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Where Have the Great Inventers Gone?

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By James Bessen

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Dean Kamen is an inventor with an ax to grind. He would like to see inventors achieve the same pop culture "superstar" status as NBA athletes. Kamen achieved considerable success as an inventor of medical devices, but he feels that public recognition of inventors remains elusive. He argues that modern inventors do not achieve the same fame as the inventors of the past, "New science and technology doubles every year, but the history textbooks still talk about Eli Whitney and the cotton gin."[1] To help correct this lack of recognition, Kamen founded FIRST, For Inspiration and Recognition of Science and Technology, in the early 90s. FIRST uses "wholesale marketing and media techniques" to motivate young people to learn about science and technology.

Although we live in an era of rapid technological change, it is surprisingly difficult to identify today's Great Inventors comparable to James Watt, Thomas Edison or Jonas Salk. The picture of technological innovation found in history textbooks and science museums—centered on such inventive geniuses—somehow seems different from modern reality. Yet the textbook perspective inevitably influences thinking about innovation and patent policy.

The *reason* for the puzzling decline in the public recognition of inventors is significant. It may reveal important features of innovation today, features that are critical to understanding the effect of patent expansion on innovation. It may help explain why some modern inventors feel so frustrated by the patent system.

Perhaps the difference is just a problem of marketing and media relations, as Kamen suggests. Or perhaps, instead, the difference reflects a fundamental change in the nature of innovation. Indeed, some people argue that modern technology just isn't as significant as the technologies used by the Great Inventors of the past. Others suggest that the low visibility of modern Great Inventors reflects a critically weakened patent system.

Or perhaps modern innovation is more collaborative, so that individual inventors are not as prominent. Perhaps the *complexity* of modern technology requires a higher degree of collaboration. Because no single individual can realize all of the insights necessary for success with complex technologies, even modern inventors of genius must find ways to work together, either through market-based coordination or through other institutions. Then, because the innovation is shared, individual innovators do not achieve the same fame as in the past.

This last explanation, in particular, may account for some of the persistent frustration modern innovators express about the patent system. Although the patent system may have worked well for the simpler industrial technologies of the past, perhaps the expansion of patents to cover new complex technologies gets in the way of innovators' efforts to collaborate.

Fame, Past and Present

Is Kamen's assessment of poor recognition of modern inventors correct? Measuring fame is not easy. To obtain a rough measure, I counted the number of articles appearing in the New York Times that mentioned an individual inventor. I included all articles through the end of 2001 or the year of the individual's death, whichever came first. Although this count is not exactly a measure of public recognition, it does provide a measure of the number of times an individual is brought to public attention.

By this measure, the fame of modern inventors is, indeed, far less than that of NBA stars. Shaquille O'Neal (1,657 articles), Wilt Chamberlain (2,343), and Michael Jordan (5,217) have been covered much more than Dean Kamen (11).

To obtain a sample of modern inventors, I assembled a list of all inductees into the National Inventors Hall of Fame in Akron, Ohio. I included those inventors whose inventions (patents) were made after 1970. There were 39 such inductees through 2002. Note that this list of inventors only includes inventors who patent—it does not include people like Dan Bricklin (spreadsheet program) or Tim Berners-Lee (World Wide Web) whose inventions were not patented. For several reasons, patents may be less important to innovators today than for the Great Inventors of the past, but non-patenting inventors do not appear to have greater fame than those inventors who do patent.[2]

On average, each inventor was mentioned in 13 articles. But this fame was largely concentrated among just a few inventors, the top five accounting for almost two thirds of the articles. The five most famous inventors are shown in Table 1.

Table 1. Number of New York Times Articles during Person's Lifetime (through 2001)

Recent Inventors		Inventors of 100 Years Ago	
Steve Wozniak	144	Thomas Edison	4,709
Seymour Cray	69	Orville Wright	849
Baruch Blumberg	44	George Eastman	536
Raymond Kurzweil	36	Alexander Graham Bell	533
Willem Kolff	35	George Westinghouse	439
Recent Business Leaders		**Business Leaders of 100 Years Ago**	
Bill Gates	5,139	John D. Rockefeller	9,288
Rupert Murdoch	3,374	Henry Ford	7,930
Ted Turner	2,959	Andrew Carnegie	4,965
Donald Trump	2,778	Alfred P. Sloan	3,158
Michael Eisner	1,191	John Wanamaker	2,148

I then compared these to similar counts of articles from the historical file of the New York Times (from 1851 to the death of the inventor) for some famous inventors of roughly one hundred years ago. The five most famous of these inventors are also shown. Clearly, the Great Inventors of the past achieved a much greater fame, by an order of magnitude.[3] The modern inductees in the Inventors Hall of Fame do not appear to have much fame in comparison.

Although these counts measure newspaper coverage rather than actual name recognition, it seems likely that coverage is highly correlated with recognition. Most people would be hard pressed to identify the top five modern inventors or to name some of their inventions. Most people would have a much easier time recognizing the inventors from the earlier period and, I suspect, most people could name some of their inventions as well.

Of course, it is possible that the New York Times covered technology much more in the past than it does today. But this seems unlikely for several reasons. First, poll data show that the public holds scientists and engineers in high regard and thus it seems likely that newspaper readers would have interest in new technologies.[4] And, indeed, the New York Times has excellent coverage of science and technology including a weekly science section and a weekly column on patents.

Moreover, the low fame of recent inventors is not the result of a shift in media attention toward athletes and pop-culture superstars: business leaders receive comparably high recognition. The lower part of the table shows fame rankings for recent and past business leaders. And by comparison, today's business leaders enjoy a fame that is only modestly less than that of the business titans of a hundred years ago.[5]

So, modern inventors do not endure a lesser fame simply because media attention has been distracted to cover athletes and entertainers. Indeed, Dean Kamen has been in the media spotlight himself. Primarily an inventor of medical devices, Kamen recently developed the Segway Human Transporter, a two-wheeled self-balancing device that carries an upright person at up to 10 M.P.H. or so on sidewalks and roads. After months of public speculation with rumors circulating about a secret project code-named "Ginger," he introduced the Segway on *Good Morning America* in December, 2001 and a torrent of publicity followed. *Time* magazine headlined the invention as "re-inventing the wheel" and technology pundits called it "as big a deal as the PC" and "maybe bigger than the Internet;" Kamen claimed that it would replace the automobile in cities and Steve Jobs of Apple Computer predicted that in the future, cities would be "architected" around it.

Yet getting into the history textbooks may prove to be more difficult. Unless this invention lives up to its hype—and current sales fall far short—then Dean Kamen is unlikely to achieve the same stature as Edison—or Eli Whitney—either in pop culture imagination or in historical perspective. But the reason won't be for a lack of media attention.

Not so great?

Of course, the Great Inventors of the past were not unfamiliar with media hype either. They were never so great nor so solitary as depicted in "heroic" accounts of invention. The reputations of many of these inventors were greatly enhanced by self-promotion or public relations efforts undertaken by interested related parties. Thomas Edison was an adept self-promoter and Jonas Salk was lionized by the March of Dimes to the point of alienating much of the scientific community.

But James Watt was, perhaps, the first Great Inventor in the modern heroic mold. Historian Christine MacLeod documents how Watt's friends, relatives, assorted political allies and, importantly, textile manufacturers conducted a public relations campaign to have a large statue of Watt placed in Westminster Abbey. In the process, they changed public perception of Watt and of the rising manufacturing economy.[6] This effort was undertaken in part to commemorate Watt's accomplishment, at some expense to other inventors. But textile manufacturers also joined the effort to lobby for a legislative ban on machinery exports—the "exceptional" nature of Watt's contribution and its central importance to the British economy meant export of machinery might endanger the wealth of the nation, not to mention textile profits.

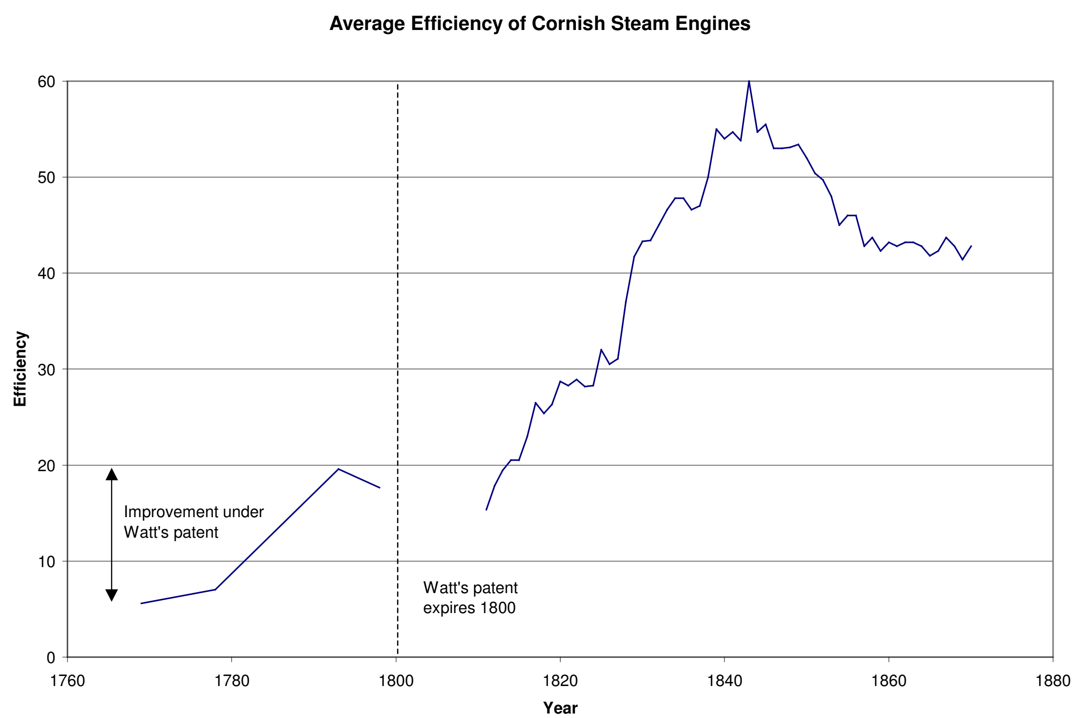
Before the nineteenth century, inventors were not often cast as heroes. Often inventions were seen as the work of the Divine Hand. Inventors merely uncovered ideas that had been left for them to uncover. For example, the invention of the printing press had been seen as part of God's preparation for the Reformation.[7]

With the commemoration of Watt, the focus shifted to one man's self-directed genius and perseverance. This was, of course, part of a broader cultural shift celebrating the romantic role of the individual. Prior to the eighteenth century the word "genius" applied to all people. Since ancient Roman times, the word referred to the spirit allotted to each individual at birth that determined his or her fortune and character. But the Oxford English Dictionary records a new usage beginning in the mid-eighteenth century during the rise of Romanticism. Today the most common usage of "genius" applies only to the exalted few who have an "instinctive and extraordinary capacity for imaginative creation, original thought, invention, or discovery."[8]

In the apocryphal story of James Watt, he had a "flash of genius." As an instrument maker at Glasgow University, he was given a model of a Newcomen steam engine to repair.[9] On doing so, he discovered that this engine was very inefficient and so he spent a number of months experimenting on it to understand why. Then "on a fine Sabbath afternoon" in 1765, while walking on the Green of Glasgow, he received the idea of building a steam engine that cooled the steam more efficiently by using a separate condensing chamber. Three days later, he had built a small model of such an engine that demonstrated much more efficient operation.

When the public relations campaign for Watt's statue reached full speed, Watt's genius was allegedly responsible for winning battles in Europe, for raising Britain to international pre-eminence, for the prodigious advance of wealth and population under George III and for a revolution in manufacturing and social conditions. And this celebration set the ground for Toynbee's later assessment of the "Industrial Revolution" as a discrete jump in the productive powers of the nation arising from the genius of a few inventors.

Yet careful quantitative estimates by recent historians suggest a much more sober assessment. Measured by productivity, the Industrial Revolution was a much more gradual affair, with productivity growing at a *slower* rate than for most advanced nations today (and far slower than many modern industrializing economies). And the contribution of the steam engine itself was significant, but not dramatic. Nicholas von Tunzelman, in a careful study of the quantitative effects of the steam engine in Britain, concludes, "the level of national income reached on 1 January 1801 would not have been attained much before 1 February 1801 without James Watt."[10] Indeed, the American Industrial Revolution ran largely on water power instead of steam power.



Source: Alessandro Nuvolari, 2001, Eindhoven Centre for Innovation Studies, Working Paper 01.04.

Part of the reason for this more modest assessment of Watt is that steam engine efficiency was just one among very many technological changes boosting the new manufacturing sector. Another reason is that many other inventors also made enhancements to the steam engine—despite a popular misconception, Watt did not invent the modern steam engine, but just some of the many enhancements to it. Recent scholarship by Alessandro Nuvolari shows that Watt's inventions brought a large jump in the efficiency of steam engines used in Cornish mines (see Figure ??).[11] Watt made an improvement to the existing steam engines and this was under patent protection (extended by Parliament) until 1800. During this period, the mines could only use these engines under contract with the firm of Boulton & Watt and Watt used his patents to prevent modifications or improvements to his design. After the key patent expired, however, local engineers began making a large number of improvements. Clearly *most* of the gains in technical efficiency realized by the mid-nineteenth century in absolute terms were made by other inventors. As economic historians have found for many technologies, most of the economic gains were realized through incremental improvements by a large number of inventors.

Nevertheless, Watt *does* deserve to be called a Great Inventor. Watt's invention did bring about a discrete jump in the efficiency of steam engines, an improvement that was critical to the expansion of the market for steam engines from the mines to the emerging manufacturing sector. More important, this improvement—combined with Watt's patent monopoly and subsequent refinements—allowed the firm of Boulton & Watt to dominate the nascent steam engine market for over two decades in mining and longer in manufacturing. Note that this accomplishment required the involvement of many more people than Watt and much more effort than Watt's initial "flash of genius." After his three days of effort to development a working scale model, it took eleven years of incremental innovation in materials, metal boring and operations to achieve a commercially viable model. And Watt relied on the inventions of others, both within the firm of Boulton & Watt and outside—most notably improvements in metal boring technology from Wilkinson.

Few other inventors worked as solitary geniuses. Typically, the Great Inventors worked in collaboration with others, they built on the work of others, and they contributed to an extended period of incremental improvement. Edison ran an R&D laboratory. He was not the first to develop a working light bulb, but his lab did make improvements to the light bulb and, more important, developed many components of the required system of electrical generation and transmission. But many other such components were, to Edison's dismay, invented by competitors, including Westinghouse. Nevertheless, Edison, like Watt, was involved with the ongoing development and enhancement of his inventions that allowed Edison Electric (later General Electric) to maintain a major market role. Jonas Salk was also not a lone inventor. His polio vaccine was an application of the research of John Enders who had figured out how to grow the polio virus in the laboratory a few years before. Enders and two colleagues, not Salk, received the Nobel prize for their research. Also, other labs provided the developments necessary to produce the new vaccine in large volumes. Although the Salk vaccine was widely used and reduced the incidence of polio in the U.S. by 90% in just a few years, it was replaced in less than a decade by the more effective Sabin oral vaccine.

Other Great Inventors of the past were also, by and large, successful innovators like Watt. That is, they were actively involved in the successful development and commercialization of their inventions, either becoming entrepreneurs themselves or working in close cooperation with entrepreneurs. This impression is confirmed by the systematic analysis of 160 Great Inventors from 1790 to 1865 by B. Zorinna Khan and Kenneth Sokoloff.[12] Khan and Sokoloff identified this sample of individuals from biographical dictionaries and histories of technology. Over 85% of these inventors about whom information is available were directly involved in commercial exploitation of their inventions through manufacture (many also licensing in addition to manufacturing). The inventors of over half of the patents were noted manufacturers, appearing in directories of successful manufacturers.

Thus, despite the hype, the Great Inventors of the past *were* great; their market success demonstrates their economic significance.

This sustained involvement in the development and commercialization of inventions by the Great Inventors of the past contrasts sharply with the activity of modern day inventors from the Hall of Fame. Only seven of the thirty-nine inventors (eighteen percent) became entrepreneurs or worked in small entrepreneurial companies to develop their cited inventions. Twenty-three of the remainder (fifty-nine percent) worked in large companies and many of the rest were academics. Moreover, of the seven entrepreneurial inventors, none played a dominant role in their industry for an extended period of time. Some left their startup companies after a short time, and some inventions or companies were sold to larger firms. Only one of the thirty-nine inventors, Raymond Damadian, an inventor of magnetic resonance imaging (MRI), has remained an entrepreneur in a company still selling MRI equipment, but his company, Fonar, has only a small share of the MRI market and has largely functioned as a patent licensing firm (see more below).

Consider the difference between Watt and Steve Wozniak, the most famous of the recent inventors in the Hall of Fame. The Hall of Fame identifies Wozniak as the inventor of the personal computer for his patent number 4,136,359, "Microcomputer for use with video display," filed in 1977. Steve Wozniak was the chief designer of Apple Computer's first two models (the first a kit, the second a fully assembled computer with basic software). But, with all due respect, Wozniak, who *is* an important inventor, was not *the* inventor of the personal computer. The idea of a microcomputer had been "in the air" since the late 60's and certainly since Intel ran an ad in 1971 with the exaggerated claim, "Announcing a new era in integrated electronics: a micro-programmable computer on a chip."[13] During the mid-70's several companies offered kits that allowed hobbyists to assemble their own microcomputers. And a network of microcomputer enthusiasts sprung up across the country where people exchanged ideas, freely shared designs and sold each other products. The early microcomputer industry has been described by economist Peter Meyer as an episode of "collective invention" where inventors freely share technical information (the Cornish mining engineers were another instance).[14]

The local branch of this network in the Silicon Valley was the Homebrew Computer Club, founded in 1975. The club quickly grew to over five hundred members and eventually more than twenty computer companies were started by its members, including Apple Computer.[15] Wozniak joined in 1976 and found he had much to learn; he was unfamiliar with the latest chips. Learn he did, and Wozniak soon designed the Apple I, a kit sold to hobbyists, and then the Apple II, a complete microcomputer sold to a larger market. Of all the computers that came out of the Homebrew Club, this model achieved the greatest success.

Engineers have described some portions of the design of the Apple II as brilliant and surely this contributed to its success. But clearly the Apple II also drew on the collective contribution of many other people. It is hard to separate Wozniak's contribution from these contributions and unlike Watt, no single invention itself provided a markedly discrete jump in performance or capability. The technology was simply much too complex, involving microprocessors, memory, video displays, power supplies, operating systems, applications software and more. No single invention and no single inventor could achieve a critical advance that was not soon imitated or "invented around." Indeed, patent 4,136,359 covered not the "personal computer," but an inexpensive circuit for controlling a standard color video display from a microcomputer. This was a helpful improvement, but hardly critical—most purchasers of the soon-to-follow IBM PC did not buy a color video display at all.

And even much of the success of the Apple II was due to people outside of Apple. Indeed, sales of the Apple II did not really take off until someone else—Dan Bricklin and Bob Frankston—developed their spreadsheet program, VisiCalc. This was the "killer application" that made the Apple computers useful for a large new market and provided the critical reason for commercial customers to buy.

Because so much of the technology was outside Apple's control, Apple Computer did not remain dominant for long. In short order, the Apple III turned out to be a flop and IBM introduced its Personal Computer with an open architecture that permitted "clones" and the rapid incorporation of new improvements. Despite the innovative Macintosh computer a few years later, Apple has remained with small market share.[16]

In other industries, such as chemicals and pharmaceuticals, inventors run into a different sort of complexity. Consider pharmaceutical innovation. A single scientist or a small group of scientists can identify a potentially useful compound and conduct pre-clinical research that demonstrates *in vitro* efficacy (the drug has a positive effect in the lab). However, to actually reach the market, that compound has to go through a maze of complicated additional studies that are well beyond the reach of that small lab. Before human studies can begin, a battery of toxicology, mutagenicity and pharmacokinetic studies in animals need to be conducted and, based on these, a research plan developed and approved by the FDA. There are then three phases of human clinical trials before the drug can be approved: first to test the safety of the compound, second to show that it has positive effects, and third to show that the compound offers overall advantages in comparison to standard treatments. This last stage may involve hundreds or thousands of people. Given this complexity, almost all pharmaceutical research involves large companies, although the original pre-clinical research may be done in a university or small biotech company.

The relatively greater complexity of modern technology explains much of the difference in economic performance between famous inventors then and now. Because of this complexity, innovation today is simply a more collaborative process. For the most part, recent famous inventors either work in large corporations, as members of large teams, and/or their work passes relatively quickly to large teams through acquisition or licensing by a larger company. And often their individual inventions are smaller parts of the total innovation—they rely on many previous innovators for much necessary technology and subsequent innovations are often responsible for much of the economic benefit. Much of this innovation necessarily occurs outside any single firm. Except for chemical and pharmaceutical inventions, the companies of few inventors from the Hall of Fame were able to maintain a dominant market position for long. The individual inventor today has a fundamentally different relationship to the total innovation of which his or her invention is part.

This difference provides a simple explanation for the lower relative fame of modern inventors. The Great Inventors of the past either were business leaders themselves, or like business leaders, were involved with a dominant product over an extended period of time. Both they and business leaders then and today make many newsworthy announcements over time as inventions are enhanced and adapted to new markets. But modern inventors are either part of a much larger team, so their individual activity is not newsworthy, or they play a leading role for only a short period of time. There are simply fewer opportunities to make news for the modern inventor because the individual modern inventor does not dominate the process of innovation.

Is modern invention less important?

Skeptics argue that modern invention is less significant, echoing John Horgan's argument about the "end of science."[17] There are no Great Inventors today because there are no Great Inventions and there are no Great Inventions because the opportunities to make such inventions have been exhausted. But there is an important distinction to be made here. Modern inventions may be more incremental as with, for example, the many minor improvements made in frequent software upgrades. Each of these improvements is less significant *individually*, but this does not necessarily mean modern innovation is less significant when taken as a whole. That is, the nature of innovation today may be more incremental, but modern inventions may *collectively* be just as important for the economy and society as in the past.

One such skeptic is economist Robert J. Gordon. He makes this argument regarding information technology (IT) in an economics paper, "Does the 'New Economy' Measure up to the Great Inventions of the Past?"[18]

Gordon argues that IT does not bring the same level of productivity benefits as inventions such as the electric motor and internal combustion engine of the Second Industrial Revolution (1860-1900). These inventions provided dramatic improvements in the ability to transform and transport materials, basic needs of a large spectrum of industries and consumers. But Gordon argues that IT is different because it faces rapidly diminishing returns: "I cannot type or think any faster than I did with my 1983 personal computer that contained 1/100th of the memory and operated at 1/60th of the speed of my present model." Consequently, the productivity benefits of the last twenty years of improvements are, he argues, necessarily limited. Taking the example of word processing,

> "The real revolution in word processing came at the beginning [for him, WordPerfect 4.2 under DOS], by ending repetitive retyping and by allowing revisions to be inserted while the rest of the document would automatically reformat itself. The productivity enhancement of WYSIWYG [what-you-see-is-what-you-get] was minor in comparison, and what was contributed by the final step to the latest version of Word for Windows, beyond some ease of training for novice users, escapes me. [p. 63]"

But although Gordon sees little value in more recent word processing programs, large numbers of consumers apparently disagree with him. Attempts to sell relatively "de-featured," low price word processing programs have not found a large market. Similarly, inexpensive computers with somewhat slower speeds and less memory have repeatedly met with limited success. Consumers seem to vote regularly with their dollars by spending hundreds more for technology that Gordon feels is not worth the difference.

Consider WYSIWYG displays, the simulation of typeset pages on the computer screen. For Gordon, a writer, WYSIWYG is a minor improvement—it does little for anyone concerned primarily with text alone. But for many people who layout and design publications, from newsletters to newspapers, WYSIWYG has been a godsend.[19] It permits designers and editors to directly control the appearance of their publications, allowing them to improve the quality of their work without involving the cost and time of typesetting and composition at each iteration. It has transformed the printing and publishing industries. It has allowed streamlined production and control of publications, often leading to reorganization of the workforce, shifting production inhouse, and contributing to sharp reductions in the employment of typographers, compositors and layout artists. It has also dramatically broadened the use of typeset composition. Twenty years ago the words "font" and "point size" and the names of typefaces were part of the arcane vocabulary of people involved in print production; today most computer users know these terms.

So although WYSIWYG may be a minor improvement for many or most computer users, for some it is a very important improvement. By itself, this inevitably means that WYSIWYG is *not* as important an invention as, say, the internal combustion engine, which brought significant benefits to most people. But it is a mistake to view WYSIWYG as an isolated invention—it is just one of a large number of complementary, related improvements in composing typeset words on pages that have been enabled by computers.

Indeed, the ability to address important heterogeneous needs of small groups of users is a hallmark of information technology. Consider the changes in composing typeset text. Movable type for printing was first developed in China during the 11th century. Gutenberg perfected a Western version using metal type during the 15th century. With this technology, individual type characters are selected from a type case and assembled on a composing stick. Each line of type is then locked into a frame for printing. After printing, the type blocks are sorted back into the type case.

The manual work of selecting and sorting type was tedious and slow. This problem succumbed to the wave of mechanical invention during the nineteenth century. After attempts by many inventors, Ottmar Mergenthaler developed the first successful linecasting machine in 1886, the Linotype "hot metal" typesetter. On these machines, a skilled typographer typed a single line on a keyboard, usually in a single font and size, and each line was cast in hot metal (hence "line o'type"). The machine automated the selection of type characters and the sorting after composition, increasing the speed of typesetting of body text by a factor of three or four times.[20] This invention proved to be a major benefit for the production of a wide variety of printed matter. It gained Mergenthaler entry into the ranks of Great Inventors and it became the dominant technology for producing body type for eighty years.[21]

Although this invention automated a task common to the production of many varieties of printed matter, it did not automate everything, however. The Linotype operator could see a single line at a time, but complex publishing required manipulation of entire paragraphs, columns, pages, or even entire sections or chapters. Different kinds of printed matter such as newspapers, display ads, classified ads, books, typeset forms, financial tables, etc., have very different requirements and Linotype operators had to develop highly sophisticated techniques to adapt this technology to these many applications. Despite the early hopes of printers and publishers that the Linotype machines could be operated by relatively unskilled labor, this proved not to be the case. The necessary skills were considerable, requiring a four year apprenticeship, and this permitted the International Typographers Union to emerge as one of the most powerful craft unions.

Until computers. Beginning in the 1960s, computers began to be used as "front ends" to the typesetting process and were often used in tandem with new phototypesetting output technologies and with offset printing. The result was a flowering of new capabilities. In place of a *single* technology requiring highly skilled operators, one now finds all sorts of specialized systems for books, newspaper pages, display ads, classified ads, directories, catalogs, technical documentation, magazines, etc. Now the specialized techniques required for different publishing applications are realized through different software programs, using WYSIWYG and other, more specialized features. Each niche application is served by one or more commercially available systems. Not only do a great variety of specialized programs address publishing niches, but many advanced programs allow users to program their own customized adaptations. For example, publishers of cattle-breeding magazines in Kansas City now have specialized software routines to typeset the bloodlines of bulls. Much of the detailed technical knowledge formerly learned by typographers is now embodied in software.

These IT-enabled inventions are much more heterogeneous than the earlier technology for several reasons. Software can handle problems of greater complexity than either mechanical devices or human skill. The mechanical typesetters could only feasibly manage a single line of type at a time; skilled typographers could only visualize a few lines at a time. But because computers have extensible memory, software can solve publishing problems that involve a line, a paragraph, a page, a whole chapter or document, or even many different versions of a document. Also, the trial-and-error search for better techniques is faster and less costly with software than with mechanical inventions. After modification, software code need only be re-compiled; mechanical typesetters had to be rebuilt. And a successful software innovation can be diffused rapidly and with little cost compared to the time and cost of training new typographers.

In a sense, IT is a set of technologies and techniques for rapidly developing new technologies. This differs qualitatively from the technologies of the First and Second Industrial Revolutions. The steam engine, the electric motor, and the Linotype machine were each general purpose technologies that could be put to use in a wide variety of applications, but doing so usually required substantial additional engineering and/or the development of specialized skills and technical know-how by the users of the new equipment. With information technology, these adaptations can be made much more quickly and inexpensively, so IT lowers the cost of developing niche applications, allowing the development of hundreds of thousands of specialized computer applications.

Such improvements, addressing many heterogeneous niche needs, are unlikely to provide opportunity for any Great Inventors. But this does not mean that these innovations, taken collectively, are any less significant. The substantial growth of the consumer desktop publishing market and the diversity of high-end publishing systems suggest that someone is gaining significant value from these innovations. This example suggests that an exhaustion of innovative opportunity does not explain the dearth of Great Inventors. Rather, the kinds of innovations made today are just qualitatively different, more incremental, more niche-oriented, than those well-known inventions made by a few Great Inventors one hundred years ago.

Patents and Great Inventors

Another view holds that the patent system is responsible for the demise of the Great Inventor. Consider the Congressional testimony of Raymond Damadian, inductee into the Hall of Fame for magnetic resonance imaging, (MRI),

> Finally, Mr. Chairman, I wanted fervently in the development of the MRI to use my invention to build a great new multi-billion dollar manufacturing enterprise for America in the same way that Edison and Bell did. I have found that even though I have now labored diligently for more than a quarter of a century, the tools for doing what Edison, Bell, Eastman and others did, no longer exist. Indeed we have had the disheartening experience that no amount of toil at creating new innovations could reverse the process, but that by a combination of willful patent infringements and industrial espionage our innovations were stripped from us as fast as we could create them. Moreover, I believe you will not find my experience unique. Indeed I believe you will find it universal. (Testimony before the Senate Intelligence Committee and Senate Judiciary Committee, February 28, 1996).

According to this view, the patent system has been fatally weakened so that patents cannot be effectively enforced as they were in the age of the Great Inventors.

But more patents are being granted today, more patents are being litigated, patent holders enter litigation with new advantages such as preliminary injunctions that allow patent holders to shut down alleged infringers, and patent litigation is producing awards to patent holders that are far larger than at any time in history (in deflated value).

Indeed, Damadian forgot to mention in his testimony that he had won a very large award for infringement against General Electric just the previous year. At the time of his testimony, General Electric was still appealing the award (and Damadian was counter-appealing), but when litigation was over, Damadian's company was awarded $128,705,766. Moreover, Damadian did not begin to assert his patents until 1992, although his first patent for MRI-related technology was awarded in 1974. And according to the Fonar website, Fonar "successfully obtained satisfaction from nearly every one of its competitors in the MRI industry, including giant multi-nationals such as Toshiba, Siemens, Shimadzu and Philips."[22]

Given such awards it seems hard to argue that weak patent enforcement provides a serious obstacle to potential Great Inventors today. Damadian's award can be compared to the total royalties earned by George Selden's famous automobile patent one hundred years ago. Selden was a lawyer, not an auto maker, but he had a general patent that covered most automobiles and most automobile manufacturers paid him royalties, with the famous exception of Henry Ford.[23] Adjusting for monetary inflation, Selden earned royalties over eight years totaling about three million dollars, far less than Damadian earned from one company. Although one might argue that the patent system has been tilted against small and independent inventors, there is little basis to argue that patent enforcement is much weaker than in the past.

But because of differences in the complexity of technology, the *effect* of patent enforcement is different. Damadian's patent did not permit Fonar to establish a dominant market position. Instead, Fonar has had a small market share and has only earned positive profits in eight of the last twenty-three years, despite the licensing royalties. Similarly, neither Steve Wozniak's patent number 4,136,359 nor any of Apple's other patents allowed it to maintain a dominant market share for some substantial duration.

In contrast, a single patent (which was extended by a special act of Parliament) allowed Boulton & Watt to maintain a monopoly over steam engines for over two decades.[24] Because steam engine technology was so much simpler in comparison to computer technology (although it was by no means simple), a single patent on a single invention could facilitate a sustained position of market dominance. Other Great Inventors of the past realized similar advantages. Most of the inventors in Khan and Sokoloff's sample pursued patent protection (150 out of 160), many of them held "virtual monopolies" in their markets and others achieved dominant market share. Yet those inventors who patented only obtained an average of 7.8 patents during their lifetimes.

No such luxury was afforded Apple, nor could it be, given the broad contribution of many people outside of Apple and the complexity of the technology. Modern computer companies acquire hundreds or even thousands of patents each year without achieving similar market dominance to the Great Inventors.

Nor did Damadian's patents establish a monopoly in MRI even though the patents were enforced. That technology is also complex. Damadian's initial patent, in fact, did not actually cover spatial imaging (at best, it can be interpreted as covering scanning in one dimension) and only a rather generous interpretation of the patent's claims allowed the appeals court to find that General Electric infringed this patent. The spatial imaging technology was developed by others, most notably Paul Lauterbur and Sir Peter Mansfield, who did not patent these innovations. In 2003, Lauterbur and Mansfield received the Nobel Prize in Medicine—Damadian was not included and he subsequently took out full page newspaper ads in protest. But the contributions of Lauterbur, Mansfield and many other people permitted other firms to enter and dominate the new industry.

In other industries today, such as pharmaceuticals or specialty chemicals, one or a few patents *can* provide a foundation for market dominance. But, as above, in these industries, inventors face another sort of complexity that makes it very difficult for individual inventors to fully develop and implement an invention.

A New Edison?

Thus weak patent enforcement is not responsible for the diminished fame of inventors in either the pharmaceutical industry, or in the computer and medical equipment industries. Nor is the problem that inventors are insufficiently media-savvy. Nor has technological innovation gone into a terminal decline so that modern inventions are not as important as those of the past.

Instead, the complexity of modern technology makes innovation a collaborative process, involving many different people. It is just not helpful to pretend that the important inventions today are carried out by a few lone anointed individuals.

Of course, things may change. Perhaps a new style of invention may emerge where individuals play a more significant role. Indeed, although it is true that no modern inventor has comparable fame to Thomas Edison, some inventors *claim* to be "Edisons for a New Age." One such claimant is Jay Walker, the founder of Walker Digital, a "laboratory" modeled after Thomas Edison's Menlo Park lab.[25] But where Edison's lab produced electrical and mechanical inventions, Walker Digital's "inventions" are patents on methods of doing business. Half of Walker Digital's "R&D" staff consists of lawyers with patent experience. They brainstorm to identify Internet-oriented solutions to problems that can be patented, then licensed or turned into businesses. The most famous of these patents cover Priceline, the Internet site that permits travelers to bid for airline seats and hotel rooms.

Such new uses for patents are an important part of the recent expansion of the patent system. The general validity of patents on methods of doing business was firmly established by a court decision in 1998. If Walker is able to exclude others from using successful business models that emerge from the application of new technologies such as the Internet, then there may emerge a new generation of Great "Inventors." Although patents on technology may no longer allow a single individual or company to maintain sustained dominance in many markets, patents on the *business models* that use new technologies may allow dominance or even monopoly. Then history may repeat and Walker may, indeed, become a New Edison. The only question then is whether history repeats as tragedy or farce.

Until (and if) that happens, however, the myth of the Great Inventor should be retired. Talented and inspired individuals *are* essential for innovation today and these individuals should be honored and respected. But because modern technologies are complex, no single individual is likely to realize all of the ideas necessary to make a successful innovation nor is this necessary or desirable. Instead, talented individuals—perhaps even geniuses—work in diverse collaborative institutions to innovate. Some of these institutions are market-based, such as the licensing and consulting agreements between academic scientists and biotech startups; some are not, such as the Homebrew Computer Club. This is not to say that independent inventors or inventors in small companies are not important. They are, but even small companies innovate within an "ecosystem" of supporting institutions.

[1] New York Times, February 14, 1993, p. F10.

[2] E.g., Dan Bricklin had 29 cites in the New York Times and Tim Berners-Lee had 5 cites. These are fewer cites than the top 5 patenting inventors.

[3] Jonas Salk had 557 articles in the Times.

[4] For example, the Harris poll of October 16, 2002 ranks scientists as the most prestigious occupations with 76% rating scientists as have "very great" or "considerable" prestige; 66% ranked engineers as such, but only 47% ranked business executive so.

[5] Of course, the Great Inventors of one hundred years ago *were* also business leaders in general, a point I return to below.

[6] Berg and Bruland [1998], p. 96-116. MacLeod [1988]. *Inventing the Industrial Revolution: the English Patent System 1660-1800.*

[7] MacLeod [1988], p. 202-4.

[8] See also, Braudy [1998]. Oxford English Dictionary [1989].

[9] Scherer, "Invention and Innovation in the Watt-Boulton Steam Engine Venture," in *Innovation and Growth: Schumpeterian Perspectives*, (1984), Cambridge, Ma.: MIT Press.

[10] Von Tunzelman [1978].

[11] Alessandro Nuvolari (2001) "Collective Invention during the British Industrial Revolution: The Case of the Cornish Pumping Engine," Working Paper 01.04, Eindhoven Center for Innovation Studies.

[12] "'Schemes of Practical Utility:' Entrepreneurship and Innovation among 'Great Inventors' in the United States, 1790-1865," *Journal of Economic History*, v. 53, (1993), pp. 289-307.

[13] Paul Freiberger andMichael Swaine "Fire in the Valley: The Making of the Personal Computer," New York: McGraw-Hill, 1984, p. 20.

[14] Peter B. Meyer, 2003, "Episodes of Collective Invention," U.S. Bureau of Labor Statistics Working Paper 368.

[15] Saxenian, AnnaLee, "Regional Advantage: Culture and Competition in Silicon Valley and Route 128," Cambridge, Ma.: Harvard U Press, (1994) p. 34.

[16] Steve Wozniak did not play a central design role at Apple after 1981, although he did participate in some aspects of the Macintosh design. One reason for this may have been an unfortunate airplane accident he was in that year. Another reason may have been that the great wealth he achieved when Apple went public permitted him to pursue other interests—something the Great Inventors of the past could not have done. But it is unlikely that more active participation by Wozniak would have substantially altered Apple's fate.

[17] John Horgan, *The End Of Science : Facing The Limits Of Knowledge In The Twilight Of The Scientific Age*, New York: Broadway Books (1997).

[18] Robert J. Gordon, "Does the 'New Economy' Measure Up to the Great Inventions of the Past," *Journal of Economic Perspectives*, v 14 n. 4, (2000), pp. 49-74.

[19] Full disclosure: I played a role in developing the first WYSIWYG desktop publishing program (see below).

[20] John W. Seybold, *Fundamentals of Modern Photo-Composition,* Media, PA: Seybold Publications.

[21] The Monotype machine, also developed in the late 19th century, was a second technology. The operator worked at a keyboard that produced a paper tape. This tape was then fed into a linecasting machine similar to the Linotype.

[22] http://www.fonar.com/history.htm accessed 2/8/04.

[23] Ford challenged Selden's patent in court. Although the patent was not invalidated, Ford's four cylinder engine was found not to infringe. This effectively ended Selden's royalty stream, but this occurred only a year before the patent was to expire.

[24] He obtained additional patents, but his patent on the separate condenser proved to be key.

[25] "An Edison for a New Age?" Forbes, 05/17/99, Vol. 163 Issue 10, p178.