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Retooling R&D: Technology brokering and the pursuit of innovation

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Retooling R&D: Technology brokering and the pursuit of innovation

Planning ahead, organizations are again investing in research and development. But, reluctant to return to the frenzied spending of the1990s, many are questioning the traditional R&D model that searches for breakthroughs at the leading edge of science and technology. Is there a better way? This author says "Yes."

By Andrew Hargadon

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The late 1990s were a good time to be in research and development. In a manic effort to stay ahead, keep up or catch up to their competitors, corporate executives pumped millions into their R&D organizations. The goal? To stake claim to the leading-sometimes bleeding-edge of technology. The revolution was in full swing, the old rules no longer applied, and anyone holding onto the past would be left behind. Seasoned veterans were shunted aside while young revolutionaries had carte blanche to invent the future. Then the bubble burst, and the pursuit of innovation was all but forgotten while firms focused on simple survival.

Once again, the need for innovation is emerging in many industries but, having been burned, managers are questioning the wisdom of returning to the old model for managing R&D. The old model assumed that breakthrough products and processes lay at the leading edges of science and technology. To get there, firms had to hire the most advanced scientists and engineers in the field, buffer them from the demands of the operating divisions, give them discretionary time and money to pursue their pet projects, push them to think out of the box, and then wait for the inventions to flow.

But just how valid is this model after all? I have spent the last 10 years comparing the innovation process in modern organizations and in their historic counterparts-from IDEO Product Development to Edison's Menlo Park laboratory, from Henry Ford to 3M, from Bell Labs to the IdeaLab. The most successful firms in this study had systematized their innovation process in ways that turned traditional assumptions about the pursuit of innovation upside down.

Rather than chasing wholly new ideas, these firms focused on recombining old ideas in new ways. Rather than insulating themselves from the existing work of the operating divisions, they drew extensively from the divisions. And rather than nurturing individual geniuses, they developed strong social networks both within and outside their groups.

These firms pursued an innovation strategy I have termed *technology brokering*. They spanned multiple, otherwise disconnected industries and markets and, by doing so, put themselves in a position to be the first to see how existing technologies in one market could be used to create breakthrough innovations in another. The results, counterintuitively, sparked many of the technological revolutions of the past century and a half. Perhaps the best way to see this innovation strategy is by looking backstage at what many historians have called America's prototypical R&D lab.

Edison and the original R&D Lab

In 1877, on a single workbench that ran the length of Thomas Edison's Menlo Park, N.J., laboratory, a small collection of objects had gathered and would, in the next

few years, profoundly change the technological landscape of America and, in short order, the rest of the world. From 1876 to 1881, that lab produced innovations in high-speed, automatic and repeating telegraphs; telephones; phonographs; generators; voltmeters; mimeographs; light bulbs and filaments; and vacuum pumps.

Yet for all we know about the man, we've learned very little about how to manage modern companies in the pursuit of innovation.

Edison certainly exploited the image of the inventive genius. Echoed by countless revolutionaries today, for example, Edison famously insisted that his inventive

Thomas Edison, Henry Ford and, now, their modern counterparts were capable of creating one breakthrough after another because they built innovation strategies around recombining existing technologies rather than inventing new ones

Edison built the laboratory, in his own words, for the "rapid and cheap development of an invention" and promised "a minor invention every 10 days and a big thing every six months or so." And he delivered. In six years of operation, the laboratory generated over 400 patents and was known worldwide as an invention factory. It was Edison's most prolific period as an inventor.

The Menlo Park laboratory represented the first dedicated research and development facility and showed the industrial world the power of organized innovation. Over a hundred years later, it remains the model for modern firms. But what do we really know about the Menlo Park laboratory?

In truth, we know more about Thomas Edison than we do about the organization behind him. Countless books and articles recount Edison's every move from childhood on: born in 1847 in Milan, Ohio; the youngest of seven children; more interested in tinkering with machines than in schoolwork; a constant experimenter. When Edison died in 1931, *The New York Times* said of him:

> No figure so completely satisfied the popular conception of what an inventor should be. Here was a solitary genius revolutionizing the world and making an invisible force do his bidding-a genius that conquered conservatism, garlanded cities in light, and created wonders that transcended the predictions of utopian poets.

abilities came by ignoring the existing knowledge: "When I start in to experiment with anything, I do not read the books; I don't want to know what has been done."

Backstage, however, he worked hard to create that future from the best pieces of the past that he could find and use. Indeed, his own notes show that he placed an emphasis on existing technologies: "1st. Study the present construction. 2nd. Ask for all past experiences…study and read everything you can on the subject."

The very icon of invention-the electric light-was not a product of Edison's vivid imagination. J. W. Starr filed a caveat for a patent for the incandescent bulb in 1845, 30 years before Edison began his own work. Another bulb, built by Joseph Farmer in 1859, hung in a Boston machine shop window where Edison worked. Edison did not invent the electric light. But he did put together a system of electric lighting from pieces of many different technologies-existing electric lights, the telegraph and gas lighting-in a way that sparked a revolution.

What made Edison's laboratory so successful? Not the ability to shut itself off from the rest of the world, create something from nothing, think out of the box. Exactly the opposite. It was the ability to connect that made the lab so innovative. If Edison ignored anything, it was the belief that innovation was about the pursuit

of invention. Edison was able to continuously innovate because he knew how to exploit the existing technologies of his time in ways that his competitors couldn't yet see.

Recombinant innovation and the origins of inventions

Edison is not alone in pursuing such a strategy for innovation. William Gibson, the science fiction author who crafted some of the earliest visions of the Internet in his novel *Neuromancer* (and coined the phrase "cyberspace"), was once asked how he got his fantastical yet prescient ideas about the future. His answer: "The future is already here, it's just unevenly distributed." The history of technological revolutions is a history of recombinant innovations.

Henry Ford, who neither invented the automobile (first demonstrated over a century before) nor the components of mass production that he used to build his Model T., was well aware of this. The Ford Motor Company succeeded instead by bridging a wide range of industries, and building from the pieces of those different worlds an organization that combined the best people, ideas and objects they could find. Ford's system was revolutionary in its impact on the automobile industry, on manufacturing and on society, but it was revolutionary *because* its origins drew on existing technologies. Ford once testified:

> I invented nothing new. I simply assembled into a car the discoveries of other men behind whom were centuries of work….Had I worked fifty or ten or even five years before, I would have failed. So it is with every new thing. Progress happens when all the factors that make for it are ready, and then it is inevitable. To teach that a comparatively few men are responsible for the greatest forward steps of mankind is the worst sort of nonsense.

Such recombinant innovation can also be found at the heart of the biotechnology revolution. PCR, or polymerase chain reaction, is the biochemical process by which single strands of DNA can replicated in great quantities. It is to molecular biology what Ford's mass production was to the modern factory-a chance for individual laboratories to mass-produce DNA for use first in their experiments and later, as entrepreneurs, in developing and producing genetically modified organisms.

Edison's advantages lay not in his ability to build something out of nothing, but rather his ability to exploit the network-he implicitly, but certainly actively, pursued a strategy of technology brokering.

Was PCR an invention? In words that echoed Henry Ford almost a century earlier, Kary Mullis once described his achievement:

> In a sense, I put together elements that were already there, but that's what inventors always do. You can't make up new elements, usually. The new element, if any, it was the combination, the way they were used.…The fact that I would do it over and over again, and the fact that I would do it in just the way I did, that made it an invention….The legal wording is 'presents an unanticipated solution to a long-standing problem,' that's an invention and that was clearly PCR.

Mullis brought together an already existing technique for (1) making oligonucleotides (particular fragments of DNA), (2) separating those strands from others by gel electrophoresis, and (3) transferring and detecting them on a membrane. Each of these techniques was relatively well understood in biochemistry, and new techniques and technologies were rapidly improving their performance. Mullis's innovation was to recognize that these techniques could be combined in a way that produced a (polymerase) chain reaction-a feedback loop by which the DNA fragments that were created would be used to produce even more such fragments. Thanks to Mullis's recombinant process, the time and money needed to produce a workable quantity of any fragment of genetic code plummeted.

And of course, we could not understand the history of innovation at Microsoft without seeing how its ideas built firmly on past technologies. One of Bill Gates's and Paul Allen's first commercial efforts was BASIC for the Altair, a programming language that allowed others to write applications software. This program borrowed from the existing versions of BASIC (written for mainframes and minicomputers) and from prior work done by DEC. MS-DOS, Microsoft's operating system for the IBM PC, was acquired for $75,000 from tiny Seattle Computer Company. Microsoft Word was originally written by Xerox PARC engineers as Bravo (but never marketed), and came about when Microsoft hired Charles Simonyi away from PARC. Excel derived from Visicalc, by Software Arts, and from Lotus. Internet Explorer built on the ideas of Netscape Navigator. And the graphical user environment that is Windows, of course, first appeared at PARC in the Alto personal computer, then in the Apple Macintosh, before becoming Microsoft's flagship product.

Technology brokering

Thomas Edison, Henry Ford and, now, their modern counterparts were capable of creating one breakthrough after another because they built innovation strategies around recombining existing technologies rather than inventing new ones. Technology brokering requires two distinct and often contradictory strengths. First, the ability to bridge distant communities: Firms that move easily across a range of different industries or markets are in a better position to see how the technologies of one market can be used in new ways (and in new combinations with other technologies) to solve the problems of another. But that's just the first step. Technology brokering also involves building new communities around those innovative recombinations. Rather than rebelling against the old social order, technology brokering focuses on building new networks-new social orders-around the emerging ideas. And here lies the central challenge in technology brokering. The strengths that enable organizations to build new communities-focus, economies of scale, strong ties to customers and suppliers alike-inhibit those same organizations from moving easily into new markets and experimenting freely with other technologies. But those who find a way to master these competing strengths gain a powerful advantage in the pursuit of innovation.

Edison as technology broker

Edison got his start in the emerging telegraph industry of the 1860s, working as an itinerant telegraph operator across much of the Midwest before ultimately landing in Boston. There, his constant tinkering with the artifacts of telegraphy- the transmitters, receivers, the chemicals needed to build batteries-fit right in with independent inventors and machinists that inhabited the local machine shops. His earliest products brought the ideas and objects of this industry to new markets. His electric fire and police alarm consisted of a dedicated telegraph line from house to police station. His gold-price indicator used the telegraph and an automatic recorder to transmit and print gold prices from the stock market to nearby offices. His electric mimeograph pen borrowed from a perforating device in automatic telegraphy that punched holes in paper to record the dots and dashes of incoming signals. After selling patents for his work on an improved quadruplex telegraph and seeing market success with his mimeograph and electric pen, Edison became a consultant to many of the large firms (and a number of smaller ones) hoping to exploit the newly emerging potential of the telegraph industry.

In 1876, he moved his operations from Newark, N.J., to a small farming community 20 kilometres to the south called Menlo Park. There he built a laboratory and put together a team that worked with a wide range of organizations on an equally wide range of projects, both inside the telegraph industry and elsewhere. Built to Edison's specifications, the laboratory was 30 metres long and nine metres wide. The upstairs was devoted to the engineers, or "mockers" as they called themselves, and was a single room with workbenches through the centre and shelves of materials, chemicals and books along the walls. The mockers would work for days straight in pursuit of a solution, then punctuate their work with late-night breaks of pie, tobacco and bawdy songs around the giant organ that dominated one end of the laboratory.

Edison's Menlo Park lab offers valuable insights into the process of technology brokering. In the Menlo Park laboratory, Edison had created the ideal conditions for the continuous generation of innovations. In the words of one historian, those five years Edison spent at Menlo

Park represented "the most concentrated outpouring of invention in history." But Edison's success came less from what he learned while selling newspapers on the Grand Trunk line as a child than from what his team learned while working on last month's projects. Edison's advantages lay not in his ability to build something out of nothing, but rather his ability to exploit the network- he implicitly, but certainly actively, pursued a strategy of technology brokering.

The organization at Menlo Park split its time between doing engineering work for clients in the telegraph, electric light, railroad and mining industries and conducting its own experiments. By working for a range of clients and in a range of industries, Edison was able to move between the worlds that made up each of these industries-using his work for different clients to bridge the different worlds when he and his team saw ideas in one that showed promise elsewhere. As Andre Millard notes in *Edison and the Business of Innovation*:

> Edison quietly blurred the line between the experiments he did for others and those he did for himself. Who was to know if a result from contract research was applied to another project or if experimental equipment built for one customer was used in work for another?

Edison borrowed often from the ideas of other industries. And the laboratory's range of clients from many different industries meant that any one development project offered valuable information that Edison would exploit for use in other projects.

As importantly, Edison built a community at Menlo Park that was deeply committed to the innovation process. The group at Menlo Park numbered approximately 14, including Edison. Of these, five had prominent roles working closely with Edison: Charles Batchelor, John Adams, John Kruesi, John Ott and Charles Wurth. Edison worked most closely with Batchelor, an Englishman whose training as both a mechanic and a draftsman complemented (and grounded) Edison's more flighty visions. Indeed, Edison and Batchelor split all patent royalties 50-50.

Edison modelled the laboratory after the machine shops from which he and many of the others had emerged, the kind of places where mechanics and independent entrepreneurs would work side by side, sharing machines, telling stories and passing along promising ideas or opportunities. According to Francis Jehl, one of Edison's assistants, the lab's culture was, like these earlier shops, "a little community of kindred spirits, all in young manhood, enthusiastic about their work, expectant of great results," and for whom work and play were indistinguishable. Many of the breakthroughs in the electric light, the telegraph or phonograph would be attributed to insights by Batchelor, Adams or one of the others who were working on the projects while Edison was dealing with clients or scrambling for investors. And when an experiment looked promising, Edison would not hesitate to incorporate a new company and build a team in order to pursue it. As Jehl said, "Edison is in reality a collective noun and means the work of many men."

technology brokering offers lessons for effective work practices that shift the focus of traditional R&D groups from invention towards recombinant innovations

Technology brokering strategies

Not all firms can replicate the success of Edison's Menlo Park lab. But others have pursued a strategy of technology brokering in ways that exploited their own contexts and competencies. Some have chosen to do so at the level of the firm, others by chartering internal technology brokering groups, and others through effective work practices that bridge their research and development organizations.

IDEO Product Development is a modern technology broker that operates in much the same way as Edison's original laboratory. The company has developed over 3,000 new products in over 40 different industries since it was founded in 1978, designing everything from the

first Apple computer mouse, to ski goggles for Smith, to the Twist 'n Go cup for Pepsi, to PalmPilots for 3Com. IDEO's designers use what they learn from this diverse past work to create one original product after another. CEO David Kelley says:

> Working with companies in such dissimilar industries as medical instruments, furniture, toys and computers has given us a broad view of the latest technologies available and has taught us how to do quality product development and how to do it quickly and efficiently.

For example, the slit valve IDEO developed for Specialized's bicycle water bottle was inspired by similar valves they had seen in shampoo bottles and artificial human heart valves. And they first saw the reliable and inexpensive motor used in a docking station they designed for an Apple laptop computer in a Chatty Cathy doll.

For large firms, dedicated technology brokering strategies are neither possible nor appropriate. These firms depend on developing tightly knit relationships with suppliers and customers alike. But the larger such organizations get, the harder it is to move valuable ideas from where they're known to where they're needed, especially when nobody has recognized any connections yet. This is especially true in decentralized and geographically dispersed firms like Hewlett-Packard. A common saying at HP, often attributed to former CEO Lew Platt, is that the company would be better off "if HP only knew what HP knows." Technology brokers thrive under just these circumstances. During the past decade, for example, Corey Billington founded and led the Strategic Process and Modeling Group (SPaM), which disseminated knowledge about supply chain management across HP and, in the process, kept learning good ideas that were unknown to the rest of the firm. Billington was then tapped to lead the new HP Professional Services group, which includes about 200 professionals who provide diverse services to HP operating divisions including hardware engineering, software engineering, organizational change management and education, along with supply chain management (the success of this experience has since led Billington to become CEO of Second Edison, a consulting firm that innovates in supply chain, procurement, and design outsourcing for clients in a wide range of industries).

In addition to strategies that drive firms or dedicated groups within large organizations, technology brokering offers lessons for effective work practices that shift the focus of traditional R&D groups from invention towards recombinant innovations. These work practices include, for example, pulling R&D scientists out of the lab and into the marketplace, where the valuable problems lie. As one IBM scientist, raised in the R&D lab, said after visiting customers, "For me it was a real eye-opener, coming from the lifestyle of writing academic papers to learning about markets and what business is all about.…It was like going to a foreign land-there were aha! moments in both directions." Another effective practice is to populate R&D teams with not only scientists but also people with managerial, marketing and manufacturing skills. These diverse skill sets are critical to building ties between individual R&D projects and the operating divisions that will ultimately accept or reject their results. Finally, firms can use their R&D groups as external consulting firms-encouraging them to search for business outside the firm's traditional markets. It's useful when the cost of equipment or expertise is more than one firm can justify, and it's useful for retaining employees whose interests draw them in different directions.

Conclusion

Pursuing a strategy of technology brokering doesn't mean throwing out the old R&D organization altogether. Aside from trying to invent the future, traditional R&D provides two critical competencies. First, these labs foster the expertise needed to evaluate existing technologies that are developed and used elsewhere. Second, the labs are best equipped to provide process innovations that fit within the organization's particular constraints. For example, Crawford Greenewalt, president of DuPont from 1948-1962, once said of the famous DuPont labs:

> For the DuPont Company and I believe this is also true for the chemical industry, I can say categorically that our present size and success have come about through the new products and new processes that have been developed in our laboratories.

Yet of the 25 most significant product and process

innovations at DuPont from 1920 to 1950, just 10 originated within the R&D labs. Eighteen of the 25 innovations were new product innovations and, of these, 13 came from the outside.

Pursuing a strategy of technology brokering means recognizing that a key role of corporate R&D is bridging the many different industries and markets that exist, and building the necessary combinations of technologies and people to make potential breakthroughs possible. But making this happen means moving the organization-and the culture-of R&D away from the "leading edge" pursuit of inventions. The Menlo Park laboratory of 1881 still has the potential to serve as a model for corporate R&D today, but only if we recognize and replicate the critical ways in which Edison's lab organized to exploit the past in building the future. **I**