data throughout the United States. Data for the project is being collected from a wide range of sources, including ground- and satellite-based sensors, computer-generated simulations, and thousands of independent scientists uploading their files. Specialized software applications run on the grid will accelerate the execution of climate models a hundredfold and allow scientists to perform high-resolution, long-duration simulations that harness the community's distributed data systems. The ESG's founders anticipate the project will revolutionize our understanding of global climate change.

Projects like these have inspired researchers in many fields to emulate the changes that are already sweeping disciplines such as bioinformatics and high-energy physics. Take astronomy. The editors of *Nature* recently observed, "A decade ago, astronomy was still largely about groups keeping observational data proprietary and publishing individual results. Now it is organized around large data sets, with data being shared, coded and made accessible to the whole community."[8]

As large-scale scientific collaborations become the norm, scientists will rely increasingly on distributed methods of collecting data, verifying discoveries, and testing hypotheses not only to speed things up, but to improve the veracity of scientific knowledge itself. Rapid, iterative, and open-access publishing will engage a much greater proportion of the scientific community in the peer-review process. Results will be vetted by hundreds of participants on the fly, not by a handful of anonymous referees, up to a year later. This, in turn, will allow new knowledge to flow more quickly into practical uses and enterprises.

In fast-moving disciplines like high-energy physics and bioinformatics, this collaborative way of aggregating and reviewing work is already becoming a reality. In 1991, Paul Ginsparg established arXiv as a public server where physicists could post digital copies of their manuscripts prior to publication. While beginning life as a vehicle for sharing preprints in theoretical physics, it quickly became the principal library for a large fraction of research literature in physics, computer sciences, astronomy, and many mathematical specialties.

"I was originally anticipating about one hundred submissions per year from the roughly two hundred people in the one little subfield it originally covered," explains Ginsparg. "But there were multiple submissions per day from day one, and by the end of the year a few thousand people were involved."[9] Today more than half of all research articles in physics are posted here. And they keep on coming in at a rate of about 4,500 new papers every month. Users can even get RSS feeds that alert them when new research is published in their field.

Dr. Paul Camp of Spelman College, an avid user of the site, says that "[arXiv] is way faster than the traditional publication cycle." Yet the self-organizing community emerging around arXiv manages to preserve the elements of peer review that matter. "What we want is valid, peer-reviewed information," says Camp. "What does it matter if that occurred by means of an editor farming an article out for review, or by direct feedback from the community of people interested in a topic by e-mail in response to your preprint on arXiv? It amounts to the same thing."[10]

Recent efforts such as Google Book Search, the Public Library of Science, and the World Digital Library are now building on the open-access concept. These projects are aggregating vast repositories of scientific research and human culture in easily accessible forms. New science results that might have been available only to deep-pocketed subscribers will now be widely and freely available for education and research. Older resources that might otherwise have wallowed in dusty archives will be given new life and new audiences in digitized formats.

When fully assembled, open-access libraries will provide unparalleled access to humanity's stock of knowledge. Improved access to knowledge, in turn, will help deepen and broaden the progress of science, giving everyone from high school students to entrepreneurs the opportunity to tap its insights.

Collaborative Science in Action

Digital libraries are only the first step in modernizing scientific research and publishing. More profound breakthroughs will come as scientists come to rely less on the "paper" as the prime vehicle for scientific communication and more on tools such as blogs, wikis, and Web-enabled databanks. Blogs such as Bioethics, CancerDynamics, NodalPoint, Pharyngula, and RealClimate suggest that at least a handful of scientists, especially of the younger generation, are already embracing new forms of communication.

Scientists involved in OpenWetWare, an MIT project designed to share expertise, information, and ideas in biology, are heralding the arrival of Science 2.0. Twenty labs at different institutions around the world already use the wiki-based site to swap data, standardize research protocols, and even share materials and equipment. Researchers speculate that the site could provide a hub for experimenting with more dynamic ways to publish and evaluate scientific work. Labs plan to generate RSS feeds that stream results as they happen, and use wikis to collaboratively author/modify reports. Others have suggested adopting an Amazon-style reader review function that would make the peer review process quicker and more transparent.

Meanwhile, over at the European Bioinformatics Institute, scientists are using Web services to revolutionize the way they extract and interpret data from different sources, and to create entirely new data services. Imagine, for example, you wanted to find out everything there is to know about a species, from its taxonomy and genetic sequence to its geographical distribution. Now imagine you had the power to weave together all the latest data on that species from all of the world's biological databases with just one click. It's not far-fetched. That power is here, today.

In a recent editorial on scientific data issues, the editors of *Nature* (one of the world's leading scientific publications) suggest that to harness the power of Web services, scientific institutions will need to rethink the way they collect and manage data.[11] Web services only work if computers can get real-time access to data. Many large public databases like GenBank already allow unimpeded access to their data. But, *Nature* claims, many research organizations still cling to outmoded, manual, data permission policies, and this thwarts the development of Web services.

Scientists invest heavily in collecting data, so it's understandable that many feel justified in retaining privileged access to it, says *Nature*. But there are also huge amounts of data that do not need to be kept behind walls. And few organizations seem to be aware that by making their data available under a Creative Commons license, they can stipulate both rights and credits for the reuse of data, while allowing uninterrupted access by machines.

As Web services empower researchers, *Nature*'s editors rightly point out, the biggest obstacle to fulfilling such visions will be cultural.[12] "Scientific competitiveness will always be with us," they say, "but developing meaningful credit for those who share their data is essential to encourage the diversity of means by which researchers can now contribute to the global academy."[13]

These problems are transitory. Over time cultural inertia will give way to new and improved ways of working and collaborating. Institutional silos, nearsighted data policies, and the static, labor-intensive undertaking of crafting scientific papers will come to represent jumbo-size stumbling blocks in the path of networked scientific communities that thrive on open and rapid communication. Like a river torrent that washes away debris, the flood of peer-to-peer networking in scientific communities will dispose of obsolete policies and practices.

Large open collaborations like the Human Genome Project, to be sure, would not have been possible in today's time frames without the Internet and the emergence of increasingly distributed systems for aggregating, reviewing, and disseminating knowledge. True, there will always be aspects of scientific inquiry that are painstakingly slow and methodical. But as the pace of science quickens there will be less value in stashing new scientific ideas, methods, and results in subscription-only journals, and more value in wide-open collaborative knowledge platforms that are refreshed with each new discovery.

THE PRECOMPETITIVE KNOWLEDGE COMMONS

Speaking of the Human Genome Project, it is certainly among the most important scientific endeavors of our time. When efforts to map the human genome began back in 1986, scientists had barely an inkling of how this fundamental part of our existence works—and to a large degree they still don't! But thanks to massive, distributed collaborations across institutions, countries, and disciplines that took over fifteen years to complete, we are now much, much further ahead than we were in 1986.

One thing that scientists have long suspected is that our genes determine things like what we look like, our intelligence, how well we fight infection, and even how we behave. But armed with a fully sequenced genome, scientists are now convinced that these microscopic spirals of DNA amount to something like an operating system for humans. Learning how to "program" this operating system could hold the key to eliminating dreadful diseases such as Alzheimer's, diabetes, and cancer. Applications of this research in fields such as agriculture and ecology could help us end world hunger and take better care of the planet.

But for us the Human Genome Project is important for an additional reason: It helps illustrates our key thesis in this chapter. The Human Genome Project represents a watershed moment, when a number of pharmaceutical firms abandoned their proprietary human genome projects to back open collaborations. By sharing basic science and collaborating across institutional boundaries, these brave companies challenged a deeply held notion that their early stage R&D activities are best pursued individually and within the confines of their secretive laboratories. As a result they were able to cut costs, accelerate innovation, create more wealth for shareholders, and ultimately help society reap the benefits of genomic research more quickly.

So what exactly were these firms up to? We call it a "precompetitive knowledge commons," and we agree it's a bit of a mouthful, but we're talking about something big—a new, collaborative approach to research and development where like-minded companies (and sometimes competitors) create common pools of industry knowledge and processes upon which new innovations and industries build.

Prospecting the Genome

Thanks to these efforts the race to sequence the human genome bequeaths an impressive legacy. GenBank, the National Institute for Health's repository of gene sequences and other related information, is now the world's largest public database of genetic information. It is the culmination of myriad public and private efforts that placed genetic information in the public domain.

This public resource promises to be enormously valuable. It provides an infrastructure of freely available scientific information for millions of biomedical researchers and will spur follow-on innovation for decades. Recent GenBank statistics already demonstrate its growing value. As of August 2005, researchers have collected and disseminated over 100 gigabases of sequence data. That's 100,000,000,000 "letters" of genetic code from over 165,000 organisms. For a frame of reference, 100 gigabases means 100 billion base pairs of DNA, which is just slightly less than the number of stars in the Milky Way.

Impressive growth and usage statistics, in turn, lend credibility to those who argue that a robust scientific commons is the best way to ensure we realize the full potential of the genomics revolution. David Lipman, director of the National Center for Biotechnology Information, speculates that this thriving knowledge commons will soon give researchers the ability to map and understand the genetic makeup of entire ecosystems, not just the human genome.[14]

Truth is, however, the efforts to sequence the genome could easily have gone the other way. In the wake of controversial court rulings that have allowed patent rights over genetic information since the early 1980s, for-profit and nonprofit entities became enthusiastic participants in the patent system. By the mid to late 1990s researchers and industry participants feared that patents on large amounts of DNA sequence data would confer potentially very broad rights to exclude others from working on scientific and therapeutic applications. As tens of thousands of patent applications flooded the United States and European Union patent offices, debate erupted over the patentability of isolated gene fragments and the future of biomedical research.

Biomedical researchers feared (and still do) that access issues would erode the culture of open science and impede scientific progress. Some 20 percent of the human genome was already under private ownership, including the genes for hepatitis C and diabetes. The owners of these patents now influence who does research and how much it will cost them, playing a disproportionate role in determining the overall rate and direction of research in these areas.

While scientists worry about academic freedom, pharmaceutical firms worry about paying excessive licensing fees to a new class of competitors—the biotechnology companies—that have emerged at the interface between academic and commercial research. By the late 1990s only a handful of firms had mastered the technologies to synthesize, analyze, and annotate the escalating volumes of data produced by public and private gene-sequencing projects. Big Pharma was eager to mine this information for potential blockbusters but lacked the requisite capabilities. With few suppliers and everyone moving quickly in the race to prospect the genome, biotech firms could command premium prices for the latest information and tools. Many firms used this leverage to negotiate "reach-through rights" that allowed them to lay claim to future discoveries.

Both the academic and commercial communities warned that locking up significant portions of molecular biology was raising costs and lowering the efficiency of drug discovery. As patents proliferated, R&D budgets were rising to inefficient levels, and biotechnology companies, pharmaceutical firms, universities, government entities, purchasers of health care, and the legal system were getting entangled in expensive and damaging struggles for the associated economic benefits.

In short, the industry was in crisis, and there seemed to be little that any one player could do about it except join in the genomic gold rush.

Big Pharma Fights Back

One company, however, saw another option that could rewrite the rules completely. In 1995, Merck Pharmaceuticals and the Gene Sequencing Center at the Washington University School of Medicine announced the creation of the Merck Gene Index, a public database of gene sequences. Merck immediately released 15,000 human gene sequences into the public domain and announced that it would characterize and make freely available as many gene sequences as possible. Under the terms of the agreement, no one could gain advance access to—or even delay or restrict the release of—any of the sequence data from Merck and Washington University. This included Merck researchers, who gained access to the data via the same public databases available to all interested researchers.

By 1998, Merck and Washington University had published over eight hundred thousand gene sequences. As long as the gene sequences were public no company could lay claim to them. The strategy appears to have worked: Recent evaluations of the threat of gene sequence patents to biomedical research progress suggest that the gene index (along with other parallel public efforts) has significantly eased the gold rush dynamic. But why would Merck make this investment, which, according to one estimate, cost them several million dollars?

Dr. Alan Williamson, former vice president of research strategy with Merck, explains it in philanthropic terms: "Merck's approach is the most efficient way to encourage progress in genomics research and its commercial applications. By giving all research workers unrestricted access to the resources of the Merck Gene Index, the probability of discovery will increase. The basic knowledge we and others gain will lead ultimately to new therapeutics for a wide range of disease, while providing opportunities—and preserving incentives—for investment in future gene-based product development."[15]

Nice sentiments, but a subtle element of competitive sabotage underlies this apparently soft strategy. Like many pharmaceutical firms, Merck sees gene sequences as inputs rather than end products. Their business is developing and marketing drugs, not hawking genetic data and research tools. By placing gene sequences in the public domain, Merck preempted the ability of biotech firms to encumber one of its key inputs with licensing fees and transaction costs.

Fortunately for Merck, other pharmaceutical firms shared its concern over patents on upstream genetic information. Similar collaborative projects that built on Merck's approach were soon launched on a much larger scale.

In 1999, the SNP Consortium was established as a collaboration of eleven pharmaceutical companies, a nonprofit institution, and two IT firms. This unique joint venture brought highly competitive companies together—which rarely share any information, let alone information from a potentially path-breaking basic science initiative—to produce what the founders call "a public biological blueprint for all human life." Their common goal: to hasten a new era of "personalized medicine" in which treatment is tailored to an individual's unique genetic profile.

Many pharmaceutical executives believe that thanks to advances in gene technology, the key to future blockbuster therapies is identifying which drugs work best for which patients. Scientists are increasingly convinced that minute genetic differences largely account for people's different health traits and explain why a drug works for one person but has no effect—or ill effects—on another.

In the mid-1990s, scientists discovered that tiny chemical landmarks inside or near genes are posted at regular intervals along the DNA molecule, like road signs and mile markers on a stretch of highway. These landmarks, called single nucleotide polymorphisms (SNP), could be used to create a catalog of the ever so slight genetic variations that make some individuals susceptible to disease. As Francis Collins, a director at the National Human Genome Research Institute, put it, "SNPs serve as a blinking light on DNA sequences showing there is something very interesting here—for example, something that is contributing to diabetes."[16]

The SNP Consortium set out to identify the hundreds of thousands of chemical landmarks along human DNA. Alan Williamson, then recently retired from Merck, helped organize the initial talks among the consortium's partners. He recalls the excitement: "Suddenly, there was going to be a genetic map powerful enough to define which patients respond to a given drug versus those which don't respond to a given drug. . . . It would allow doctors to tailor treatments to patients more exactly than ever before."[17]

The initial goal was to map 300,000 common SNPs. At the completion of the project in 2001, 1.8 million had been mapped. To achieve this goal, the consortium invested approximately $50 million to pay university researchers to discover SNPs and place them in the public databanks. The consortium also filed patents to establish priority and obtain legal standing to contest other filings. Applications were abandoned once the SNPs were securely in the public domain.

Now that the SNPs have been mapped, the harder interpretive discovery work leading to new diagnostics and therapies is beginning. As a testament to its effectiveness, a generous flow of follow-on innovation is proceeding in the wake of the SNP project.

Commercial and academic scientists are currently using the map to filter rapidly through genetic profiles from thousands of patients to uncover which of the one hundred thousand or so genes that make up human DNA predispose people to such common but hard to treat ills as diabetes, depression, cancer, arthritis, Alzheimer's, and heart disease. The underlying biological causes of these illnesses remain largely mysterious, but if uncovered, this knowledge could lead to a treasure trove of new treatments.

The Value of Collaborative Discovery

But why collaborate when competition would let the winner extract proprietary gains? And why put this valuable information in the public domain? Why not limit disclosure to the consortium's members? As with Merck's Gene Index, there is blocking value in making public valuable but noncore information. The consortium's initiative competed directly with the biotech companies (including Incyte, Millennium Pharmaceuticals, and France's Genset) that were making their own proprietary catalogs of genetic landmarks. Though wary of sharing their valuable data with rivals, the consortium's members worried even more about biotech companies' projects. Daniel Cohen, former lead scientist at Genset, claimed at the time that Genset's plan to patent SNPs and sell them to the highest bidder would net between $50 million and $100 million a patent.

SNP members deny any concerted attempt to disrupt biotech competitors. "The idea here isn't to restrict the ability of biotech firms or anyone else to patent genes," says Williamson. "The idea is to make sure the underlying map we all need to find genes is available to anyone who wants to use it."[18]

But it's in the interests of Big Pharma to level the playing field for gene-hunting biotech firms, large drug companies, and academic scientists. The competencies of the consortium's members lie overwhelmingly in drug development, approval, and marketing. They are collectively better off competing to bring valuable end products to market than competing with the biotech firms in upstream research. Lawyers also reportedly advised consortium members that making the map public would help the companies avoid antitrust problems. In the end, however, the consortium members' big prize for collaborating is not the blocking value, but the benefits of speeding the industry toward personalized medicine. Before agreeing to collaborate, many consortium members were already building their own proprietary SNP maps. Under the leadership of Alan Williamson, they realized that a common map was crucial to the success of personalized medicine.

As Allen D. Roses, senior vice president of pharmacogenetics for GlaxoSmithKline, explains, "It was crucial that we had something whose accuracy we all agreed upon. If each of us had produced our own map, it would, for one thing, have taken much longer to create, and it would have been very unlikely that the companies would have accepted one another's map as being valid."[19] Among other things, the Food and Drug Administration (FDA) also needed to know that the map was accurate, reliable, and accepted by the scientific community.

By fusing corporate resources with the relatively low-cost contributions of academic scientists—which after all could only be bought for a low price if the data remained public—the consortium was able to discover many more SNPs than it imagined: 1.5 million more! And they did so in a fraction of the time it would have taken a single firm. This meant resources that may have been wasted pursuing duplicate research could be redirected toward other goals, namely the pursuit of follow-on diagnostics and therapeutics.

OPEN SOURCE DRUG DISCOVERY

Despite the major scientific achievements of sequencing of the human genome, progress in other areas of biomedical research and drug development has so far been disappointing. No new broad-spectrum antibiotics have been marketed in almost forty years, and many forms of cancer, as well as chronic diseases and disorders such as Alzheimer's, Parkinson's, and schizophrenia still lack effective and well-tolerated treatments. There has been almost no research on tropical diseases such as malaria and typhoid, the burden of which falls almost entirely on the world's poorest populations. In fact, only 1 percent of newly developed drugs will help the millions of people in Africa who die annually from these diseases.

Even the blockbuster drug business is suffering. In 2002, the FDA approved only seventeen new molecular entities (NME) for sale in the United States—the lowest since 1983, and a fraction of the fifteen-year high of fifty-six NMEs approved in 1996. In 2003, the FDA approved twenty-one NMEs, of which only nine were designated as "significant improvements" over existing drugs. This decline occurred despite a substantial increase in R&D spending: Between 1995 and 2002 U.S.-based pharmaceutical companies roughly doubled their R&D expenditures, to about $32 billion.[20] Numbers like these have the popular press and trade journals talking about "dry," "weak," or "strangled" pipelines, and a productivity crisis with dire consequences for investors (who can expect "permanently lower multiples"), taxpayers, patients, and insurers, who will have to pay an ever higher bill to maintain the pace of technological progress in the industry.

Dr. Frank Douglas, former executive vice president and chief scientific officer of Aventis, agrees that there are many concerns to address: "The productivity of large pharmaceutical innovation has decreased," says Douglas. "We lack the ability to properly predict the side effects of new compounds, and we don't have good ways to monitor and assess them once they are in the market. Pricing models have become untenable. So has the 'blockbuster' mentality. Across the board, a lot of old models really need to be examined."[21]

Indeed, as increased research spending collides with pressure to contain health care costs—and as alarm grows at the seemingly callous neglect for diseases that disproportionately affect the world's poor—the factors that affect the efficiency of drug discovery and development have rightfully come under scrutiny. The promise of biomedical research to relieve human suffering and create wealth has never been higher. But the ability of the industry to deliver on this promise depends critically on its ability to control costs, marshal resources effectively, and manage its knowledge base efficiently.

The Open Source Opportunity

Having witnessed what Linux has done for software production it seems natural to wonder whether a flurry of open source activity could unleash a similar revolution in the life sciences. What if the drug discovery process, for example, was opened up so that anyone could participate, modify the output, or improve it, provided they agree to share their modifications under the same terms? Could the collective intelligence of the life sciences community be harnessed to enable a more coordinated and comprehensive attack on the intractable diseases that have so far stymied the industry? Could opening up the process to tens of thousands of volunteer researchers lower the cost of drug development to the point where the resulting medicines are within reach of the world's poor? A small number of visionaries think there is an enormous opportunity here. But no one is suggesting it will be easy.

For one, there are fundamental differences between creating software and developing new drugs. Software production is easy to break up into bit-size pieces that can be carried out on a laptop while sitting in Starbucks. Drug development is harder to parse out and requires access to expensive laboratory instruments. Software projects can be completed in months, or even days and weeks. A typical drug currently takes ten to fifteen years and an average of $800 million to develop. Making software inventions commercially viable is easy and inexpensive—just post it on the Internet. Biological inventions take years of painstaking clinical trials and a healthy dose of regulatory know-how to reach that point. All these factors make drug development less hospitable to peer production than software.

On the other hand, there is much that unites open source programmers and the biomedical research community. Both communities share similar goals (free software and accessible medicines) and are driven by similar motivations (such as reputation and learning). They share strong community ethics, such as reciprocal sharing and collaborative discovery. And most of the people who contribute to collaborative projects in software and biomedicine are either paid to do so directly (i.e., as employees of companies and universities), or do so in their spare time while earning a living in some facet of the industry.

The fact that drug discovery is increasingly conducted in computer networks rather than in test tubes opens another window to open source activity. Indeed, many of the tools for sifting through the mountains of genomic data produced by the Human Genome Project are already available as open source. Bioinformatics.org, one of several hubs for collaboration in the biomedical community, hosts over 250 active projects that extend open source software development practices to the biological research databases and software tools. Freely available genomic search-and-comparison algorithms such as BLAST (Basic Local Alignment Search Tool) are becoming de facto standards in the community.

These factors suggest that peer production will have a significant role to play in drug discovery, particularly in the early stages, where the minds of thousands of scientists can be harnessed to identify promising candidates. But the costs and risks of drug development escalate as promising drug candidates move farther down the pipeline. The deep investments firms make at these stages are premised upon the availability of patent protection, which provides a period of exclusivity in the marketplace. The need to obtain patent protection, in turn, drives firms to throw up iron curtains around their research the moment they get close to a viable drug candidate.

Today a variety of nonprofit initiatives are seeking answers to these conundrums. Public-private partnership models that pool the resources of Big Pharma, philanthropists, government, and nongovernmental organizations currently offer the most hope for neglected diseases. Though a variety of different partnership models are plausible, the most promising would link upstream open source drug discovery efforts to downstream consortiums that usher good candidates through the later stages of development. This way companies would minimize R&D costs by involving partners at various stages of the development process, particularly at the costly clinical stage where suitable partners in the public sector can take over.

So far, projects led by the Institute for OneWorld Health, the Gates Foundation, and the Drugs for Neglected Diseases Initiative (among others) are making significant headway on diseases such as malaria and tuberculosis. Companies such as GlaxoSmithKline, Novartis, AstraZeneca, and Sanofi-Aventis have recently become enthusiastic participants in these initiatives. They may not stand to make any profits, but they can at least enhance their corporate images while taking advantage of a low-risk, low-cost route to getting established in developing-country markets. What's more, if open source drug discovery works, then these companies can apply a similar formula to cut costs and increase innovation in their ailing blockbuster business.

RETHINKING INDUSTRY-UNIVERSITY PARTNERSHIPS

Innovation can come from many sources and in many different forms. Smart companies realize that remaining competitive means innovating in all aspects of their business. Innovation, after all, is not just a product of science and invention. Cocreating with customers, peer producing value with partners, and optimizing supply chains (among other things) are equally pivotal.

Still, advancing the basic sciences is really the only way to guarantee that industries will continue to be innovative over the long term. Imagine farming without organic chemistry, or medicine without microbiology, or electronics, computing, and semiconductors without quantum mechanics. Without new insights and advances in the underlying disciplines our stock of knowledge becomes stale. If the well of knowledge dries up, so too does innovation.

Until recently firms took on a large share of the responsibility for advancing the underlying sciences. But, as explained in Chapter 4, they engaged in too much invention for invention's sake, while their R&D proceeded at a leisurely, academic-like pace.

Some of this basic research yielded large dividends for society and their shareholders: Think of DuPont's investments in basic chemistry that led to the invention of synthetic rubber, or the invention of the transistor in AT&T's Bell Labs. But much of it did not translate into immediate opportunities to market new products and services. Lack of a clear return on investment led to a dramatic scaling back of basic science in corporate R&D departments beginning in the late 1980s and continuing into the 1990s.

Today it is more important than ever that R&D activities are fast and efficient and earn a clear ROI. Innovators will still need to know the underlying sciences, but their primary aim in-house cannot be to further the science. For that they will increasingly rely on partnerships with universities and other research organizations, while corporate research teams use their skills and resources to move quickly to practical application. Indeed, smart firms see university partnerships as a nimble and cost-effective means for detecting and launching disruptive innovations.

The problem for many mature companies is that the very commercial success of their products increases their dependency on them. Making radical changes in the product's capabilities, underlying architecture, or associated business models could cannibalize sales or lead to costly realignments of strategy and business infrastructure. It's as though popular and widely adopted products become ossified, hardened by the inherent incentive to build on their own successes. The result is that entrenched industry players are generally not motivated to develop or deploy disruptive technologies, as Harvard Business School professor Clayton Christensen has pointed out.

So success breeds complacency. R&D departments have often stopped learning about alternative technologies and channel their resources into refining components, adding new features, or tweaking the product architecture. This strategy of marching down a well-defined product road map may pay dividends for some time. But complacency creates two kinds of vulnerabilities.

The first is that research conducted in pursuit of well-defined product road maps rarely leads to entirely new business lines or significant changes in corporate strategy. Yet both new business lines and periodic changes in corporate strategy are required to keep employees refreshed and to support long-term company growth.

The second is that focusing narrowly on improving existing products will inevitably lead firms to fail to detect disruptive innovations that may threaten the product road map itself. Ideally, companies will detect such innovations long before they reach the marketplace, giving themselves enough time to turn potentially fatal developments into distinct competitive advantages.

The problem is that the kind of exploratory research required to renew corporate strategies and detect disruptive innovations is also the most costly and risky. David Tennenhouse, a renowned technologist and former vice president of Intel's corporate technology group, thinks these are costs and risks that are best shared through a new open and collaborative model of industry-university partnerships.[22]

Intel's Open University Network

Having spent much of his career working at DARPA (Defense Department Advanced Research Project Agency), structuring close collaborations among public and private agencies is something that Tennenhouse knows a lot about. He took that knowledge to Intel, where he built a highly successful approach to managing Intel's university partnerships.

Tennenhouse identifies a couple of reasons for the growing relevance of university research. "The number of talented electronics and IT researchers has grown substantially, and the talent pool is widely dispersed," says Tennenhouse. "Ideas now flow through leading universities and their faculty rather than any one industrial lab, however prestigious."[23]

Accelerating technological change and heightened competition from Asian semiconductor firms are also putting the heat on Intel. Close cooperation with leading universities helps Intel maintain its edge, while spreading the upfront costs of R&D across a much broader research ecosystem. Tennenhouse says that by leveraging its university connections skillfully, it gains access to the results produced by the bulk of the research community.

In the spring of 2001, for example, Intel established exploratory research labs adjacent to the University of California at Berkeley and the University of Washington in Seattle. Two more labs, near Carnegie Mellon University and the University of Cambridge (UK), were added later. Intel selected leaders in the research areas it wanted to explore who had a strong track record of collaborating with industry, and whose faculties collaborated well with one another.

Each lab houses twenty Intel employees and twenty university researchers. "Company and university researchers work side by side," says Tennenhouse, "and communicate their findings instantaneously rather than waiting to present them first via formal channels, such as conferences and publications." Each lab has a unique research focus—from ubiquitous computing to distributed storage.

When a promising research thread is detected, Intel puts a coordinated set of efforts in motion that includes additional grants to leading university researchers and the initiation of its own complementary projects. At the same time, Intel works closely with its corporate venture group to identify and invest in promising start-ups in each new sector.

The key to the program's success in transferring people and technology across university/industry boundaries is funding multiple projects at a time. Intel sets things up so that university and Intel research teams work in parallel, while meeting regularly to exchange results. This way, says Tennenhouse, "the researchers at different institutions compete among themselves but also work together to achieve the program objectives. These cycles of competition and hybridization," he adds, "lead researchers to quickly adopt the best of each other's ideas."

In the four years since the first exploratory lab was launched, Intel Research has matured more quickly than expected, accelerating research in a number of key areas. Already, five strategic research projects, in the areas of polymer storage, microelectromechanical systems (MEMS), optical switching, inexpensive radio frequency, and mesh networking have been transferred downstream toward product development. "The labs are generating strong intellectual results (as evidenced by publications at premier conferences), our efforts in the areas of sensor networks and PlanetLab have been widely acknowledged, and our ubiquitous computing team is recognized as one of the best," says Tennenhouse.

Making the Most of University Partnerships

To replicate some of Intel's successes and make the most of university partnerships in your firm, we recommend adopting the following principles.

Use industry-university partnerships to shake up product road maps

Though incremental movement is a powerful and important feature of innovation, focusing solely on incremental product improvements can easily lead to stagnation.[24] With a few notable exceptions, corporate research teams have been unable to sustain a high level of success over time. Beyond a decade, their agendas, once bold and innovative, become conservative and incremental. To fight attrition, Intel uses industry-university partnerships to deliberately introduce disruptive elements into its strategy.

Make sure the collaboration is a win-win

Cash-constrained university departments generally welcome industry sponsorship of their research programs. But such partnerships are not free from controversy, so it's wise to take note of the following considerations. First, don't poach all of the university's top staff. Universities live and die by the quality of their faculty—star faculty attracts students and funding and generates top rankings. Second, be sensitive to the need for faculty to publish and conduct ongoing research. Published research is the key metric by which faculty are evaluated, both by their employers and the wider research community. Finally, create lasting relationships between company and university researchers that continue to create value long after the formal partnership itself has ended. Intel researchers, for example, often keep in touch with faculty members, and occasionally lean on them when they're running into difficulties.

Deepen and broaden collaboration across research communities

Many industry-university partnerships are structured such that individual project teams at different institutions work in isolation. Yet Intel has found that some of its most promising insights and applications may flow from unexpected synergies that arise when teams get together to discuss their research. With sufficient critical mass and geographical reach, collaboration across institutions could even jump-start whole new research communities.[25] Tennenhouse describes this practice as "reverse technology transfer." Instead of transferring technologies from the university to Intel's business units, Intel sometimes reverses the flow, moving technology back upstream to university researchers. Doing so allows Intel to foster vast research communities with the scale to collectively address huge research challenges of strategic importance to the company.

Keep the science open and the applications proprietary

Rather than wrangle over who gets to control and exploit the fruits of joint research efforts, Intel and its academic partners sign on to Intel's open collaborative research agreement, which grants nonexclusive IP rights to all parties.[26] This way both sides retain their freedom to engage in further research, develop new products, and partner with other players. This may sound like martyrdom in the name of openness, but in fact the benefits of casting a wide net for new ideas and learning rapidly from the external research ecosystem greatly outweigh the advantages gained from keeping the research proprietary. "Proprietary advantage," says Tennenhouse, "is more effectively obtained in the downstream stages of a project, as the work moves toward technology and product development."

Learn from "proxy" customers–early and often

One of the elements so often missing in exploratory research is the customer's perspective. Intel strongly encourages each of its project teams to place interim results and prototypes into the hands of proxy customers as soon as it is practical to do so. These early users provide feedback about which aspects of their research are most valued by customers (or not) and which applications are worth pursuing—applications that are frequently different from those originally envisioned.

LAYING THE PUBLIC FOUNDATION

Competition through free enterprise and open markets are at the heart of a dynamic economy, but if there is one additional lesson to take away from this chapter it's that we can't rely on competition and short-term self-interest alone to promote innovation and economic well-being. Vibrant markets rest on robust common foundations: a shared infrastructure of rules, institutions, knowledge, standards, and technologies provided by a mix of public and private sector initiative.

A growing number of leaders in the private sector now appreciate the value of a strong public foundation. These New Alexandrians understand that creating a shared foundation of knowledge on which large and diverse communities of collaborators can build is a great way to enhance innovation and corporate success.

Some companies use cross-licensing and patent pools to lower transaction costs and remove friction in their business relationships. Some industries embrace open standards to enhance interoperability and encourage collaboration. Others invest in a precompetitive knowledge commons to boost the productivity of downstream product development. Still others prefer to help weave networks of university partners that will unleash a fertile stream of ideas and inventions that can blossom into new businesses. Regardless of which method—or combination of methods—firms choose, the result is usually the same: a more dynamic and prosperous ecosystem.

Despite this promising flurry of open activity there are still far too many companies, and their allies in public office, that take the public elements of the innovation equation for granted. They see calls to further open up infrastructures for communication and collaboration, to enlarge the public domain, or to create a more balanced intellectual property system as inimical to economic prosperity. Somehow the dismal record of economic development in many developing nations, where such public institutions are weak, has not convinced them otherwise.

These are book-length topics, and it's hard to do them justice here. But the way we manage intellectual property, in particular, affects everything we have discussed in this chapter—and indeed most of the new business models we cover in this book—so it's worth reflecting on the topic. Of course, as authors and business people we recognize that rewarding creativity and investment is central to promoting innovation. In theory, intellectual property law exists to do just that. But expansion in the law's breadth, scope, and term over the last thirty years has resulted in an intellectual property regime that is radically out of line with modern technological, economic, and social realities. This threatens the chain of creativity and innovation on which we (and future generations) depend.

In today's economy we need an intellectual property system that rewards invention and encourages openness—one that fuels private enterprise and sustains the public domain. The existing intellectual property system isn't working as well as it could.

Increasingly vocal critics argue that our knowledge economy has become overprivatized. Scholars such as James Boyle and Lawrence Lessig point out that in recent decades intellectual property rights have been consistently strengthened, while the public domain has become dangerously constricted. These voices need to be heard.

Since the Bayh-Dole Act extended patent eligibility to public research organizations in 1980, for example, property rights have been migrating farther upstream into the realm of basic science. On the one hand, property rights in basic research offer the promise of substantial economic gain from increased commercialization of inventions. On the other hand, commercialization could erode the culture of open science that has fueled centuries of scientific discovery.

Science and commerce depend upon the ability to observe, learn from, and test the work of others. Without effective access to data, materials, and publications, the scientific enterprise becomes impossible. Recent studies show a disturbing trend: Increasing secrecy, pressures to patent, cumbersome technology-transfer agreements, and complex licensing structures are making it hard for scientists to share research data. In a recent survey by the American Association for the Advancement of Science, 35 percent of academic researchers reported difficulties that had affected their research because they were denied access to data, while 76 percent of scientists working in industry reported similar problems.

Concerns about access are serious. Strong, well-funded academic research institutions are a pillar of any nation's commercial success. In the United States, National Science Foundation figures show that while American academic institutions perform 13 percent of national R&D (spending about $36 billion), they perform 54 percent of all basic research. A significant portion of this basic research (50 percent in 2001) goes into the biological and medical sciences—a key frontier for scientific discovery and economic growth.

By comparison, large, research-driven pharmaceutical firms like Merck with an annual R&D budget of about $3 billion conduct less than 1 percent of the biomedical research in the world. To gain access to the remaining 99 percent of biomedical research, pharmaceutical firms tap into the research conducted in universities and public research organizations around the world. If royalties or restrictive licensing conditions inhibit public researchers' access to patented research tools, then the industry's opportunity to harvest this research diminishes.

The Balancing Point

Finding the right balance between the public foundation and private enterprise is key to the long-term competitiveness of firms and economies. We have to be able to apply existing knowledge to generate new knowledge. At the same time society must elicit the private investment needed to translate new knowledge into economic and technological innovations that contribute to social well-being.

In short, we must encourage innovation without eroding the vitality of the scientific and cultural commons. We need an incentive system that rewards inventors and knowledge producers *and* encourages dissemination of their output.

The hard questions are as follows: How much protection is enough or too much? What's the right balance between private enterprise and the public domain? And what will best achieve that balance—market mechanisms or government intervention?

Public policy reforms are undoubtedly warranted. In intellectual property law, many practitioners are calling for the courts, Congress, or international treaties to roll back—or at least counterbalance—property rights. Well-targeted legal measures could significantly reduce some of the current costs and uncertainties that have accompanied the recent wave of privatization.

But curbing the excesses of the intellectual property rights system will require a broader portfolio of initiatives that includes collective action by firms and nongovernmental organizations, and above all, a new way of thinking about openness and sharing. Indeed, while policy measures are being debated, smart firms should be taking action.

The prompt publication of data, methods, and source code in the life sciences industry, for example, appears to have been a powerful constraint on patenting. To the extent that this "push back" preserves commercial freedom of action on the one hand, and freedom of inquiry on the other, it contributes to the long-run performance of biomedical research and the pharmaceutical industry. Indeed, if academics were to be squeezed out of a patent-laden field, industry would be cutting off its most important lifeline.

On the other hand, the scorched-earth strategy of placing data, methods, and source code in the public domain may have undesirable consequences. If patents become more difficult to obtain, commercial researchers may become secretive to protect their investments, thereby limiting access to important knowledge and making duplicated research more likely. Even worse, fundamental aspects of the industry's infrastructure may suffer due to chronic underinvestment.

Balancing these concerns is critical to maintaining the health of the life sciences industry ecosystem. Analogous concerns arise in any industry where R&D activities are distributed among upstream and downstream firms, and at some stage, a nonprofit research community—a scenario that describes almost all science-intensive industries today.

This brings us to one last lesson, which pertains to the importance of choice and balance. Companies can't open the kimono all of the time. Companies need to defend their assets and work hard to create proprietary advantages. Pharmaceutical firms may harness openness in the early stages of drug discovery. But nobody is giving up patent rights over end products. Indeed, every member of the SNP Consortium is fighting tooth and nail to be the first to get new drugs to market.

Every firm has to reach its own set of conclusions about the appropriate balancing point. Indeed, it is essential to the competitive and evolutionary process that rival forms of strategy and organization can do battle. There is something truly inspiring about a world where the clash of worldviews between Microsoft and IBM or Big Pharma and the biotech firms can play itself out in the marketplace. This, as IBM strategist Joel Cawley put it, "will generate an evolving set of commons, an evolving set of protected areas, and an evolving set of walled gardens."[27] It is the vitality of this evolution that is important. So long as the playing field remains level, it is one reason to remain optimistic about the future.