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Revolution or evolution?: The role of knowledge and organization in the establishment and growth of R & D at Corning

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Abstract
The rise of R & D, as it is usually told, is a story of revolution: that the coming of science to industry wiped away the irrational patterns of invention and ruthless competition and ushered in a new rational scientific order. However, the history of Corning Incorporated suggests a different view. Rather than being a revolution, R & D evolved over two decades at Corning. During this evolution, Arthur and Alanson Houghton relied on different kinds of knowledge – direct experience, craft skills, as well as science – to create new products and processes. To provide an overview of how different kinds of knowledge can be leveraged for innovation, we draw on Six Sigma methodology to create a SIPOC (Supplier-Input-Process-Output-Customer) diagram of the innovation process. Moreover, to promote innovation, the Houghtons also employed different organizational arrangements including using consultants, employing experts, creating separate companies, and establishing departments inside the company. Eventually, the company did hire scientists and establish a Chemical Department in 1908, but we would argue that this tradition of using different forms of knowledge and experimenting with organizational arrangements preceded the Chemical Department and continues to inform how R & D is practiced today at Corning.

Key words  • innovation • R & D management • Six Sigma • technology strategy

When companies celebrate anniversaries do they celebrate a moment, a process, or a set of enduring practices? In 2008, Corning Incorporated celebrated the centennial of the founding of its research and development (R & D) organization.1 But what actually happened in 1908? Was it simply the moment (on 21 April of that year) that Corning hired a PhD chemist, Eugene Sullivan, to head up a new chemical department? Did the sudden appearance of scientists in the company instantaneously transform the way the company created new products and did business? Does 1908 mark a process, particularly the transition in how Corning moved from relying on the craft knowledge of its owners and workers to using science to innovate? Or was it in the years running up to
1908 that the company fashioned the practices and strategies that have proven essential to its success as an innovator in the specialty materials industry?

Much of the existing literature on the history of R & D would suggest that the anniversary of the founding of a laboratory should be the celebration of a moment and not a process or set of practices. In the dark decades of the late 19th century, companies supposedly did not worry about improving their products or processes and what innovation there was came from heroic, non-scientific inventors such as Thomas Edison. As firms got bigger in science-based industries — such as chemical and electricity — their managers decided to harness science in order to protect their growing organizations. As a result, corporations in the early decades of the 20th century set up research laboratories and hired university-trained scientists, and — presto! — these labs used pure science to produce a cornucopia of wondrous new products. The rise of R & D, as it is usually told, is a story of revolution: that the coming of science to industry wiped away the old, irrational patterns of invention and ruthless competition and ushered in a new rational order of sustained growth and prosperity.2

But as we have studied the history of R & D at Corning, we have found that the story is much messier — and far more interesting — since it is less about a moment and much more about a process. While Sullivan played a fundamental role in shaping the R & D lab at Corning over several decades, he was not actually the first PhD scientist Corning hired. The Chemistry Department was not the first laboratory set up inside the company. And during the last two decades of the 19th century, Corning was systematically improving its materials, processes, and products; in fact, its survival into the twentieth century was based on how well Corning’s proprietors — the Houghton family — understood glass technology and how to improve it.

To make sense of these anomalies, we have found it helpful to set aside the standard story of revolution and instead think about how the history of R & D at Corning might be better told as a story of evolution. In this article, we will suggest that the process of learning how to use science for business goals did not happen instantaneously at Corning but rather took place across two decades, from 1896 to 1916. In particular, this process involved trying several kinds of knowledge and then experimenting with different organizational arrangements in order to use knowledge to innovate. After working with different experts and trying different organizational arrangements, the company’s leaders, Alanson and Arthur Houghton, eventually settled on a new institutional arrangement, the Chemical Department. Moreover, as Sullivan worked in this new department, he and the company developed new ways of linking materials, products, and processes, with the result that R & D gave Corning a distinct competitive advantage.

In recasting the story of R & D at Corning not as a revolutionary moment but rather as an evolutionary process, we are not simply trying to set the historical record straight. Indeed, what is significant about this story of experimenting with different kinds of knowledge and various organizational arrangements is that these practices have come to be embedded in Corning’s culture and are central to the company’s ability to create competitive products and processes. Consequently, after recounting the
story of the evolution of R & D at Corning in the early decades of the twentieth century, we will examine how these practices continue to inform how Corning pursues innovation in the 21st century.

**Borrowing from Six Sigma: Using a SIPOC Diagram to Think about Innovation as Evolutionary Process**

To think about the rise of R & D as evolution and not revolution, we need to reconceptualize the innovation process. To do so, let us start by picturing the traditional notion of innovation in an R & D laboratory (Figure 1). In most treatments of R & D, it is generally assumed that the key input is science that is supplied by professional scientists. Indeed, the history of most R & D labs start when the professional scientists show up and drive out the inventors, craftsmen, and other irrational folk. Using a systematic, experimental method, scientists then discover new products that are then eagerly purchased by customers. In simplistic terms, far too many histories of R & D are only about science, scientists, and products; little else matters.

Instead, what we want to suggest is that innovation at a typical firm—whether today or a hundred years ago—is far messier. Companies can and do hire all sorts of individuals other than scientists to innovate, and these people possess all kinds of knowledge. Through the innovation process, companies seek not only new products but also a variety of other outputs that they sell or share with other groups. To make sense of all these different inputs, outputs, suppliers, and customers, we have found it useful to borrow a diagramming technique—SIPOC (Supplier-Input-Process-Output-Customer)—from the quality-enhancing methodology known as Six Sigma.

Six Sigma is a data-driven approach for eliminating variance in manufacturing, marketing, customer service, and staffing. The methodology’s name comes from the central goal of driving towards six standard deviations (or sigma) between the mean and the nearest specification limit. Put another way, six sigma equals 3.4 defects per million opportunities. Pioneered by engineers at Motorola in the 1980s, Six Sigma has since come to be used to analyze operations and save money at thousands of companies worldwide. At Corning, the introduction of advanced Six Sigma tools has saved the company US$700m since 2003.

One of the first steps in the Six Sigma methodology is to obtain a broad overview of how an organization goes about a particular process by drawing what is called a SIPOC Diagram. To create this diagram, Six Sigma analysts begin by listing the general steps involved in the process and identifying the inputs and outputs. They then
look at who supplies the inputs and the customers who use the outputs. Thus, a SIPOC diagram depicts the flow from supplier to customer, and helps to identify bottlenecks and other problems in a process.

Just as a SIPOC diagram can be used to analyze any number of activities pursued by an organization, this diagram can also be modified and used to think about how a company engages in research and innovation (Figure 2). To explain this diagram, let us start in the middle with the process column and work outward. Although it might be tempting to think that inventors and scientists create new technology by following an orderly sequence of steps from idea generation through prototype testing to marketing, much of the literature on invention and innovation suggests that innovators do not move simply from abstract idea to commercial product. Instead, because innovators often jump around from thinking to experimenting to marketing, we find it useful to draw on Joseph Schumpeter’s notion of innovation. In his *Theory of Economic Development*, Schumpeter suggested that innovation was not simply technical change but involved several kinds of change. Among the changes that firms might pursue were: (1) creating a new product; (2) creating a new process; (3) creating or finding new materials; (4) developing new markets; and, (5) introducing new modes of organization or management (Schumpeter 1934, 66; see also Elster 1983, 116). Over the years at Corning, much of the discussion about R & D has centered on the first four of Schumpeter’s categories, and thus we have listed those in the process column in Figure 2. Moreover, as we will see, one of significant things that occurred as R&D evolved at Corning was that managers and scientists learned that they could gain a significant competitive advantage by linking several kinds of change over the course of the innovation process.

Let us consider next the inputs that can be used to innovate. While innovation undeniably requires a rich supply of materials – Edison liked to say that his laboratory
stockroom carried 'everything from the hide of an elephant to the eyeballs of a United States Senator' – we want to focus here on the forms of knowledge that people can utilize to innovate (Carlson 1991). For centuries, most new devices were produced by creative artisans who drew on their skill and experience in working with materials and processes. Indeed, we should remember that two key inventors of modern technology – Edison and Henry Ford – had little formal education and that much of the creativity was based on their hands-on knowledge and experience. Hence, we need to include skill and experience in the Input column in Figure 2.

But along with skill and experience, new technology can also be based on knowledge organized into disciplines. For instance, innovation often requires the expertise of engineers who can design and manufacture devices or lawyers who know how to convert an inventor's vague idea into a patent or other form of intellectual property. During the 19th century, knowledge underwent a significant reorganization, with the appearance of professionals, professional societies, and training at the university level. While lawyers such as Abraham Lincoln in the early 19th century served an apprenticeship with a practicing lawyer (known as 'reading for the bar'), the typical path into the legal profession by the early 20th century was by attending a law school affiliated with a university (Lupton n.d.). Equally, engineers in early America were trained on the job, but by the end of the 19th century, dozens of universities had formed engineering schools that trained the thousands of engineers needed as industry scaled up. One consequence of this rapid growth of disciplines and professions was that, by the turn of the 20th century, firms could hire these new experts to improve processes and products; it became possible for professional knowledge to be an input for technological innovation.

Along with engineering and law, an obvious body of knowledge to use for innovation was science. In the 19th century, as the sciences proliferated in terms of new disciplines and the number of practitioners, many hoped that science would be a source of new technology (Bernal 1970). In doing so, 19th-century scientists could hearken back to Francis Bacon's vision in the New Atlantis (1626), of how science could be used to improve industry as well as point to how recent developments, such as how Joseph Perkin used chemistry to create the first artificial dye, mauve, in 1857 (Garfield 2001).

Yet rather than simply accept the broad optimism of 19th-century scientists that science would generate a host of innovations, let us consider what specific things about science might be useful for technological innovation. Of course, inventors and scientists can draw on the ideas and theories of science to understand natural phenomena, and inventions might spring from a deeper understanding of the materials and forces being manipulated. Equally, inventors and scientists might undertake a systematic series of experiments to develop a new technology. Inspired by the English electrical scientist Michael Faraday, Edison imitated Faraday's methodology by conducting experiments in which he carefully varied different components of the telegraph devices he was trying to invent (Israel 1998). And yet another way that technologists may draw on science is to borrow instruments and measuring techniques. Alexander Graham Bell, for example, utilized a new instrument, the phonoautograph, in his research leading up to the telephone since this instrument produced tracings of sound waves which
helped Bell better understand acoustic phenomena (Gorman et al. 1993). The point here is that science provides not only theory but also methods and instruments that may be used to create new technology.

Turning from the knowledge inputs for the innovation process to the outputs, we would argue that companies engage in research and innovation because these activities may result in a variety of useful things. Naturally, innovations can be new products and processes, but since we have listed these in the Process column, we find it preferable to talk under Outputs about the outcomes resulting from new products and processes. For instance, a new product might offer customers greater safety or convenience, and we would list safety or convenience in the Output column. Similarly, a new manufacturing process might reduce labor costs or it might speed up operations, and we would list these as outcomes. An innovation might also help other parts of the company such as sales and customer support. Finally, research might also produce new knowledge in the forms of patents or scientific papers, both of which might serve the company’s goals.

While some outputs can be readily measured (such as reduced costs or number of patents), others (such as convenience or customer support) cannot be easily quantified. Equally, it is important to note that the knowledge outputs can be both explicit (in the form of publications or laboratory notebooks) as well as tacit (in the form of hands-on knowledge acquired by the researcher during an experiment). Our point here is that one should be sensitive to all the ways that companies use innovation and not just focus on the measurable outcomes.

Moving to the outermost columns of the diagram, we need to consider who provides the knowledge inputs and who is affected by the process. In terms of Suppliers, we have listed the people who typically possess expert knowledge, namely skilled workers, engineers, lawyers, and scientists. In addition, owners and managers often possess a great deal of experience and knowledge about the business. Equally, companies can purchase knowledge and materials needed for the innovation process from consultants and organizations (including other companies as well as universities). And finally, astute companies often learn from their customers about how well a product works and how it might be improved.

Turning to the last column on the right, the label ‘Customers’ may seem misleading since retail customers are only one of several groups who might be affected by an innovation. The term customer here is intended to embrace any individual or group affected by the outputs. These groups can include the owners and stockholders who enjoy greater profits or control from the innovation produced as well as workers whose jobs may be reshaped (or even eliminated) by innovations. At the same time, innovations can have a broad impact on society and culture, reshaping daily life as well as beliefs and values, and hence we have included the public at large.

The value of this diagram is that it can serve as a heuristic and help clarify our thinking about innovation as a process. It gives us a matrix of the elements going into and coming out of the innovation process; to use a cooking metaphor, the diagram provides a list of the possible ingredients that can be used to make innovation ‘soup’.
Moreover, the diagram also suggests that we might ask new questions when we look at the evolution of R & D at Corning:

- What kinds of knowledge were used for innovation (Inputs)?
- Who provided these different kinds of knowledge (Suppliers)?
- What benefits did Corning get from the innovation process (Outputs)?

To begin to answer these questions, let us now look at what was going on at Corning in the decades before the creation of the Chemical Department in 1908.

**Establishing a Pattern of Innovation at Corning, 1870s–90s**

As a company, Corning dates back to 1851 when Amory Houghton, Sr. bought a stake in the Union Glass Works in Somerville, Massachusetts. Amory Sr. learned how to make glass first-hand by working closely with a master glassblower or gaffer named Teasdale. The company relocated to Brooklyn in 1861. Hoping to secure fresh capital from local merchants and take advantage of nearby coal deposits, Amory Sr. moved his glass company to Corning, New York in 1868. There, the company initially manufactured a range of glass products including jars, dishes, and lamp chimneys, only to find that the local coal was not suitable for making lime glass. In response, the company resorted to making flint (lead) glass, but this placed it in competition with the larger glass factories in West Virginia and Ohio. By 1870, the company was bankrupt. Local investors reorganized the company as the Corning Glass Works and placed it under the control of a second generation of Houghtons, Amory Jr. and his brother Charles (Dyer and Gross 2001, 24–47).

Eschewing mass-market products such as bottles, Amory Jr. and Charles focused instead on specialty glass for industrial customers. From the 1880s to the 1900s, Corning concentrated on making the glass bulbs for incandescent lamps and the lenses and lantern globes used in railroad signals. To gain a foothold in the railway and electric lighting markets, Amory Jr. and Charles pursued two general strategies of innovation (see Figure 3). Amory Jr. devoted himself to supervising work on the factory floor and looked for ways to improve the process of making glass. In particular, he experimented with enlarging the furnaces and changing the layout of the factory floor so that his glassblowers could turn out more bulbs and globes (Figure 4). Meanwhile, Charles, who handled sales, sought to improve Corning’s products. For instance, because the bevels on the surface of Fresnel lenses used in the railway lanterns collected dirt and ice, Charles redesigned the lenses with the bevels inside the lens. To develop this new lens, Charles sought information about optics from the physicists at nearby Cornell University, William Anthony and George Moler. Notably, Charles kept the results of his research inside the company and patented the improvement himself in 1877. As a result of the combined efforts of Amory Jr. and Charles, sales of Corning products grew tenfold between 1875 and 1902 (Dyer and Gross 2001, 79). By the time of Amory Junior’s death in 1909, annual sales had reached US$1.5m, up from US$822,000 in 1900.
Together, Amory Jr. and Charles established a pattern of innovation at Corning, of using knowledge to solve immediate problems in the business of making glass. The knowledge that they used was largely personal – observation of the factory floor and trial-and-error design – and outsiders (such as the Cornell scientists) were kept distinctly at arm’s length. In this regard, Amory Jr. and Charles were typical 19th-century manufacturers who knew that their power rested largely on their mastery of the processes central to the business and that they should rely on their own knowledge if they had to innovate. Sharing knowledge about new techniques with outsiders posed the risk that the outsiders could set up their own business or sell the knowledge to one’s competitors (Navin and Sears 1955).

**Figure 3** Innovation at Corning under second generation of Houghtons, 1870s–1890s

Diversifying the Inputs to Innovation, 1890s–1910s

During the 1890s, while Amory Jr. and Charles continued to run Corning, Amory’s sons were groomed to be the next generation of management. While Alanson took over sales from Charles, his brother Arthur concentrated on production. As Alanson and Arthur assumed the business, they found themselves operating in an environment that involved customers and competitors who were much larger than Corning. Much of Corning’s sales at the start of the 20th century came from selling products, railway signals and light bulbs, that were key enabling components in two well-established technological systems, the railroads and electric power. While there was steady demand for both components, the risks for Corning arose from the fact that they were surrounded by larger organizations; both its customers (the railroads and electrical manufacturers like GE) and its competitors (Libbey, Owens, and Pittsburgh Plate Glass) were significantly larger than Corning. Faced with big customers and big competitors, it would have been quite easy for the Corning Glass Works to have been crushed by either – think of the power that General Motors has over the smaller
companies that supply components for their automobiles. Not surprisingly, with GE controlling about half the market for incandescent lamps, Corning felt obligated in 1901 to enter into a three-year contract with GE, promising to sell lamp bulbs to GE for 15 percent less than Corning charged other customers (Dyer and Gross 2001, 81). So how could Alanson and Arthur address this imbalance of power and avoid getting wiped out?

Their response was to carry on the tradition of innovation started by their father and uncle. Alanson and Arthur assumed that if they could continue to improve Corning’s products, they should be able to capture market share from their competitors. At the same time, they knew that products with unique characteristics could help create long-lasting relationships with their major customers. For instance, Alanson and Arthur encouraged William Churchill (about whom more later) to work with the railroads to standardize the colors used in signals, knowing well that Corning’s participation in the standardization process could guarantee orders from the railroads for years to come.

But in taking up innovation, Alanson and Arthur gave it a new twist: rather than rely on personal knowledge as their father and uncle had done, they decided to experiment with using several kinds of inputs – skill, experience, chemical analysis, instruments, and mechanical expertise – to innovate (Figure 5). In part, Alanson and Arthur
probably tried different inputs because the marketplace did not necessarily offer any clear signals about which way to go; no one – in the glass industry or elsewhere – knew for sure how to go about generating the next round of technological improvements.

One of the first innovation projects undertaken by Arthur was to develop a better process for producing glass tubing. Traditionally, glassmakers made tubing by drawing out an oblong blank of hot glass by pulling it horizontally, parallel to the floor. As

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**Figure 5** Innovation at Corning under Third Generation of Houghtons, 1890s–1990s
it was being stretched, workers rotated the blank, but in so doing they inadvertently introduced a spiral twist to the tubing. To overcome this problem, Arthur decided to experiment with drawing the tubing vertically. Arthur got the idea for switching to a vertical draw based on observations he made while visiting factories in England, and to develop the process, he sought the help of Charles Githler, one of the most skilled tube makers at Corning. Together, Arthur and Githler set up a 60-foot tower in 1896 in which they used a rope and pulley to slowly pull the blank up. This arrangement worked well, and in 1897 Arthur patented this process. Corning went on to build a 187-foot draw tower that permitted the company to produce large quantities of tubing for use in precision products such as thermometers (Dyer and Gross 2001, 77). In this situation, we see that Arthur used observation and skill to innovate, in much the same fashion as his father and uncle had.

Another problem tackled by Arthur concerned the red lenses needed for railway signaling. To manufacture these lenses, Corning used a flashing technique which involved pressing a lens, coating it with copper ruby glass, and then heating it to bring out the color. Since this technique did not consistently produce lenses with a uniform red color, Charles had started experimenting in the 1890s with adding small amounts of minerals to the molten glass. After Charles died, Arthur continued this research. To analyze the make-up of the glass samples he produced, Arthur consulted with Joseph A. Deghuee, a PhD chemist with the New York City Health Department. In the course of these experiments, Arthur found he could make lenses with a uniform red or ‘cerise’ by adding selenium to the glass formula and then heating the lenses in small kilns. Together, Arthur and Deghuee patented this new glass in 1900 (Dyer and Gross 2001, 80–1). Here we see that Arthur chose to rely on the expert knowledge and analytical skills provided by an outside consultant.

While Arthur was working on these lenses, his brother Alanson was thinking broadly about the signaling business. In 1899, Alanson attended a lecture by Edward Wheeler Scripture, a professor of psychology at Yale. Seeking to develop a ‘science of color’, Scripture complained that his research was hampered by the fact that railroads used too many different colors in their individual signaling systems. In the course of managing Corning’s railway sales, Alanson too had noticed the wide range of colors and wondered whether it might be possible to improve railroad safety by developing a standard set of signal colors.

To pursue this project, Alanson retained one of Scripture’s PhD students, William Churchill, in 1902 to investigate glassmaking techniques in Europe and to then come to work for Corning in the Sales Department. Trained in psychology at both Yale and Liepzig, Churchill had devised optical experiments in order to study visual perception and hence create an empirical basis for Scripture’s ‘science of color’. Anxious to improve the quality of Corning’s lenses and globes, Churchill set up a small optical testing laboratory in the Sales Department in 1904. At the same time, Churchill worked closely with the Railway Signal Association to establish a standard set of six colors to be used in all railroad signaling systems. As a result of his efforts, Corning’s share of the railroad glass market grew dramatically; while in
1905, it held about one-half of the market, by 1910, Corning accounted for two-thirds of the sales of railroad glass (Dyer and Gross 2001, 81–2; Graham and Shuldiner 2001, 48–50). As an innovation project, this episode is similar to the development of the cerise lenses since in both cases Arthur and Alanson took advantage of the expertise provided by outside consultants, Degltuee and Churchill. At the same time, this case is different in that Churchill’s success at establishing standard colors grew out of Scripture’s ‘science of color’, and that Churchill was hired in 1904 as the company’s first professional scientist. Alanson was not only leveraging analytical techniques but also the ideas of science.

Yet another innovation project undertaken by Alanson and Arthur concerned achieving tighter controls over the temperature in the glass furnaces used to make light bulbs. Based on their experience on the factory floor, both men knew that furnace temperatures could vary unexpectedly and change the quality of the bulbs produced, but since the temperature for working with glass was in excess of 1200ºF, there were no simple ways to measure temperature in the furnaces. To address this problem, George Hollister, the company’s manufacturing superintendent, suggested that the Houghtons consult with Arthur Day, a geologist at the US Geological Survey [USGS] in Washington. Day had earned his PhD at Yale and was an expert on measuring high temperatures. Drawing on his experiments at the USGS, Day recommended in 1905 that Corning employ two instruments to monitor furnace temperature – platinum rhodium thermocouples and optical pyrometers. By using the pyrometers to calibrate the thermocouples, Day showed Hollister and the Houghtons how they could measure furnace temperature reliably and in turn control the temperature so as to improve the quality of the bulbs (Graham and Shuldiner 2001, 40–1). In this situation, the input leveraged by the company was scientific instruments. Impressed with Day’s contribution, the Houghtons sought to convince Day to join the company; although Day eventually spent two years (1918–20) at Corning, he chose to return to his position as director of the geophysical laboratory at the Carnegie Institution in Washington. Nevertheless, Day continued for many years after that as a member of Corning’s Board of Directors.

But beyond measuring temperature in the furnaces, Day also helped Alanson and Arthur undertake an even more challenging problem – how to mechanize the production of lamp bulbs. Since the 1880s, Corning had relied on the skill of its gaffers who blew each bulb individually into a mold. To increase output, Amory Jr. built more furnaces and experimented with how to arrange as many gaffers as possible around each furnace. Determined to maintain quality, Amory Jr. insisted on using skilled workers and strongly resisted any efforts to mechanize the process. For Amory Jr., Corning’s competitive advantage came from the skill and knowledge of its owners and workers.

Although opposed by their father, Alanson and Arthur suspected that the future lay with mechanization. Several of their competitors (such as Libbey and Owens) had already developed machines for mass-producing glass bottles and other rivals were experimenting with machines for making lamp bulbs. If these competitors could make good bulbs cheaply, then it was entirely possible that GE would turn to them and abandon
Corning. Faced with the threat of extinction, Alanson and Arthur decided in 1906 to begin to develop their own bulb-making machine, and they turned to Day for advice on how to start. Day recommended that they retain the services of Benjamin D. Chamberlain, a technician in Day’s Washington laboratory. Because their father was so opposed to mechanization, Alanson and Arthur underwrote Chamberlain’s work by quietly organizing a separate company, Empire Machine (Dyer and Gross 2001, 89).

While Chamberlain worked on a bulb-making machine for several years in Washington, he eventually moved to Corning after Amory Jr. died. In Corning, Alanson and Arthur rented space at the Glass Works for Empire Machine, and there Chamberlain tested a series of prototypes, A through D. To help develop these prototypes, the Houghtons hired two college-trained engineers, Albert J. Mayer and James A. Bailey, in 1911–12. Alanson and Arthur were extremely anxious about these prototypes since in 1911 GE began making some of its own bulbs and in 1912 introduced a new tungsten-filament lamp which allowed GE to quickly capture a significant portion of the lighting market. In early 1913, the team at Empire Machine began trials with a fifth version, the E Machine, which permitted one skilled and two unskilled workers to make over 400 bulbs an hour (Dyer and Gross 2001, 95–8). Satisfied with this dramatic increase in output, Alanson and Arthur installed a number of E Machines in the Works, and in the 1920s, they encouraged Billy Wood, a self-educated mechanical genius, to develop a fully automatic bulb-making process known as the Ribbon Machine. But here in the period of 1906 to 1913, we see that Alanson and Arthur innovated by relying on the expertise of Chamberlain, Mayer, and Bailey.

The Creation of the Chemical Department in 1908

Taken together, these projects pursued by Alanson and Arthur between 1896 and 1907 reveal two key aspects about their approach to innovation: first, that they saw innovation as a means of addressing immediate problems confronting the company and second, that they experimented with using different inputs in order to innovate. To leverage these inputs, they tried different relationships with the individuals who supplied these inputs; while some (such as Day and Deghuee) were retained as consultants, others (such as Githler and Churchill) were employees. Alanson and Arthur also tried different institutional arrangements, as illustrated by placing Churchill in the Sales Department and creating the Empire Machine Company.

It was in this context of experimenting with the inputs for innovation and different organizational arrangements that we must view the development of the Chemical Department in 1908. Although regarded as the start of R & D at Corning, the Chemical Department was simply one of several approaches that Alanson and Arthur used to pursue innovation.

Like other innovation projects at Corning at the turn of the twentieth century, the Chemical Department began with a specific practical problem. Because railroad lantern globes often cracked as a result of sudden temperature changes, Corning was interested
in a thermally resistant glass. During the 1890s, the Houghtons had asked Deghuee to look into this problem at his New York City laboratory, but Deghuee had made little progress. While visiting Germany, Day had learned that scientists at Schott and Zeiss had discovered how to make glass stronger by using boric oxide, and he recommended that Corning investigate using this new glass to make heat-resistant globes.

To undertake this research, Day suggested that the Houghtons hire one of his colleagues at the Geological Survey, Eugene C. Sullivan. Sullivan had studied chemistry as an undergraduate at the University of Michigan and worked as an industrial chemist in the mid-1890s at a dynamite manufacturer in Indiana as well as the Price Baking Powder Company in Chicago. His experience at these companies convinced him that he should further his education, and in 1896 he went to Germany to study physical chemistry, first with Walther Nernst at the University of Gottingen and then with Wilhelm Ostwald at the University of Leipzig. Sullivan earned a PhD under Ostwald in 1899, and returned to teach at Michigan for a few years. In 1903, he joined Day at the USGS so that he could take up research on silicates. With his industrial experience, advanced training in Germany, and research with silicates, Sullivan must have seemed an ideal candidate to the Houghtons to undertake the study of borosilicate glass.

Sullivan arrived in Corning in April 1908 with the title of Chief Chemist and he immediately hired an assistant, William C. Taylor, who had just graduated from MIT with a PhD in chemistry. Since they were to work on improving lantern globes, the two chemists were given space in B Factory where there were several furnaces devoted to the production of globes, signal lenses, and glass tubing. Drawing on their cutting-edge knowledge of chemistry, Sullivan and Taylor conducted a series of experiments that led to a new glass formula with excellent thermal endurance and a remarkably low coefficient of expansion (see Figure 6). As promising as this new glass was, it did have one drawback: it was water soluble, meaning that over a period of time, water would cause the glass to dissolve. However, because the glass did not deteriorate all that quickly, the company began using it to make lantern globes. To highlight the improved non-expansion quality of the glass, Corning marketed the globes under the trade name of Nonex (Graham and Shuldiner 2001, 41–6, 54).

Nonex lantern globes were immediately popular with Corning’s railroad customers. Between 1905 and 1910, Corning increased its share of the railroad glass market from 57 percent to 69 percent. But Nonex’s durability had a significant downside – fewer broken lanterns meant less repeat business. From 1906 to 1909, Corning shipped 43,951 dozen clear globes annually to 7 major railroads. In contrast, between 1910 and 1913, these railroads purchased 68 percent fewer globes. With approximately one-third of the company’s annual revenues tied to railroad glass in 1910, the loss of repeat business was a troubling development (Dyer and Gross 2001, 95). Rather than improving Corning’s market position, Sullivan’s research instead was undercutting Corning’s railroad lantern business.
Corning responded to the deterioration of the railroad lantern market by doing more research and seeking new markets. Sullivan and Taylor resumed work on the solubility problem, which they eliminated by 1912, and this permitted Nonex to be used to make the glass jars for the electric batteries employed in railroad signaling systems. Not satisfied with the battery-jar market, Sullivan began soliciting ideas from within the company as well as from his scientific and industrial contacts about additional uses for borosilicate glass. Foremost among the suggestions that came back to Sullivan was the idea of creating a line of housewares that might include pans, pie plates, and baby bottles. ‘People believed the transparency of glass’, noted historians Dave Dyer and Dan Gross, ‘would be attractive to consumers who were increasingly concerned with hygiene’ (Dyer and Gross 2001, 100).

But to use borosilicate glass to create a new line of housewares required understanding not only the chemical but also the physical properties of the glass. To gain this
understanding, Sullivan turned to a physicist, Jesse T. Littleton, who had earned his PhD at the University of Wisconsin. While Littleton studied borosilicate glass in the lab, he also brought samples home to his wife Bessie to try out in her kitchen. Using two sawed-off battery jars made of Nonex, Bessie baked cakes and cooked other items for her husband and the other scientists to study.

Based on Bessie’s cooking, Littleton and the other researchers concluded that Nonex could indeed be used for cookware. However, because the existing formulation contained lead that could poison the food, Corning researchers felt compelled to come up with a lead-free formulation. Consequently, as it experimented with a variety of products—casseroles, teapots, and tumblers—the Chemical Department also worked on the lead problem. To help with this testing, the Department outsourced some analytical work again to Deghuee in New York and some consumer testing to Mildred Maddocks at the Good Housekeeping Institute. In 1914, Corning researchers perfected a lead-free borosilicate composition. At the same time, they also worked on production problems related to manufacturing the new bakeware; these included developing new refractory materials for inside the glass furnaces (since the new formulation had to be melted at higher temperatures) as well as semiautomatic pressing machines. Since one of the first products made with this new formulation was a pie plate, Churchill in Sales suggested calling the new glass Py-right. Although this name did not catch on, it did prompt Corning to come up with Pyrex that rhymed with Nonex.

To introduce its new line of Pyrex bakeware, Corning undertook a national marketing campaign involving demonstrations in department stores around the country and advertisements in popular magazines. To convince consumers that glass was every bit as good as metal for bakeware, Littleton fashioned a cake pan that was half metal and half Pyrex. When used in demonstrations, housewives could see that the cake on the glass side cooked more quickly than the cake on the metal side.

Not content with just this new domestic market, Corning pursued a second new market for Pyrex, laboratory glassware. Due to the British embargo on German goods coming into America during World War I, Corning used Pyrex to introduce a new line of laboratory glassware that could substitute for German imports (Graham and Shuldiner 2001, 55–60). In 1916, Corning sold US$286,424 worth of Pyrex goods and in 1917, Pyrex sales jumped to $460,353. By 1918, whereas sales of railway glassware had fallen to 12 percent of Corning’s annual sales, Pyrex products now accounted for 21.6 percent of its sales (Dyer and Gross 2001, 102–9). Using Pyrex to pursue these two new markets allowed Corning to compensate for the contraction of the railroad lantern business and for the company to grow during the late 1910s and into the 1920s.

Pyrex taught Sullivan and his fellow researchers an important lesson—that scientific research does not automatically produce growth and profitability. Like other new technologies, borosilicate glass was both profitable and disruptive; to capture the profits offered by an innovation, one had to tame the disruption by expanding the scope of one’s efforts. As we have seen, this meant that Corning researchers had to be willing to tinker with the formulation of the material, to eliminate first the solubility problem
and then get rid of the lead. It meant that they had to identify new markets and design new products; it was not at all obvious to make the jump from railroad lantern globes to pie plates and laboratory beakers. They also had to solve production problems by coming up with new refractory materials and pressing machines. And researchers had to be willing to help with the marketing and patenting, as illustrated by Littleton’s ingenious half-metal, half-Pyrex cake pan. What Pyrex taught Sullivan and Corning was that the laboratory could not just engage in scientific or theoretical research; success came by connecting the theoretical work (on a new material) with parallel work on new products, processes, and markets. Innovation now focused on creating links between these elements (as shown in Figure 2).

As the lab worked to convert Nonex into Pyrex between 1908 and 1916, Sullivan came to understand that the research laboratory would need to focus on forging these links between materials, products, processes, and markets, and he used this insight to campaign effectively for more space, staff, and authority. In 1914, the company built a new 5440 square-foot laboratory building, with connections to the A and B factories. Along with Littleton who came to Corning in 1913, Sullivan hired three more chemists (Dr Lionel D. Duschak, Dr Frederick F. Shetterly, and Rowland D. Smith), a mechanical engineer (Walter W. Oakley), and another physicist (George V. McCauley) between 1912 and 1918. To handle the administrative details of this growing staff, Sullivan asked Otto W. Hilbert, an MIT-trained mechanical engineer, to join the lab in 1916. And in 1916, the optical lab located in the Sales Department was merged with the Chemical Department in order to create one central research laboratory under Sullivan’s direction. While this merger was done in part so that Corning could respond to war-related research requests more quickly, it also meant that all of the scientific resources of the company were now under Sullivan’s direction and could be used to forge strong links between materials, products, and markets. With all of the R & D operations under Sullivan, this merger of the labs in 1916 signaled that innovation had gone from being the exclusive domain of the proprietors (the Houghtons) to being largely handled by scientists such as Sullivan (see Figure 7).

We would suggest, then, that the story of the Corning R & D laboratory was not as a revolutionary event happening only in 1908 – with the arrival of Sullivan at Corning – but rather an evolutionary process spanning the 20 years between 1896 and 1916. In these two decades, Corning learned several key lessons about innovation. First and foremost, the proprietors – the two generations of Houghtons who ran the firm in this period – chose to embrace technological innovation as their fundamental business strategy. While in hindsight it may seem obvious to focus on innovation, they could have chosen a different strategy as the path to survival. Next, while the Houghtons initially pursued innovation by drawing on their own expertise, they came to be willing to work with other experts – with physicists, chemists, engineers, technicians, and even a psychologist (Churchill). Not knowing the best way to utilize these experts, the Houghtons tried different organizational arrangements – working closely with skilled craftsmen, contracting with consultants, hiring individuals into existing departments, setting up separate
companies (such as Empire Machine), and creating new departments (like the Chemical Department). Notably, the company secured new technology by drawing on all these experts and trying all of these arrangements; they were all as efficacious as relying on chemistry and the Chemical Department. And finally, under Sullivan’s leadership with Nonex and Pyrex, the company learned that the ultimate power of R & D lay in forging links between materials, products, processes, and markets.

**From History to Today**

It would be easy to imagine that the story of how R & D evolved between 1896 and 1916 has little relevance for how Corning operates in the 21st century. After all, technology has changed dramatically, the company pursues entirely different markets, and Corning is a substantially larger enterprise. How could the problems of improving railway signal lenses, lantern globes, and Pyrex possibly have anything to do with making Corning’s current leading products, the glass for flat-screen televisions, optical fiber, or diesel-emission control systems?

Yet what Corning learned about innovation one hundred years ago is still relevant today. The key lessons of those early years – relying on different forms of knowledge, trying different institutional arrangements, and striving to link materials, products, processes, and markets – are still part of the culture of innovation at Corning today. Let us look now at how these lessons are reflected in the company’s history and contemporary practices.
Individuals and Diversity of Thought

One of the benefits of creating a diagram like Figure 2 is that it reminds us that the inputs for a process do not just exist in a vacuum but are provided by the specific organizations and individuals listed in the Supplier column. This is especially true for innovation; the knowledge and skills needed to create new products are always embodied in real people.

As one looks at the story of how research evolved at Corning, it is clear that Alanson and Arthur Houghton did not need a diagram to understand this idea. They...
knew that people mattered, that to create a new product or process meant finding the right person (whether it be Churchill, Sullivan, or Chamberlain) and creating a place for them in the organization. But more than that, the Houghtons understood that the best defense against the uncertainty of their business environment was drawing on a diversity of knowledge inputs. Rather than relying on only chemists and physicists for innovation, they were willing to work with skilled craftsmen, engineers, and other experts. In doing so, Alanson and Arthur were practicing what Corning now calls ‘Diversity of Thought’ (see Figure 8).

Within Corning’s research division – known today as Science and Technology or S&T – diversity of thought is the belief that the best way to generate new ideas is to integrate the talent of scientists, engineers, and technicians. As Charles Craig, a Vice President for S&T and Director of Administration and Operations, has noted, ‘We have intentionally sought to make our innovation culture diverse through our hiring practices in search of the best talent ... and paying a lot of attention to the overall work environment and micro-cultures that comprise it’.21

First and foremost, this diversity has taken the form of a range of disciplinary experts. Since hiring its first scientist in 1904, Corning has employed not only chemists and physicists but also engineers, biologists, mathematicians, and computer scientists. One significant step toward diversity came when Dr Sullivan decided in 1930 to hire an organic chemist, J. Franklin Hyde; this was surprising move since glass is generally studied by inorganic chemists, but Sullivan picked Hyde out of a faith that organic chemistry would broaden the knowledge base of the research organization. Another early example of diversifying the knowledge base was employing a home economist, Dr Lucy Maltby, to run a test kitchen in the 1930s and develop new houseware products from Pyrex (Blaszczyk 2000, 242–3).

Along with university-trained experts, Corning has also relied on extraordinarily skilled technicians to develop new processing equipment, whether it was Billy Woods with the Ribbon Machine for mass producing glass lightbulbs in 1920s or Jim Giffen with the machines used to make TV tubes and Corelle dishes from the 1950s to the 1970s. Scornful of anyone with a college degree and downright intolerant of PhD scientists, Giffen delighted in proving the ‘college boys’ wrong. Yet Giffen was so valuable to the company that when Jamie Houghton became division manager of consumer products he was told by the company president that his biggest challenge would be to ‘Dealing with Jim Giffen twenty-fours a day’ and keeping Giffen happy.22

Looking to move beyond its traditional glass and ceramic markets, Corning diversified its knowledge base further in the 1960s. To enter the biotechnology market, it hired a PhD biologist, Ralph Messing. Not sure exactly why a glass company was employing a biologist, Jack Hutchins, director of research, joked that Corning had hired Messing ‘to invent the tree which will grow glass lightbulbs’.23 However, drawing on Messing’s expertise, the company developed Bonded Enzymes that can adhere to glass and are used extensively in biotechnology. The success of this new product revealed that often the new opportunities lay in the boundary regions between glass technology and other fields and that Corning gains access to those boundary regions by hiring a range of experts.
In recent years, diversity of thought has come to embrace ethnic diversity. Within the S&T organization at Sullivan Park in Corning, New York, one can find individuals from China, India, Africa, Europe, and the Middle East; indeed at Sullivan Park, Corning now employs people from over 30 different nations. To help build collaborations between individuals from such diverse backgrounds, S&T has instituted a program, ‘Creating an Inclusive Culture’, which helps individuals enhance their skills for effective interaction in the innovation process.

Corning has made this substantial investment in diversity in the belief that diversity not only permits it to respond quickly to the needs of its customers throughout the world but because diversity also helps improve the quality of ideas and solutions that the S&T organization delivers. To stimulate diversity of thought, the S&T organization has pursued a multi-pronged approach; as Craig explains:

The main idea is to bring together three ingredients to create the diversity of thinking that is crucial to the quality of ideas and solutions that an R & D organization delivers.

A multi-disciplinary technical environment is the first ingredient to ensure diversity of thought – what we think about ideas and problems from the perspectives of our different technical disciplines.

A multi-cultural environment is the second ingredient to stimulate diversity of thought – how we think about ideas and problems, how we interpret data and information, how we synthesize our responses from the perspectives of our cultural, racial, gender and functional diversity.

An open, collaborative, knowledge-sharing environment is the third ingredient to develop broader diversity of thought – building a more inclusive operating culture that seeks diverse opinions, respects differences in thinking, learns and captures the often unique insights that come when these differences meld into one response. In a technical culture we want to encourage more peer review and exchange of ideas, thinking, results, next steps.

None of the three ingredients are independent of each other – they are very co-dependent, thriving or waning based on the relationships among all three.

In combining these ingredients, Corning has established a vibrant research community. As one walks through the halls of Sullivan Park today, one can hear scientists and engineers conversing in English, French, Chinese, Japanese and other languages. At lunch in the café, one can meet not only graduates of MIT, Rutgers, Clarkson, and Harvard but also from the Bangladesh University of Engineering and Technology, Nantes University, National Taiwan University, University of York, and the University of Siegen. Such diversity may seem at first glance to be a long way from where innovation began at Corning 100 years ago,
but it is really a continuation of what Alanson and Arthur Houghton learned in those formative years.

A Commitment to Organizational Innovation

As we have seen, central to the evolution of R & D at Corning was a willingness to try new organizational arrangements. Over 20 years, Alanson and Arthur tried a variety of different arrangements – consulting contracts, hiring people, creating new departments – in order to bring knowledge to bear on the problems facing the company. The Houghton brothers realized that innovation was not based simply on magic, genius, or luck but rather on carefully structuring the organization so that it could take advantage of different sources of knowledge.

Corning has continued to pay close attention to how it organizes and deploys its scientific and engineering talent. Innovation is about not only getting the technical details right but also orchestrating the social and human resources needed to move an idea from the laboratory to the marketplace. As the company notes in its description of its core values, innovation requires a willingness ‘to introduce new forms of corporate organization, and to seek new levels of employee participation’.26

Since 1908, Corning has willingly experimented with how it organizes research. From the 1920s to the 1960s, Corning repeatedly modified the structure of the R & D group in order to balance the autonomy of its scientists with the company’s business goals. In the mid-1980s, Corning recognized that its central research organization and its autonomous product divisions were not working effectively together on developing and introducing new technology. According to then Vice Chairman Tom MacAvoy, the divisions had become so disenchanted with central research that they told him ‘Stay out of our hair and fix it’, meaning that research and engineering had to change. In response, MacAvoy led a task group who created the company’s Innovation Process Model as a way of coordinating the activities needed to move from ideas to dollars. A five-stage gated model, the Innovation Process Model, has helped create a context for different people to interact, learn from each other, and shape creative ideas into profitable products and processes.27

Moreover, the company has experimented with having a network of laboratories around the world. Beginning with the establishment of a research facility in France in 1973, Corning has developed a group of labs that now includes facilities in Japan and Russia. Rather than concentrate R & D in a single location, the guiding principle behind having several laboratories is that it enables Corning to capitalize on the unique talents and perspectives of different scientific communities. Recognizing the power of global network of labs, Corning’s Chief Technology Officer, Dr Charles (Skip) Deneka, encouraged the company in the late 1990s to double S&T’s research facilities not only at Sullivan Park but in France, Japan, and Russia as well. Today Corning leverages the expertise in its global labs by having groups in each facility pursue projects independently as well as collaboratively.
Creating Links

Perhaps the most important thing about the Chemical Department under Sullivan was that Corning learned to use the department to forge links between materials, products, processes, and markets. By doing so, Corning was able to convert Pyrex from an interesting laboratory discovery to being a profitable product. Not surprisingly, Corning managers and scientists readily appreciated the value of making these links, and over the course of the 20th century, they have regularly built new businesses around these links. While the company took this approach with television tubes, Corning Ware (pyroceram), Corelle, and fiber optics, the cases of silicone and Celcor exemplify how Corning has continued to build these links.

After joining Corning in 1930, J. Franklin Hyde drew on his background in inorganic chemistry in order to study the material world that lay between glasses and polymers. In the course of this research, Hyde learned how to manipulate a group of compounds made up of a chain of alternating oxygen and silicon atoms. By varying the length of the chain and varying the groups linked to the side of the chain, Hyde discovered it was possible to dramatically vary the consistency of silicone from a liquid to a gel to soft rubber to even a hard plastic. However, as interesting as this new material was, Corning lacked the knowledge needed to manufacture and market products from it. Consequently, Corning partnered with Dow Chemical to form a joint venture, Dow Corning, in 1942. By combining Corning’s expertise in materials with Dow’s experience in chemical processing, Dow Corning was able to use silicone to create products including sealants for industrial piping, engine lubricants, electrical insulation, and medical devices. Through Dow Corning then, Corning created the links between a new material (silicone), the necessary manufacturing processes (Dow Chemical) and new product (sealants), in order to reach new markets. (While he was working on silicone, Hyde also came up with another new material, fused silica, as well as a new process, vapor deposition. Remarkably, vapor deposition was the first new technique for manufacturing glass in 3000 years. In the 1970s, Corning used both of Hyde’s inventions to develop fiber optics [Graham and Shuldiner 2001, 127–32, 157–61].)

Another example of creating links is the story of Celcor, the substrate found in the catalytic converters used to reduce exhaust emissions from automobiles. In 1970, while attempting to convince Detroit automakers to take up a new glass for windshields, Corning manager Tom MacAvoy was asked by General Motors to help develop a catalytic converter in order to meet the reduced emission standards required by the recent Clean Air Act. GM was under tremendous pressure since catalytic converters would be needed on all cars starting with the 1975 model year. Yet at the time, no one knew how to make a material that could stand the intense chemical reactions needed to remove pollutants from automobile exhaust. In response, Corning researchers created Celcor, a ceramic substrate. But for Celcor to succeed, Corning needed to complement this new material with a new product design (a catalytic converter) and a new manufacturing process (extrusion). To create these links for Celcor, Corning chose to focus the talent of the S&T organization almost
Figure 9 2005 R&D spending by Corning and Firms in Related Business Sectors. Industrial Research Institute, personal communication, Sept. 2006
exclusively on this problem, exercising what is known in the company as ‘flexible
critical mass’ (Graham and Shuldiner 2001, 353). As a result, Corning was able to
take Celcor from concept to customer delivery in just four years. Today, Celcor is
manufactured on four continents and Corning has developed new anti-pollution
deVICES for diesel engines.

A Continuing Commitment to Innovation

But perhaps the ultimate indication that history continues to shape contemporary prac-
tice at Corning is its commitment to innovation. Just as Alanson and Arthur chose to
concentrate on innovation in the early 20th century, so Corning continues this tradition
of technological leadership, even in the face of adversity. In 2001–2, as the communica-
tions industry collapsed and orders for telecommunications products disappeared,
Corning suffered the most severe downturn in its history and was forced to lay off half of
its workforce. Although he had just been hired to head up S&T, Joseph Miller, the Chief
Technology Officer, feared that he would be fired by Jamie Houghton, then the CEO.
Instead, Jamie called Miller into his office in 2002 and gave Miller a different order. ‘He
told me to do what I had to do, but to save Sullivan Park’, Miller recalled in a recent
newspaper interview, ‘He said it was the future of the company’ (Wilson 2007).

True to his word, Jamie insisted that Corning increase its commitment to R & D. In
recent years, Corning has invested between 8 percent and 10 percent of its annual sales
revenue in R & D, which is significantly more than most companies in Corning’s busi-
ness sectors, where the average is 6.7 percent of sales revenue. Notably, while Corning is
one of the top investors in R & D, it is the smallest company in its business sectors in
terms of total revenue (see Figure 9). Under the leadership of Wendell Weeks, the cur-
rent CEO, and CTO Miller, this investment in R & D has resulted in Corning breaking
ground in November 2007 on a new 150,000 square foot addition to Sullivan Park.

Conclusion

For Corning, the year 2008 marked the 100th anniversary not of a revolution but rather
an evolution. The creation of the Chemical Department in 1908 was not a miraculous
moment in which Corning suddenly committed itself to innovation by hiring scientists
and using scientific theory. Instead, the anniversary marks a process spanning 20 years
(1896–1916) during which several practices were established at Corning:

• First, that the Houghtons committed to innovation as a central feature of business
strategy;
• Second, that Alanson and Arthur Houghton pursued innovation not only by relying
on their own knowledge but by leveraging different kinds of expertise;
• Third, that they were willing to try different organizational arrangements (consul-
tants, employees, labs, departments) in order to utilize experts for innovation; and,
• Fourth, that in developing Pyrex, Sullivan learned how the lab could play a major
role by integrating materials, processes, products and markets for the company.
In thinking about the rise of R & D at Corning as evolution rather than revolution, we would suggest that there are several key lessons for historians of business and organizations. First, it is important to note the role of the Houghtons in the story. Clearly, the path by which innovation came to be institutionalized at Corning was strongly influenced by how members of the Houghton family understood glass technology and their ideas about how to survive in this industry. Given the powerful role played by the Houghtons in the Corning story, historians looking at the rise of R & D at other firms should not just assume that R & D was something ‘in the air’ circa 1900 but instead need to look closely at what prompted specific individuals to bring R & D inside the firm.

Another significant point concerns the importance of organizational innovation for R & D. In most accounts of R & D, the assumption is that the key change was replacing craft knowledge with scientific theory – that firms automatically gained a competitive advantage by bringing scientists into the company. However, the story at Corning suggests that the rise in R & D was not just about shifting to science but rather a willingness on the part of management to experiment with different organizational arrangements – to see which best suited the experts available and which arrangements allowed knowledge to be effectively applied to the problems facing the company. Generalizing from the Corning story, we would suggest that historians and organizational theorists need to develop a better understanding of how firms locate knowledge within their structure. To make money from science (or any other body of knowledge), a company must be willing to think carefully about how it positions experts within the organization – just hiring scientists is not enough in order to innovate.

And finally, it is important to consider the sources of innovation. While it is easy to assume that new technology is based on scientific theory, we would point out here that science was not the sole source for innovation. During the formative years, Corning drew on experience, craft skills, scientific instruments, and other sources to innovate. Indeed, what is significant about Alanson and Arthur Houghton was their willingness to draw on a variety of people and sources in order to innovate. At Corning today, this willingness to rely on different sources for innovation continues in the policy of S&T to hire talented researchers from a variety of disciplines and from all over the world. If telling the story of R & D at Corning as an evolutionary process teaches us anything, it is that innovation requires flexibility. To create the technology that we will need for the future, we must be willing to draw on the full range of knowledge and resources and to bring them together in creative ways, much as Corning has done for more than one hundred years.

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Notes

1. To the best of our knowledge, the Corning lab was the first in the glass industry and one of the first five industrial research labs to be founded in the USA.
3. There was a member of the Houghton family at the head of the company for most of the period between 1851 and 2007. Six Houghtons over five generations have managed the company.
4. Innovation as a process refers to the overall concept and components of innovation and not the formal innovation management process used by Corning and other organizations that are based on Robert Cooper's stage-gate methodology.
8. As part of its current business strategy, Corning seeks to develop technologies that will become key enabling components in the systems used by their customers. As Wendell Weeks, Chairman and CEO of Corning explains: ‘Innovation our way is a very long development cycle, and it’s capital intensive. We look to develop a highly engineered component that becomes part of an overall system. We end up with an enabling component, and we have a competitive advantage in technology and manufacturing ... ’ (see USA Today, 3 June 2005).
10. It is not entirely clear what field Churchill studied at Yale. According to the archivists at Yale, Churchill’s dissertation was presented to the Department of Philosophy in 1901. It would appear that psychology research may have been done at Yale under the auspices of the Philosophy Department at that time. In Cattell (1927), Churchill listed his fields as psychology followed by applied optics. This would suggest to us that Churchill saw himself as an experimental psychologist.
11. Another example of a Corning scientist using instruments to improve is H.P. Gage and the spectrometer. In the 1900s, Gage created a series of filters, which made the light from incandescent lamps seem more like sunlight in terms of its spectral makeup (see Graham and Shuldiner 2001, 46–52).
14. Thanks to the Ribbon Machine, Corning maintained its leadership in the lamp market for more than 50 years, and only exited the field in 1983 when a competitor purchased an old Ribbon Machine that was being scrapped.
15. Sullivan Pamphlet.
17. Sullivan Pamphlet.
20. Regina Lee Blaszczyk made a similar observation about innovation at Corning circa 1916:

   "To be sure, successful product innovation was a task that required constant watching and few understood this principle better than managers at Corning Glass Works. At the turn of the century, Corning executives crossed numerous boundaries as they embraced a science-oriented corporate strategy that was unique among the nation’s glassmakers and distinct from the approaches of the country’s R & D pioneers.

   See her dissertation (Blaszczyk 1995, 21)."
24. According to a 2003 study of Corning conducted by MBA students from Lehigh University:

Diversity is a valued part of Corning’s culture. This includes visible differences such as race and gender and also diversity of thought, philosophy, and problem-solving techniques. Company culture is nurturing and supportive of differences. Corning encourages employees to participate in a wide range of outside organizations. This ensures that while turnover of personnel is low, turnover of ideas is high. Employees are encouraged to seek training of all kinds.

See Henninger et al. (2003).

27. Corning developed in the 1980s a way to orchestrate ideas with manufacturing and marketing—the Innovation Process Model. This Model is several things at once: first, it is a description of the steps by which an idea typically moves through the organization from conception to commercialization. Second, it is a flexible set of checkpoints at which innovators must make explicit how they think the product will be manufactured, marketed, and used. Third, it is a framework which invites different people from across the organization and from across disciplines to share ideas and take responsibility for bringing a product to fruition. The fourth facet is that it serves as a common language for people at Corning to talk about—and act on—innovation. For a discussion of how the Innovation Process Model was developed at Corning (see Graham and Shuldiner 2001, 409–14, for the quote from MacAvoy see 409(xs).

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USA Today. 2005. 3 June.


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