Invention, History, and Culture

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Invention refers to the activities by which individuals create new devices or processes that serve a human need or wish. To create a device or process, an inventor must often investigate phenomena in nature. In some cases, an inventor need only observe nature closely to discover what will work, but in other cases, he or she must tease out new insights by experiment or ingenious manipulation. Because nature does not readily yield up her secrets, one could say that an inventor "negotiates" with nature.

At the same time, invention is not simply discovering how to make something; an inventor must also connect his or her invention with society. In some situations, needs are well known and society readily takes up a new invention. For instance, railroads in the mid-19th century needed stronger rails and armies wanted stronger cannon barrels, so there was a ready reception for Henry Bessemer's new steel-making process in 1856. In many situations, though, there is no well-defined, pre-existing need and an inventor must convince society of the value of an invention. For example, when Alexander Graham Bell invented the telephone in 1876, he found few people who wanted to buy his invention and use it; indeed, it took the Bell Telephone Company decades to convince Americans that every home should have a telephone. Bell and his successor company not only had to invent the telephone but also develop a marketing strategy that reflected the needs and interests of users. In this sense, inventors "negotiate" with society.

One of the most popular sayings about invention is that "Necessity is the mother of invention." For economists, this slogan embodies the idea that some inventions are "demand-pull," meaning that inventors respond to demands already being voiced in the marketplace. While we often imagine that most inventions are demand-driven, that people

are clearly identifying needs and wishes, this is not always true. Indeed, many important inventions are "supply-push," meaning that they arise out of what inventors know how to do. With "supply-push" inventions, the creative task is often articulating a need that the invention fulfills and then convincing people that they have this need. In the twentieth century, television is perhaps the classic example of a "supply-push" invention; by ingeniously combining several ideas in electronics, Philo T. Farnsworth developed television but the real challenge was to create the larger infrastructure and market for TV.

What makes invention interesting, then, is that inventors stand astride the natural and social worlds. On the one hand, inventors must be willing to engage nature, to find out what will work; on the other hand, they must also interact with society, negotiating a trade between their inventions and various rewards (money, fame, resources). To be successful, inventors have to be creative on both sides--in how they wrestle with both nature and society. What made Thomas A. Edison highly successful was not only his ability to perfect new devices in the laboratory but also his willingness to convince investors and the public to take up new inventions such as the phonograph, incandescent lamp, and motion pictures. Skillfully playing the heroic genius for the newspapers, Edison gave Americans a highly individualistic myth of technological creativity that served as an antidote for the impersonal corporations and organizations that were coming to dominate American culture in the early 20th century.

In negotiating with both nature and society, inventors are influenced by social, political, economic, and cultural factors. As they seek to harness nature, their efforts are shaped by the available resources and the help they get from patrons and assistants. Inventors utilize both the know-how of craftsmen as well as the theoretical knowledge of scientists. In connecting their creations with society, inventors must take into account the dynamics of the marketplace, the structure of business organizations, and the ways in which the state promotes and regulates new technology. Most broadly, inventors must grapple with

the perception of technological change in a culture: is invention welcomed and celebrated, or is it viewed by some groups with suspicion?

Invention versus Technological Creativity

Humans have a long history of technological creativity, but invention is a more recent phenomenon. Archaeologists have found that the evolution of *Homo Sapiens* is deeply entwined with technological creativity. As early humans developed hands with opposable thumbs, larger brains, and language, they utilized these capabilities to create new tools, weapons, and materials. Thousands of years before there were written records, humans learned to use fire, plant crops, domesticate animals, make pottery, and work copper. With all of these developments, we have no information about whether they were the product of an individual mind or a group effort; we will never know, for instance, who was the inventor of the wheel.

While these prehistoric developments are often called inventions, it is not accurate to do so; they were simply acts of technological creativity. Invention, instead, refers to a specific form of technological creativity in which individuals explicitly link a technological artifact with a particular human need or wish. To our knowledge, the creators of major prehistoric developments did not have to consciously articulate a connection between their creation and a social need or wish.

As a result, invention--a particular form of technological creativity--has thrived in some societies and not in others. While it is easy to assume that all societies value technological change, this is not always the case. Some cultures do not equate technological change with what constitutes the good society and instead place a higher value on stability and continuity. In these societies, technological change is not necessarily welcome and invention is not encouraged. For example, despite their many contributions to political thought, philosophy, and art, the ancient Greeks were suspicious of change and consequently

were not interested in new technologies which might alter the social order and their worldview. (Green 1990)

Hence, invention is a historical phenomenon, taking place in some societies under certain conditions. First, the society must perceive technological change as conferring an advantage to some part of society--whether it be the rulers, investors, or a powerful class. And second, technological creativity must be seen as the product of an individual mind. Both imperial China (circa 200 BCE to 1700 CE) and early Islamic society (circa 600-1400 CE) embraced technological change, with the result that they both created a host of important technologies including papermaking, printing, gunpowder, compass, and the lateen sail. However, neither society viewed technology as the product of individuals, and as a result, neither culture celebrated the creators of important technologies as heroes.

Invention in Renaissance Europe

Instead, it was in Europe and America that technological creativity came to be understood as invention. Over the last 700 years, Western societies have equated technological change with progress, assuming that the production of material abundance should contribute to social order and cultural meaning, with the result that inventors were regarded as cultural heroes.

The first technologists to call themselves inventors appeared in Renaissance Italy in the fourteenth century. As Italian city states found themselves in competition and unable to gain a distinct advantage over each other, several states turned to technology. While some cities sought to improve their military technology, others sought to gain the advantage in terms of trade or manufacture. To provide this new technology, artists such as Leonardo da Vinci cast themselves as both artists and inventors. Like artists, inventors claimed that their ability to create new technology was based on personal knowledge and that inspiration frequently came in a flash--the Eureka moment. If one wanted an invention, one had to let

the inventor pursue his craft freely. Yet, while inventors sought intellectual freedom, they also realized that they needed convince wealthy patrons to support their work.

Utilizing their training as artists, Renaissance inventors often sketched ideas for new machines. Their ideas could be fanciful, ranging from an undersea diver sketched by Jacopo Mariano ("il Taccola") to the flying machines of Leonardo da Vinci. At the same time, they skillfully combined components (such as the wedge, screw, lever, pulley, and toothed gears) to create clocks, watermills for grinding flour and sawing wood, and even a weight-driven spit for turning roasting meat. Renaissance inventors collected their ideas in notebooks, with the goal of writing technical treatises. One famous example is Georgius Agricola's *De Re Metallica* (1556) that was an encyclopedia of everything then known about mining and metals. Both Taccola and Francesco di Giorgio kept notebooks that Leonardo studied.

With the notebooks of Leonardo and his contemporaries, we see for the first time the importance of visual representation for invention. Yet visual representation was not merely about recording nature. Renaissance inventors sketched both nature and machines in their notebooks since sketching permitted them to observe and understand. During this period, artists and inventors alike acquired the belief that nature could be improved by the use of intellect and imagination. For the West, the Renaissance firmly established the idea that technology should improve.

Invention and the Industrial Revolution

From 1500 to 1800, technological change became increasingly important in Europe. Anxious to increase their power, European states encouraged exploration, military conquest, trade, and manufacturing. All of these activities depended on better ships, instruments, and weapons that in turn stimulated the development of new sources of power (such as coal and the steam engine), better materials (glass and iron) and new ways of organizing labor in the first factories. These new machines and processes were created by numerous inventors who

linked their creations to commercial and military needs. That inventors helped advance industry and commerce was sufficiently clear to governments that they began rewarding inventors with patents that gave them exclusive control over their creations. The first patents were awarded by Florence in 1421 and the first British patent law was passed in 1623.

During these centuries, inventors came from diverse backgrounds. Some began as scientists who drew on their analytical and experimental skills to create new devices. Galileo Galilei (1564-1642) not only perfected the telescope but also invented a surveyor's compass, an early thermometer, and a mechanical clock. Others were craftsmen, and their ability to fashion new machines sprang from their mastery of a craft. John Harrison (1693-1776), for instance, was trained as a carpenter, taught himself clockmaking, and went on to produce some of the most accurate marine chronometers ever made. And still others were businessmen who saw new opportunities. The inventor of the steam engine, Thomas Newcomen (1663-1729), was a hardware dealer and lay Baptist preacher, who noticed that his customers--mineowners--desperately needed to pump water from their mines.

While most European states sought to stimulate innovation, different states pursued different strategies. In France, much of the effort went to creating national institutions that consolidated the power of the king. During the reign of Louis XIV, the government sponsored the creation of royal industries in textiles and porcelain as well as a nationwide system of roads, canals, and ports. To design this transportation network, the French established in 1675 a special organization of engineers, the *Corps des ingenieurs du Genie militaire*, and the first engineering school, *the Ecole des Ponts et Chausees*, in 1747. Through these institutions, the French produced talented engineers, but they did not generate an Industrial Revolution.

In contrast to the French, the British were cautious about creating national institutions that gave too much power to the monarchy. Instead, many in Britain saw innovation as the prerogative of the individual who should be permitted to develop and own new machines. British society would grow wealthy, according to the Scottish economist Adam Smith, if

numerous people pursued their individual economic destinies. In this context, invention flourished, as hundreds of individuals developed new products and processes and set up new enterprises in order to profit from their creations. (Berg, 1998) While most of the innovations of the British Industrial Revolution involved incremental changes in the design and manufacture of goods, a few inventors--like James Watt, Richard Trevithick, and George Stephenson--concentrated on major developments such as the steam engine and the railway. Well aware of the importance of linking inventions with broad social and political goals, Watt's business partner, Matthew Boulton would dramatically tell visitors to their Soho Works in Birmingham that “We sell here, sir, what all the world wants: power.”

Just as creative technologists in England called themselves inventors, so ambitious Americans did the same. As early as 1641, American inventors petitioned colonial legislatures for patents. By the end of the American Revolution in the 1780s, the British Industrial Revolution was well underway, and the Founding Fathers fully appreciated the value of stimulating invention. As a result, when they framed the Constitution, one of the specific powers given to the Federal government was to issue patents. Early American inventors frequently developed new machines for processing agricultural products; as examples, Oliver Evans introduced an automated flour mill in 1790, Eli Whitney patented his cotton gin in 1794, and Cyrus McCormick demonstrated his mechanical reaper in 1831.

During the first half of the nineteenth century, numerous inventors contributed to the creation of American industry. Spurred by first-hand experience of using machines in trade or farming, Americans readily imagined new inventions. As one European visitor remarked, "there is not a working boy of average ability in the New England states . . . who has not an idea of some mechanical invention . . . by which, in good time, he hopes to better his position, or rise to fortune and social distinction." Two prominent inventors, Robert Fulton (the steamboat) and Samuel F. B. Morse (the electric telegraph), were trained as artists in England; modeling their inventive careers on their artistic careers, they struggled to support

themselves by invention. More typically, however, inventors frequently developed only one or two devices that they then put into manufacture themselves or sold to eager entrepreneurs.

While various inventors made their way in the ante-bellum American economy, their efforts were nonetheless circumscribed. Firms in this period were generally small partnerships and lacked substantial capital. Most industries were marked by sharp price competition, which forced businessmen to avoid the long-term investment necessary for improving technology. Although businessmen were willing to purchase patents from inventors, they generally kept inventors at arm's length, reluctant to employ them or subsidize their development costs. For example, after accidentally discovering the process of vulcanizing rubber in 1838, Charles Goodyear spent another five years and $50,000 perfecting and patenting his process. Even though he was able to sell his patent in Europe and America, he nonetheless died in 1860 with debts of nearly $200,000. Despite the fact that Americans equated invention with social progress, individual inventors found it hard to negotiate the links between their specific inventions and the needs of businessmen.

The Golden Age of Heroic Invention

In the decades after the American Civil War, this pattern remained true in many American industries--inventors were a major source of new technology but not integrated into business. For instance, Wilbur and Orville Wright initially developed the airplane without any assistance from any company. However, it was the telegraph and electrical manufacturing industries that created a new situation, a brief "Golden Age" for individual inventors.

Based on the inventions of Morse, Charles Wheatstone, and William Cooke, it is perhaps not surprising that the telegraph industry should have become a hotbed of heroic inventors in the 1870s. However, it was not the individualistic origins of this industry that determined the frenzy of individual activity, but the appearance of the giant Western Union Telegraph Company. Although Morse's invention was promoted by a host of small, regional

telegraph companies in the 1850s, it became clear by the 1860s that the telegraph would only flourish if one system connected cities across America. Under the leadership of Hiram Sibley and then William Orton, Western Union created a nationwide system by absorbing its competitors and building the first transcontinental line in 1861.

However, no sooner had Western Union achieved national dominance in 1867 than it had to fight off rival networks and governmental interference. The first threat came from Wall Street. Western Union had expanded rapidly by erecting lines along railroads and placing telegraph offices in railway stations. This meant, however, that as new railroads were built, financiers could create their own telegraph network, compete with Western Union, and attempt to gain control of the telegraph giant. Jay Gould pursued this strategy twice, and captured Western Union in 1881. A second challenge for Western Union came from Washington. As one of the first monopolies, Western Union was attacked by reformers as a threat to American democracy. Critics were concerned that Western Union had access to market information as well as private business messages, and that the firm could use this information to ruin individual businessmen and manipulate the stock market in its favor.

In responding to these threats from Wall Street and Washington, Western Union employed various tactics (price competition, political lobbying, and hostile takeovers), but invention also came to play a new strategic role. To remain dominant, Western Union needed to adopt new inventions that would permit it to operate more efficiently. At the same time, the challengers--financiers and reformers alike--also realized that inventions might be used to gain a foothold in the industry. By the mid-1870s, the combination of Western Union's dominance and the possibility of a rival network created a unique market for telegraph inventions. In response, dozens of ambitious men experimented with new devices and systems. Typical was Bell who started inventing after reading a newspaper story in 1872 about how Western Union paid Joseph Stearns $25,000 for a telegraph invention. While over 400 individuals secured patents for telegraph inventions between 1865 and 1880, the most successful inventors were telegraph equipment manufacturers such as Edison and Elisha Gray. Edison was especially skilled at

developing new systems for both Western Union and Wall Street financiers, and he used this patronage to leave manufacturing and build an “invention factory” at Menlo Park, New Jersey in 1876.

For Edison, Menlo Park was the ideal environment, and from 1876 to1883, he turned out a series of spectacular inventions--an improved telephone, the phonograph, and an incandescent lighting system. Because Edison left behind voluminous records (Jenkins et al., 1989--) historians have explored how Edison evolved a method of invention. (Hughes 1989; Carlson 2000) Inspired by the notebooks of the English electrical scientist Michael Faraday, Edison recorded his ideas in several thousand notebooks. (Tweney 1991; Friedel and Israel, 1986) At the start of a project, Edison reviewed the relevant science, existing technology, and potential markets. Within his laboratory, he brought together a team of machinists and scientists who built and tested models of his inventions. And throughout a long research campaign, Edison was an effective manager of invention, generating new lines of investigation and skillfully guiding his gang of experimenters or "muckers."

Edison’s success at Menlo Park stimulated other inventors--such as Nikola Tesla, Edward Weston, and Reginald Fessenden--to set up independent laboratories in the 1880s. At the same time, other inventors--such as the Wright Brothers and Elmer Sperry--got ahead by developing their own method of invention. Even today, American inventors and scientists frequently invoke Edison as the inspiration and model for how they organize their creative efforts.

Inventors and the Corporation

As inspiring as they were, Edison and Menlo Park were soon eclipsed by other individuals and institutions. Both inventors and businessmen realized that the real challenge in bringing new technology to market lay not with idea generation (research), but with working out the details of manufacturing and marketing (development). Moreover, because manufacturing and marketing often required millions in capital and the creation of large

organizations, business leaders concluded that they could not risk leaving either idea generation or development outside the firm. Consequently, as the high technology of the 1880s--electric light and power--took shape, inventors negotiated new roles for themselves in relation to business.

Some inventors chose to maintain their creative independence. After working for Edison, Frank J. Sprague struck out on his own, developing direct current motors for use in street cars and electric railways. While he started several new companies to promote his inventions, Sprague invariably sold these companies to larger firms such as General Electric. Likewise, Tesla sold his patents for an alternating current motor to George Westinghouse in 1888 and used his new wealth to investigate what came to be called radio waves. Refusing advice and capital from knowledgeable patrons, Tesla attempted to pull an end-run around existing power and telecommunication networks and fashioned his ideas into an fantastic system for broadcasting power around the world. In the meantime, Guglielmo Marconi developed similar electrical circuits into wireless telegraphy for the specific market of ship-to-shore communication. Depressed and disappointed, Tesla became a recluse. With creative independence came the risk of not being able to connect one's inventions with capital or markets.

Well aware of the need to be connected to business, Elihu Thomson chose to work within the corporation. A chemistry teacher from Philadelphia, Thomson began inventing arc lighting equipment in 1878 with Edwin J. Houston. Thomson quickly realized, however, that he knew little about manufacturing and marketing. Consequently, he allied himself with several entrepreneurs who could commercialize his system. After two unsuccessful attempts, Thomson found the right backers among the shoe manufacturers in Lynn, Massachusetts. Led by Charles A. Coffin, the shoemakers were able to secure capital from financiers in nearby Boston and develop arrangements for marketing electrical equipment throughout the US. Under Coffin’s leadership, Thomson invented lighting systems, motors, streetcars, and meters, and the Thomson-Houston Company soon rivaled the Edison and Westinghouse

companies. At Lynn, Thomson was joined by other inventors including Charles Steinmetz. In 1892 Thomson-Houston absorbed Edison General Electric to form the General Electric Company.

Thomson demonstrated to GE that innovation was essential to compete and grow. But by the 1900s, the leaders of GE realized that the size of their company (in terms of money invested, plant capacity, and organizational complexity) was such that they should no longer rely solely on individuals like Thomson. Unlike Western Union in the 1870s which was comfortable in contracting with Edison at Menlo Park, GE felt that it could only protect itself by fully integrating innovation into its organization. In 1900, GE created the first research and development (R&D) laboratory in the United States and staffed it with scientists. Over the next decade, AT&T, duPont, Eastman Kodak, and Corning Glass created their own R&D labs.

But why did these corporations invest in a *scientific* laboratory? Why not hire more talented inventors like Thomson? Here the answer is both economic and cultural. From an economic standpoint, one difference was the growing supply of scientific manpower. In the 1870s, only a handful of American universities offered advanced degrees in the sciences and engineering, and those few Americans wishing to become research scientists went to Germany to study. Yet by 1900, American universities had undergone a profound expansion in scientific research. Thanks to private philanthropy and Federal land grants to state colleges, American universities were now graduating hundreds of scientists and engineers every year. Given the growing supply of scientists, it made sense for GE and other large companies to hire scientists and not inventors for innovation. (Wise, 1980)

But there were also cultural reasons for choosing scientists over inventors. Although inventors do work methodically, they generally legitimate themselves by claiming that they possess unique personal knowledge (genius). The nature of their expertise is personal and idiosyncratic. If inventors actually create based insight during a Eureka moment, then their work is fundamentally discontinuous and unpredictable. Given this rhetorical stance, inventors were not especially appealing to managers trying to minimize uncertainty and

protect companies capitalized for tens of millions of dollars. Yes, a genius like Edison can do great work, but should one bet the company on him?

Instead, along with other attempts to rationalize their organizations, corporate leaders in the early 20th century turned to scientists who promised to produce new technology in an continuous and predictable manner. A central characteristic of science was its claim to predict the behavior of natural systems; if this was generally true of science, then the process of applying science to industrial problems should be predictable as well. Moreover, by taking a team approach and breaking down complex problems into a series of routine experiments, scientists assured managers that they would get results. By promising to be predictable and continuous, scientists appealed to managers seeking to protect corporations in the face of uncertainty.

Invention in the Twentieth Century

Through the 20th century, American business has tended to rely on R&D labs--and not independent inventors--for new technology. Several factors have contributed to this trend. The Federal government has periodically investigated how major corporations (including Standard Oil, AT&T, IBM, and Microsoft) may have used technology to monopolize markets. Faced with the risk of antitrust litigation, many companies chose to develop new products in-house and to avoid collaborating with other firms or independent inventors. During both World Wars and the Cold War, the U.S. military invested heavily in scientific research, and scientists played major roles in producing the atomic bomb, the jet airplane, radar, and the computer. Equally, during the race to the moon in the 1960s, the Federal government increased its commitment to scientific research. This trend is well illustrated in patent ownership; in 2001, corporations and governments owned 86.9% of the patents granted and individuals accounted for only 13.1%. (USPTO, 2002)

Yet, while corporations like duPont promise "better living through chemistry," inventors have nonetheless contributed many of the technologies that have revolutionized

daily life. (Brown, 2002) The first solid-state electronics device, the transistor, was perfected in 1947 by physicists at Bell Labs who functioned more like inventors than scientists. Like Edison, John Bardeen, Walter Brattain, and William Shockley borrowed from physics and combined it with a specific need (replace mechanical switches with electronics) and ingenious manipulation (getting a piece of gold foil to barely touch a block of germanium). A decade later, the integrated circuit or chip was invented simulataneously by Jack Kilby and Robert Noyce, both of whom relied on hands-on knowledge and creative thinking. Likewise, the personal computer was invented by several individuals, operating more like Edison than scientists. To build the first Apple computer, Steve Jobs sold his VW microbus and went to work with Steve Wozniak in the family garage. And similar stories could be told about Edwin Land and the invention of instant photography or Gordon Gould and the laser.

To be sure, these major inventions have only succeeded when they were taken up by corporations that can undertake manufacturing and marketing. While Kilby worked for Texas Instruments, Jobs and Wozniak relied on managers at Hewlett-Packard for technical advice. But even more to the point, these inventions required that their creators link the natural and social worlds; not only did these inventors make their devices work, they convinced people to invest in, patent, and buy their creations. Bardeen, Brattain, and Shockley were able to convince their boss that their crude device was the start of a radically new form of electronics.

Since the mid-1980s, there has been growing interest in teaching invention as part of the general reform of science and technology education. Early in this movement, the U.S. Patent and Trademark Office (PTO) sponsored Project XL which helped teachers develop invention curricula and the PTO has an extensive website on invention for children. At the college level, the National Collegiate Invention and Innovation Alliance sponsors an annual competition for teams of student inventors. With bequests from the inventor Jerome Lemelson, the Smithsonian Institution and MIT maintain centers that study and teach invention. Complementing the many biographies of inventors that have been published, STS

scholars have also undertaken studies of the invention as a process. (Carlson and Gorman, 1992; Weber, 1992; Gorman, 1998) Hoping to stimulate the range of people who become inventors, books and websites have appeared which explore black and women inventors. (Stanley, 1995) All of these activities indicate that invention continues to play an important part in American culture.

Bibliography

Berg, Maxine. 1994. *The Age of Manufactures, 1700-1820: Industry, Innovation, and Work in Britain,* 2 ed. London: Routledge.

Brown, David E. 2002. *Inventing Modern America: From the Microwave to the Mouse*. Cambridge: MIT Press.

Carlson, W. Bernard. 1991, *Innovation as a Social Process: Elihu Thomson and the Rise of General Electric, 1870-1900*. New York: Cambridge University Press, 1991. Paperback Reprint, 2002.

_____. Forthcoming. *Technology in World History*. 7 volumes. New York: Oxford University Press.

_____. 1992. "The Cognitive Process of Invention: Bell, Edison, and the Telephone" in D. Perkins and R. Weber, Eds., *The Inventive Mind: Creativity in Technology*. New York: Oxford University Press, 1992, 48-79.

Crouch, Tom. 1989. *The Bishop's Boys: A Life of Wilbur and Orville Wright.* New York: W.W. Norton.

Ferguson, Eugene S. 1992. *Engineering and the Mind's Eye*. Cambridge: MIT Press.

Gorman, Michael E. 1998. *Transforming Nature: Ethics, Invention and Discovery*. Dordrecht: Kluwer.

Green, Peter. 1990. *Alexander to Actium*. Berkeley: University of California Press, 467-79.

Hindle, Brooke. 1981. *Emulation and Invention*. New York: W.W. Norton.

Hughes, Thomas P. 1989. *American Genesis: A Century of Invention and Technological Enthusiasm, 1870-1970.* New York: Viking-Penguin, 13-95.

Jenkins, Reese V., Robert Rosenberg, and Paul B. Israel, eds. 1989-- . *The Papers of Thomas A. Edison.* Baltimore: Johns Hopkins University Press. Four volumes to date.

Jakab, Peter L. 1990. *Visions of a Flying Machine: The Wright Brothers and the Process of Invention.* Washington: Smithsonian Institution Press.

Pretzer, William S., ed. 1989. *Working and Inventing: Thomas Edison and the Menlo Park Experience*. Dearborn: Henry Ford Museum and Greenfield Village.

Reich, Leonard S. 1985. *The Making of American Industrial Research: Science and Business at GE and Bell, 1876-1926.* New York: Cambridge University Press.

Reid, T.R. 1984. *The Chip: How Two Americans Invented the Microchip and Launched a Revolution.* New York: Simon & Schuster.

Riordan, Michael and Lillian Hoddeson. 1997. *Crystal Fire: The Birth of the Information Age.* New York: W.W. Norton.

Schwartz, Evan I. 2002. *The Last Lone Inventor: A Tale of Genius, Deceit, and the Birth of Television.* New York: HarperCollins.

Stanley, Autumn. 1995. *Mothers and Daughters of Invention: Notes for a Revised History of Technology.* New Brunswick: Rutgers University Press.

United States Patent and Trademark Office (USPTO). 2002. "Patenting by Organizations, 2001." Technology Assessment and Forecast Report.

Weber. Robert J. 1992. *Forks, Phonographs, and Hot Air Balloons: A field guid to Inventive Thinking.* New York: Oxford University Press.

Wise, George. 1980. "A New Role for Professional Scientists in Industry: Industrial Research at General Electric, 1900-1916." *Technology and Culture* 21:408-29.