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American Chemical Society

Innovation, Chemistry, and Jobs

Meeting the Challenges of Tomorrow

ACS Presidential Task Force on
Innovation in the Chemical Enterprise

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Meeting the Challenges of Tomorrow

Prepared by the ACS Presidential Task Force on Innovation in the Chemical Enterprise

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stimulate innovation and encourage the creation of jobs

"Unlike any previous time in the history of chemistry innovation, entrepreneurs and small businesses may now hold the key to limiting the losses in jobs, in generating new job opportunities for chemists in the U.S., and in helping chemistry solve the problems faced by society."

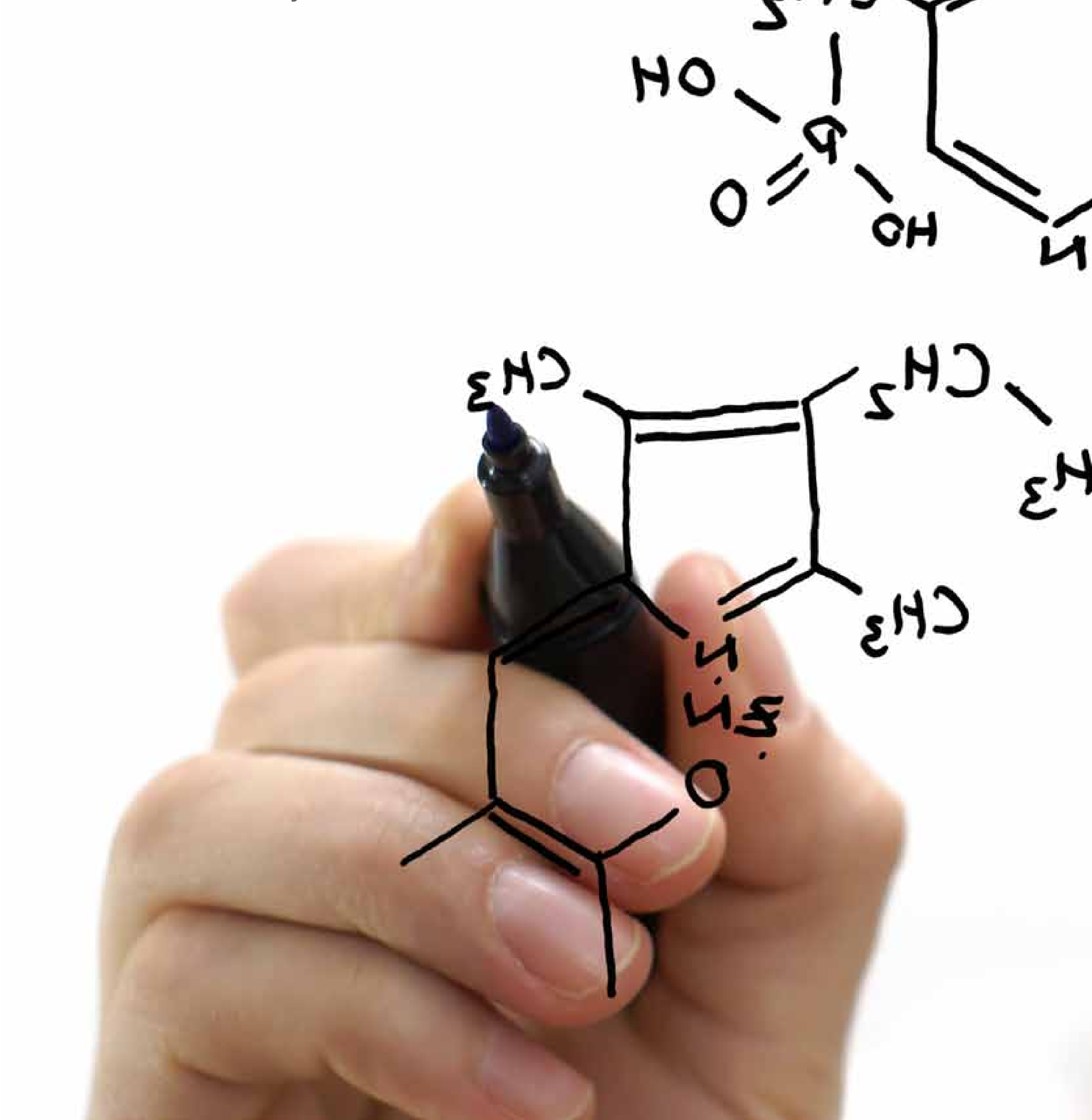
Since 2008, nearly 25,000 jobs—including thousands in research and development (R&D)[1] —have been lost in chemical manufacturing companies in the United States, and layoffs continue. For the past 20 years, a clear job loss trend is evident in Bureau of Labor Statistics data that suggests the loss of approximately 300,000 full-time chemist jobs in the U.S.[2] Patterns of hiring are also changing. Chemical companies with more than 500 employees are hiring significantly fewer new graduates than in the past, while small businesses are hiring more, albeit at slower rates. While no single factor explains these recent job losses or trends, higher input costs, shrinking margins of large companies, and growing aversion to the risks and costs of investment in longer-term R&D appear to play significant roles.

In early 2010, ACS President Joseph S. Francisco appointed a Presidential Task Force to explore the causes for these historic job losses and to recommend ways that ACS could help stimulate innovation and encourage the creation of jobs across the chemical enterprise. The Task Force was chaired by George Whitesides, the Woodford L. and Ann A. Flowers University Professor at Harvard University. It comprised eminent members of the chemical enterprise from industry, academia, and government, all with experience in entrepreneurship. They included Henry Chesbrough, University of California, Berkeley; Pat N. Confalone, DuPont; Robert H. Grubbs, California Institute of Technology; Charles Kresge, Dow Chemical; Michael Lefenfeld, SiGNa Chemistry; Chad A. Mirkin, Northwestern University; Kathleen M. Schulz, Business Results, Inc.; and Timothy M. Swager, Massachusetts Institute of Technology.

[1] Voith, M.; McCoy, M.; Reisch, M. S.; Tullo, A.H.; Tremblay, J. Facts & Figures of the Chemical Industry. *Chem. Eng. News*. **2010**, 88, 33-67. For a running account of layoffs in the chemical and pharmaceutical industry since 2008.

[2] National Occupational Employment and Wage Estimates United States, 1989-2009; Technical Report for the U.S. Department of Labor, Bureau of Labor Statistics: Washington, DC, 2009.

This report is the product of their work. It broadly outlines the current landscape of innovation in chemistry; defines barriers and opportunities for stimulating innovations; and recommends specific programs that ACS could initiate to help chemists to become innovators and entrepreneurs, and thus to create new jobs and to stem further job losses in the U.S.



The Task Force's recommendations to ACS fall into four major thrusts:

1

ACS should develop a single organizational unit—a kind of "technological farmers' market"—offering affordable (or free) help to entrepreneurs.

This unit would support entrepreneurs by facilitating more affordable access to resources that should foster the creation of small companies from startups. Relevant resources might include information, management expertise, key services, and mentors. The unit could also support entrepreneurs in making introductions to much-needed capital and fostering partnerships with large companies.

2

ACS should increase its advocacy of policies at the federal and state level to improve the business environment for entrepreneurs and startup companies.

- It should urge reforms within the U.S. Patent and Trademark Office to assure more accurate patents and faster issuance.
- It should advocate financial policies in government that encourage large companies to partner with small ones. These include preferential tax treatment for repatriated income invested in U.S.-based developers of technology and making the R&D tax credit more simplified, permanent, and transferable.

3 **ACS should work with academic institutions and other relevant organizations to promote awareness of career pathways and educational opportunities that involve or include entrepreneurship.**

4 **ACS should increase public awareness of the value of early-stage entrepreneurship** in the chemical enterprise with focused media coverage and information targeted to federal agencies that support chemistry. In addition, ACS should provide ways to recognize entrepreneurs publicly, to increase their visibility, and to enhance their opportunities for success.

As this Task Force was concluding its work in early 2011, President Barack Obama delivered his State of the Union Address. In that speech, President Obama said: “The first step in winning the future is encouraging American innovation. None of us can predict with certainty what the next big industry will be, or where the new jobs will come from ...What we can do—what America does better than anyone—is spark the creativity and imagination of our people.”

To that end, the American Chemical Society is positioned to help stimulate activities across the chemical enterprise to help spark the creativity and imagination of our country’s chemists.

chemistry & commercial innovation

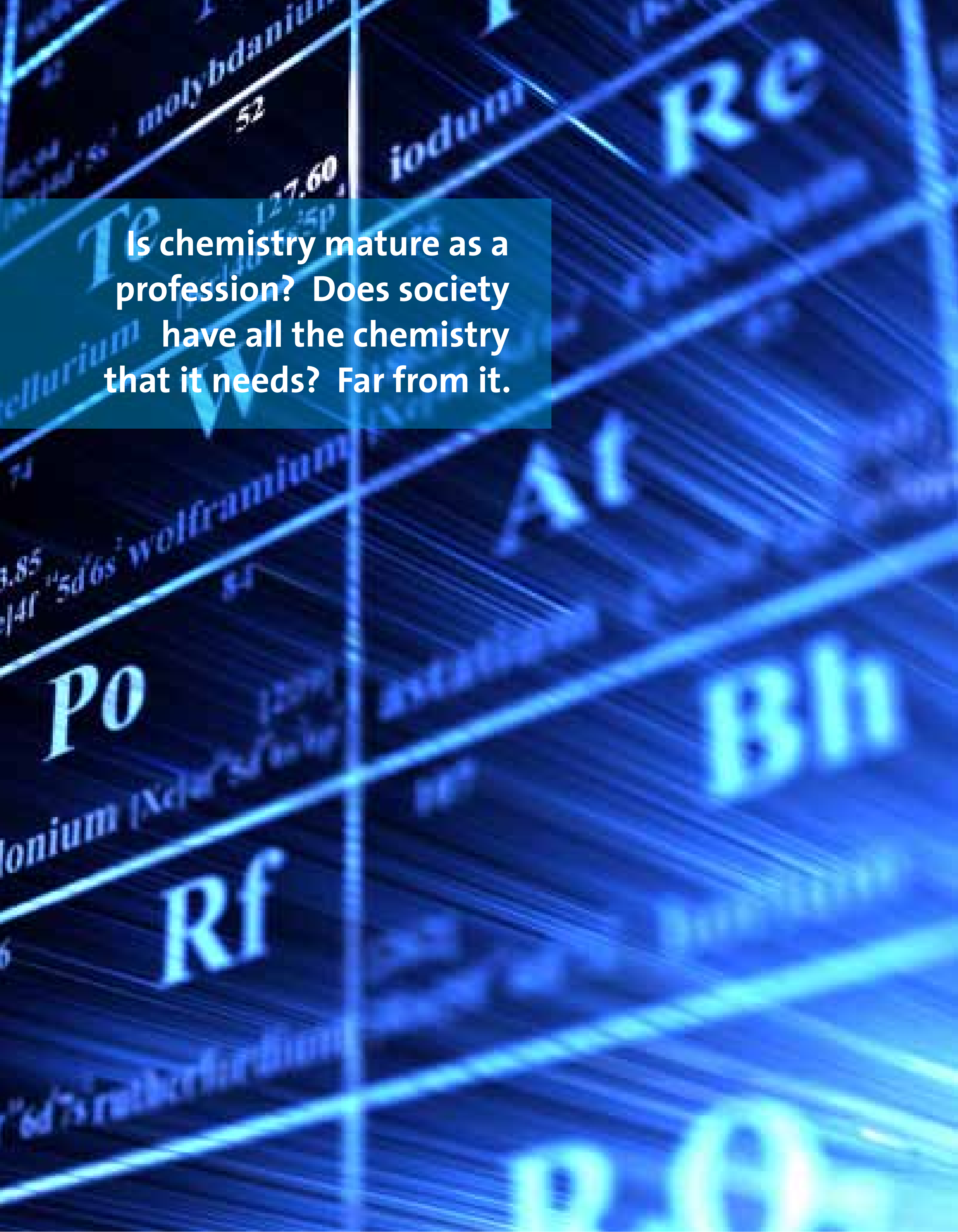
Needs and Opportunities in Society: Chemistry is Essential!

What is chemistry? In a narrow view, it is the discipline that studies, uses, and manipulates atoms, ions, and molecules. In a broader term, it is much more.

- It is the science that provides the basis for understanding the processes in life.
- It is a part of modeling global climate.
- It makes the components for many materials, and sometimes the materials themselves.
- It is the basis for drugs, and helps to shepherd drug candidates through clinical trials.
- It produces the components of the commodity infrastructure for water, fuels, and fertilizers.
- It creates the crop protection chemicals that help to feed the world and its burgeoning populations.
- It tailors polymers for radiation sensitivity in high-resolution photolithography and toughness in automotive bumpers.
- It is the science—and the profession—that covers the largest part of the perceptible world.

Chemistry is also a family of related fields: chemistry in its classical sense; fuels, pharmaceuticals, and related professions; medicinal chemistry; chemical engineering; materials science; biochemistry; environmental science; and many others. Without intending in any way to be exclusionary, they are all—and we call them all—"chemistry."

Is chemistry mature as a profession? Does society have all the chemistry that it needs? Far from it.

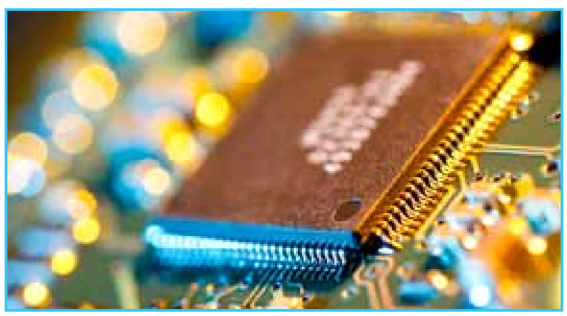


Understanding and managing global climate change; generating and conserving energy and potable water; building a more efficient, less expensive, and more humane health care system; producing products that solve problems in the largest, fastest growing markets (those in the developing world); generating new materials for high-technology products such as consumer electronics; energy-efficient transportation systems and buildings; and building a sustainable industrial economy—all will require new chemistry. And it is this *new* chemistry that has the potential to lead to true innovations and to found *new* industries.

Commercial Chemistry Supports Other Industries

One of the characteristics of chemistry is that—as a primary industry—it produces both products that are useful by themselves and products that play essential roles in other industries. For example, polymers have many primary uses such as containers, coatings, and structural components where they are used by themselves; however, they also have secondary applications in processes used to manufacture electronic components, automobile parts, and biomedical devices.

It is difficult to measure the value added by chemistry outside the conventional definitions of the profession, although it is enormous. Chemistry's primary contribution to the 2008 U.S. GDP was 12.1%; adding in secondary industries, the contribution is 15.9% (Table I-2, Appendix I).[3] An indication of the impact of chemistry on other fields can be seen through crossover of chemical technology into the patents of other industries. Chemical technology is present in the patents produced by all industries. It is "core" or important across a much broader range of industries than any other technology.[4] The creation of jobs in research and development is only a partial measure of employment due to chemistry. Introduction of new products through innovation causes a cascade of new jobs, from discovery to production to sales and application. Factoring in secondary uses of the products of chemistry in adjacent markets dramatically amplifies the number of jobs created through chemistry.



[3]Department of Commerce, Bureau of Economic Analysis. http://www.bea.gov/industry/gdpbyind_data.htm (accessed September 30, 2010).
[4]*Measure for Measure: Chemical R&D Powers the U.S. Innovation Engine*; Technical Report for The Council for Chemical Research: Washington, DC, 2005.

History: Innovation in the Chemical Enterprise

The chemical industry in the U.S. grew rapidly during the first half of the 20th century, largely because of innovations in products and processes. The pace of introduction of new products and processes around mid century was remarkable. Indeed, chemistry in the U.S. was an unparalleled generator of new science and engineering jobs nationwide. However, the nature of innovation in the chemical industry has changed. The peak decade for major chemical innovations in the U.S. was the 1960s. Subsequently, chemical innovations declined.

In May 1988, economists Martin Neil Baily and Alok K. Chakrabarti released a study titled "Innovation and the Productivity Crisis," which was published by the Brookings Institute. They analyzed the factors affecting chemical innovation during recent decades and concluded that the U.S. wasn't lacking in invention or creativity, but instead it lacked the ability to capitalize on those inventions.[5] Five key points of their study relating to the chemical industry are summarized in an ACS staff paper that appears as Appendix II, "A Brief History of U.S. Innovation in Chemistry."

Innovation and Jobs

Chemistry has historically been an important part of the industrial base of the United States (Appendix I). Many important activities of our society—healthcare, energy production, generation of food, construction of shelter, societal infrastructure such as roads and water supplies—involve chemistry. But after a period of enormous innovation and growth, with great positive impact on society, commercial chemistry—as measured by jobs, contribution to the GDP, trade balance, comparative number of patents, and other numeric measures—has entered a domestic stagnation and less innovative phase (Appendix II). This slowdown represents a problem for individual chemists, the chemical profession, the industry, and society. This is surprising because many of the most challenging and important problems now facing society seem to be problems that require chemistry for their solution.

The conundrum is: why is innovation declining in chemistry when the need for innovation in chemistry is increasing?

[5] Baily, M. N.; Chakrabarti, A. K. *Innovation and the Productivity Crisis*; The Brookings Institution: Washington, DC, 1988.

innovation in the chemical enterprise

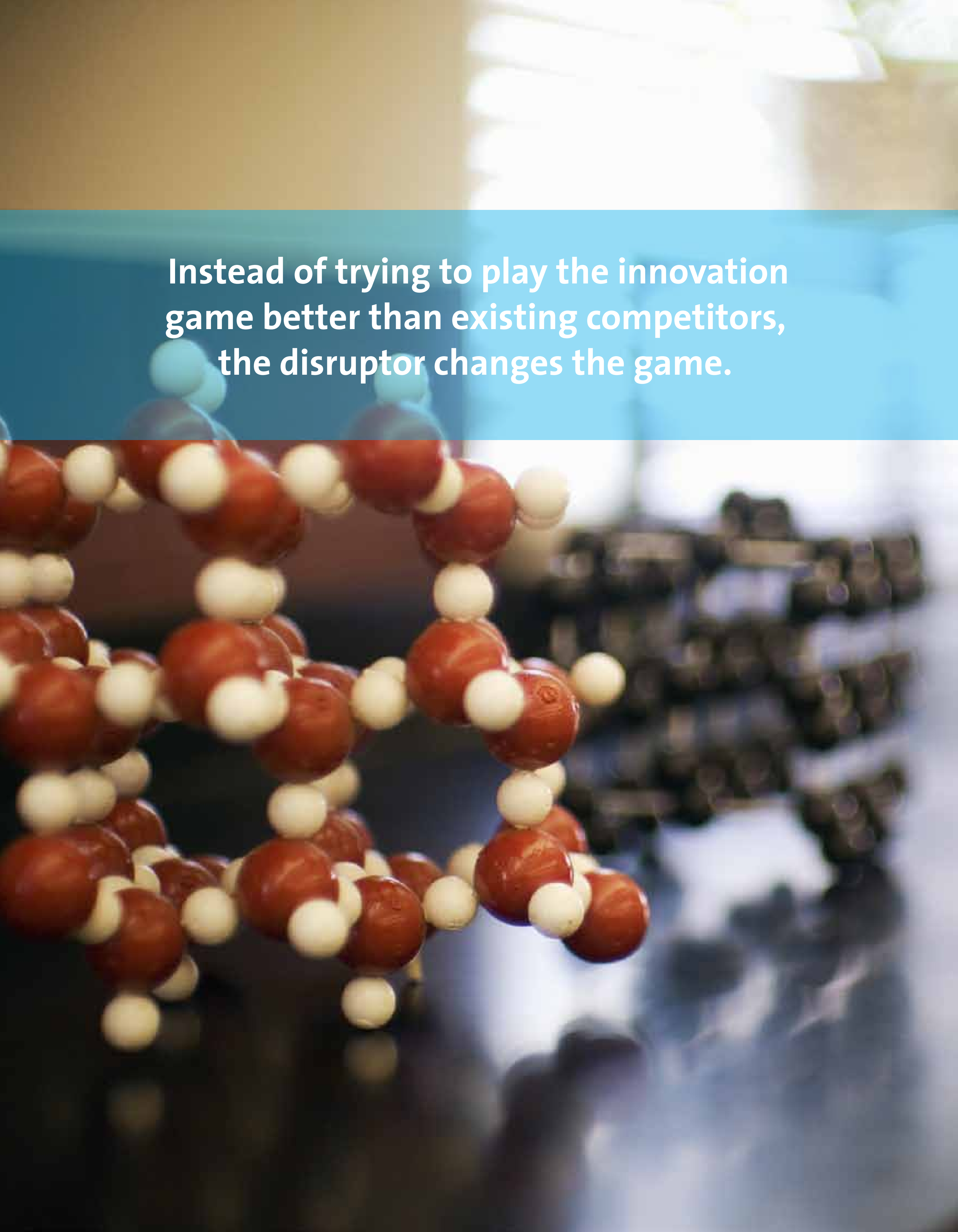
Innovation in the chemical enterprise draws in many interacting players —expending energy and resources to improve existing products, creating new products, and developing disruptive products that change markets altogether. In a rapidly changing global competitive marketplace, economic, political, and social forces are all at work. Must there be a paradigm shift? Can traditional strategies for innovation in chemistry be relied upon to meet new innovation challenges? Will less traditional chemical innovators— entrepreneurs, startups, and small businesses—play a much expanded role in the future?

Defining the Chemical Innovation Landscape: Sustaining vs. Disruptive Innovation

For the purposes of this report, innovation will be defined as the profitable introduction of a new technology (invention) to market. In the simplest terms, to be considered innovative an idea must result in revenue. Innovation can either be "sustaining"—meaning it establishes a trajectory for improvement and sustains existing products—or "disruptive", meaning it introduces new, more competitive products that displace existing ones. Disruptive innovators bring something completely different to a market, according to Scott D. Anthony, Managing Director of Innosight Ventures.

Disruptors typically transform existing markets or create new ones by focusing on convenience, simplicity, accessibility, or affordability. Academic research and Innosight fieldwork show that disruptive innovation is the more reliable way to create new growth business."[6]   In either case, innovation may or may not create jobs since some innovations can result in workforce reduction.

[6]Anthony, S.D. *The Silver Lining: An Innovation Playbook for Uncertain Times*; Harvard Business School Publishing: Boston, 2009; pp 1-21.



Instead of trying to play the innovation game better than existing competitors, the disruptor changes the game.

Innovation in Large Companies

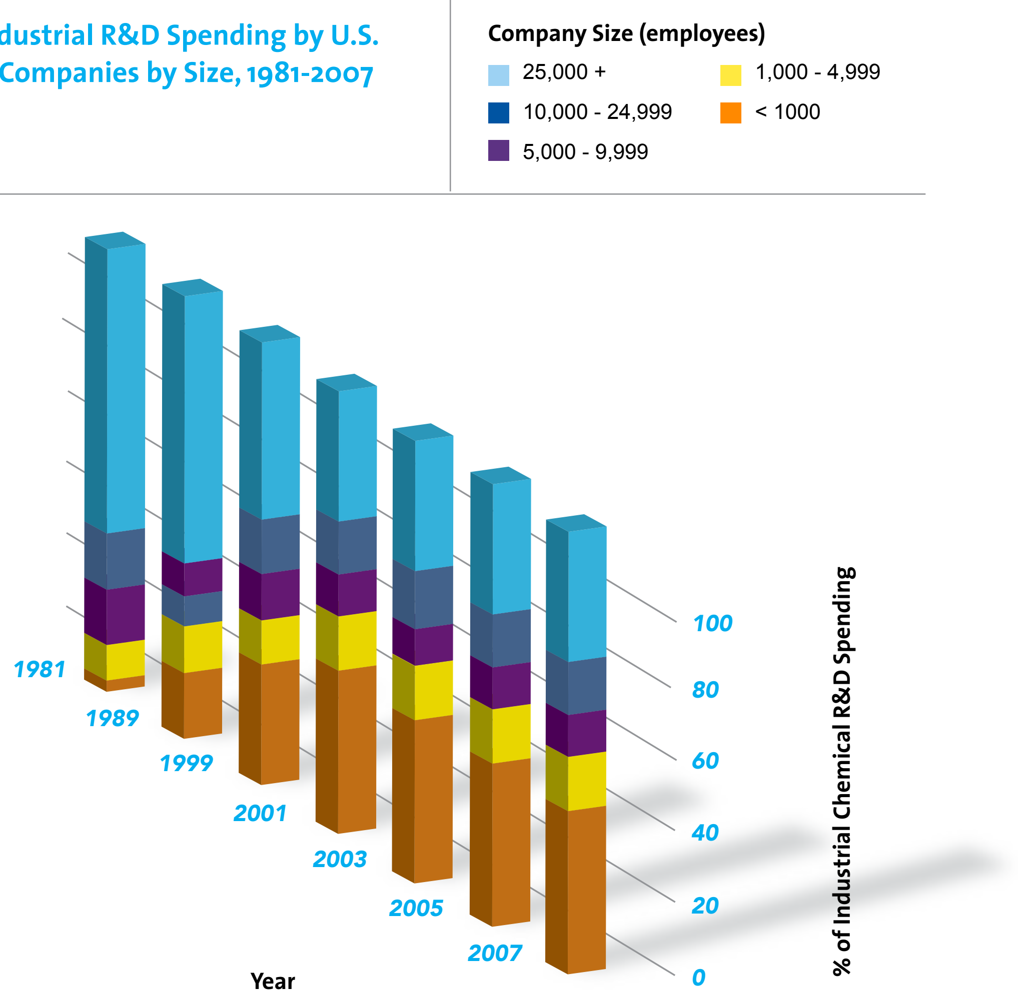
During the past two decades, most large chemical companies have favored sustained or "sustaining" innovations which have added to their capacity and to the variety of product offerings that they are able to deliver to market, but have not fundamentally changed their businesses. For example, DuPont's Chief Technology Officer has stated that innovation "is not necessarily about invention." It is more generally about combining existing technologies in new ways that create value.[7] Established companies such as DuPont are more likely to be successful through sustaining innovation than through disruptive innovation[8] , that is, through innovation that creates entirely new classes of products that may displace or eliminate older ones.

Historically, the largest employers of chemists have been large, publicly owned chemical companies. Large companies have, in general, highly developed access to customers, and a low cost of capital. Since both are crucial elements in the development of *new* technology as well as in the management of *existing* technology, there is an opportunity for them to participate as partners with small and startup companies in the development of new products. The "not invented here" mentality within these large companies must be pushed aside through any means necessary to facilitate partnerships driving toward disruptive innovation.

[7]Reisch, M. S. Profiting from Innovation. *Chem. Eng. News*. **2005**, 83, 21-22.
[8]Anthony, S. D.; Johnson, M. W.; Sinfield, J. V.; Altman, E. J. *The Innovator's Guide to Growth: Putting Disruptive Innovation to Work*; Harvard Business Press, Boston: 2008; pp 1-18.

This pattern was articulated by Henry Chesbrough in his work on Open Innovation.[9] Table 1 below shows data on R&D spending by company size, according to the National Science Foundation. In 1981, large companies of more than 25,000 employees accounted for more than 70% of R&D spending. In 2007, they accounted for just 35% of R&D spending.[10] As the table also shows, the smaller companies account for a much higher percentage of R&D activity, with firms under 1,000 employees representing one-quarter of all R&D spending in 2007.[11]

Table 1. Industrial R&D Spending by U.S. Chemical Companies by Size, 1981-2007



Sources: National Science Foundation, Science Resource Studies, Survey of Industrial Research Development 1999, 2001, 2003, 2006, 2008.

[9] Chesbrough, H.W. *Open Innovation: The New Imperative for Creating and Profiting from Technology*; Harvard Business Press: Boston, 2003; pp 48.

[10] *Survey of Industrial Research and Development*; Technical Report for the National Science Foundation, Science Resource Studies: Washington, DC, 1999. *Survey of Industrial Research and Development*; Technical Report for the National Science Foundation, Science Resource Studies: Washington, DC, 2008.

[11] The percentage of R&D is very hard to interpret, since R&D in large companies may be largely or exclusively D and strongly focused on product line protection and extension. Thus, for example, if large companies amounted to just 35% of R&D spending, and much of that was D, where is the R being done? Small companies? Universities? Outsourced from large companies into smaller organizations?

Innovation in Small Companies[12]

Small companies tend to specialize in tailoring existing products to the needs of customers, and in servicing these customers. These activities may require innovation in service, but the perception is that these smaller companies are also unlikely to be developers of radically new products—though they may be among the first to witness emerging customer needs. Nor is it probable that they will become a major new source of employment for chemists, unless the chemical enterprise in the U.S. evolves primarily into a service outlet for products produced elsewhere. There is a significant opportunity for small companies to work more collaboratively with large companies, since the small companies can move faster than their larger brethren. Such partnerships could boost the demand for chemists in these companies, but would probably not increase a demand for research. Also, small companies tend to drive new products to market with better technical and/or environmental specifications that compete with existing products already produced at scale. This means that the new products are competing with a technology that is already being manufactured at the lowest costs. With the proposed partnership model, these new products can take advantage of the purchasing power and existing capital expenditures (existing gas lines, reactors, waste management, etc.) already installed at the large company to more easily compete at a cost per unit scale.

There are several notable exceptions to the public perception that smaller companies will not be a source of new product innovation. For example, contract research organizations (CROs) have already established themselves as key providers of a broad array of drug discovery services in the pharmaceutical sector. Such partnerships have boosted the demand for chemists in CROs[13] and have enabled an outsourcing of sustained innovation and development from big pharma.

As with the pharmaceutical industry, the semiconductor industry is another chemistry-intensive industry that benefits from innovation in smaller companies. Independent foundries are manufacturing designs from smaller companies and startups, saving these companies the expense of building a new manufacturing facility to make their chips.

[12]The Small Business Administration defines small businesses by applying "size standards" for any of the NAICS codes. The size standards are either expressed by revenues or number of employees. For chemical manufacturing, standards are based on the number of employees and values range for 500 to 1,000 employees. See U.S. Small Business Administration, Table of Small Business Size Standards Matched to North American Industry Classification Codes.

[13]McCoy, M. Where Chemists Go After Big Pharma. *Chem. Eng. News*. **2010**, 88, 34-36.

Innovation in Startups[14]

The chemical industry has not been as active in generating startups as some other industries (for example, pharmaceuticals—especially biopharmaceuticals—and software). Since large new classes of products must start somewhere, the development of an active culture of startups would seem to be beneficial, both to society and to the chemical profession: it would generate options for large-scale industrial development; it would employ innovative scientists and engineers; it would draw smart students and potential entrepreneurs into innovative chemistry. Building on the currently booming CleanTech market space and funding initiatives, chemical industry startup growth can really take hold. And, of course, many large chemical companies were once startups: without babies, there are no adults.

The biotechnology industry is one example of this phenomenon. From 2001-2006, employment in the bioscience sector rose by 5.7%, which outpaced the more modest overall national private sector growth of 3.1%.[15] The Kauffman Foundation Research Report analyzed data from 1980-2005 for firms up to 28 years old to identify if the age of companies matters in job creation. Their report shows that young companies, between the ages of one and five, are responsible for highest net job creation. The same study also looked into firm size (by number of employees 1-10,000+) effect on net job creation for data from 2007. The study concluded that small to medium size firms with 20-49 employees provide the highest percent share of net job creation.[16]

[14]There are numerous definitions of what constitutes a startup company. The most common definitions describe a startup company as a company in its earliest stage of development, with a limited operating history, usually before its IPO. Startups concentrate on perfecting their business plans, developing products, and research for markets as well as build up of capitalization.

[15]Battelle Technology Partnership Practice and SSTI. *Growing The Nation's Biotech Sector: State Bioscience Initiatives 2008*; Technical report for Biotechnology Industry Organization: Washington, DC, 2008.

[16]Stangler, D.; Litan, R. E. *Where Will the Jobs Come From?* Kauffman Foundation Research Series: Firm Formation and Economic Growth; Technical Report for the Ewing Marion Kauffman Foundation: Kansas City, MO, 2009.

Innovation in Pharmaceutical Companies

The pharmaceutical industry represents a unique and particularly interesting part of the chemical enterprise. For more than 50 years, it has been among the most innovative and profitable branches of the chemical enterprise and a major employer of synthetic organic chemists. It is now widely perceived to be in trouble as an industry. The difficulties in pharma extend far beyond chemistry. The so-called "blockbuster" business model—focused on products with revenue potential of greater than $1 billion per year—is breaking down.[17] The number of New Molecular Entities (NMEs) receiving FDA clearance has remained relatively constant for the past five years, even as pharma R&D spending is at an all-time high.[18,19,20,21]

A number of factors suggest that the U.S. pharmaceutical industry – as it is currently constituted – is unlikely to again become a major employer of chemists in this country.

The barriers include:

- An increasing focus on reducing the cost of healthcare,
- The high technical risk and cost of taking new drugs through clinical trials,
- The difficulties posed by conservative regulatory agencies,
- Consolidated purchasing plans,
- Patent theft and patent lifetimes that are often not much longer than the interval required to develop a drug, and
- The technical difficulty of finding effective counters to diseases such as cancer and Alzheimer's.

Several new routes to products for healthcare seem likely to emerge from the present state of affairs. One is a more decentralized value chain, still predominantly in the U.S. and Europe, where young pharma and biotechnology firms develop promising scientific breakthroughs discovered in academia.

[17]Chesbrough, H.W. *Open Business Models: How to Thrive in the New Innovation Landscape*; Harvard Business Press: Boston, 2006; pp 13.

[18]Trusheim, M.R.; Aitken, M.L.; Berndt, E.R. Characterizing Markets for Biopharmaceutical Innovations: Do Biologics Differ from Small Molecules. *Forum for Health Economics and Policy*. **2010**, 13.

[19]*Comparison of NMEs approved in 2010 to previous years*; Technical Report for the U.S. Food and Drug Administration, Center for Drug Evaluation and Research: Washington, DC, 2010. http://www.fda.gov/downloads/Drugs/DevelopmentApprovalProcess/HowDrugsareDevelopedandApproved/DrugandBiologicApprovalReports/UCM242695.pdf (accessed March 2011).

[20]*Pharmaceutical Research and Manufacturers of America, Pharmaceutical Industry Profile 2010*; Technical Report for PhRMA: Washington, DC, March 2010.

[21]Mullin, R. Do-or-Die-Time. *Chem. Eng. News*. **2011**, 89, 12. The high water mark in the last 20 years was 45 New Molecular Entities a year. This has now dropped to around 20 per year; however, during this time period, starting in 1992, FDA enacted the Prescription Drug User Fee Act, which may also have impacted the drug review and approval process.

A second is a commoditized industry where new, high-margin, proprietary products are no longer important. A third might be a new industry focused on cost-efficient healthcare, modeled more on a public health model. A fourth might be continued innovation, but carried out largely outside the U.S.

Assuming continuing innovation in the U.S., with significant participation by small companies (a situation that would require a decrease in the cost of capital and a different attitude by the FDA), compounds that managed to enter later stage clinical trials could be sold off to – or developed jointly with – large pharma companies for final clinical trials, marketing, and distribution. Specialist firms would supply information, offsite clinical trial management, and manufacturing. With money and resources drying up, and a risk-averse FDA, large pharmaceutical companies are also examining their internal organizational structures. In the past two years, Pfizer, AstraZeneca, Merck, Eli Lilly & Co., and GSK have all refocused, downsized, and curtailed their R&D efforts. Through slightly different implementations, each of these companies has restructured into integrated networks of semi-autonomous and competing research units with a focus on specific therapeutic areas in part in an effort to mimic smaller startups. In the case of Eli Lilly & Co., the company is committed to achieving innovation through conventional and unconventional partnerships. For example, Lilly recently agreed to work with long-time competitors Merck and Pfizer by supplying resources to fund a joint venture devoted to discovering groundbreaking ideas.[22]

Innovation in Research Universities

The research university system in the United States remains the strongest and most inventive in the world. It is still the model studied by every country, region, and industry outside the U.S. As measured by metrics such as prizes and citations, the U.S. continues to be strong. As measured by the world's perception of creativity, the U.S. remains the destination of choice for young chemists interested in research.

It is, however, also clear that university systems in other regions of the world are receiving increased funding and rapidly becoming stronger in fundamental and longer-term research, and some regions (for example, China) have much stronger financial support than the U.S. .Although universities in Asia and India likely will not challenge those of the U.S. and Europe in creativity in the next decade, when looking 20 to 30 years into the future it seems almost certain that the relative strength of the different regions will continue to equalize. Nonetheless, the U.S. has a period in which it has a competitive advantage over the rest of the world in its research universities, and in their ability to generate new science. This advantage is not, however, being converted into a corresponding advantage in industrial innovation, and there is a view in industry that it is just as satisfactory (and perhaps less expensive) to acquire technology abroad than in the U.S.

[22]Jarvis, L. M. Research Recalibrated. *Chem. Eng. News*. **2010**, 88, 13-18.

It is a worrisome indication of the future that U.S. industrial engagement with our universities is minimal.[23] Foreign companies justify investment in long-term research by placing a higher value on the potential for a high-margin business in the future. Who is right?

In the past two decades (1989-2009), the fraction of the world's chemical enterprise as defined by global chemical sales attributable to U.S.-based companies has declined from 13.5% to 9.8%.

The culture of chemistry departments in most U.S. research universities—for reasons that are not entirely clear—is not a "startup" culture (as compared with many biology and electrical engineering departments). Even the field of chemical engineering has not produced new businesses at a rate comparable to those of some other fields. Undergraduate education of chemists tends to be very conservative and traditional; graduate school is focused on academic publications and grants. The conservative nature of the peer review system also tends to encourage conservative thinking in the university system. Academic chemistry would certainly offer opportunities for its students in industry if it encouraged graduate scholars to evaluate careers beyond those that occupied most students in the past.

Innovation in the National/Government Laboratories

The national/government laboratories — although a major recipient of federal support for R&D—have historically not been important contributors to innovation in chemistry (including adjacent areas). That is, relatively few of the products or processes invented in national labs make it to market. Additionally, the national laboratories' formal technology transfer programs have produced very few successful startups. The successes are generally the work of self-identified entrepreneurs leaving the labs, taking advantage of attractive entrepreneurial support programs offered by some of the laboratories. These entrepreneurs' successes have primarily been in areas of applied chemistry such as materials science, electronics, clean energy, etc. (for example, Nanophase, Advanced Diamond Technologies).

Recent federal directives have placed increasing pressure on the laboratories to commercialize inventions. At the same time, the national laboratories are not a monolithic category. The national security-based cost structure and engineering focus of some of the national laboratories does not favor low-cost practical innovation, and the culture and incentive structure of some of the other laboratories is not well-matched to a commercial (large company or startup) culture.

[23] *Science and Engineering Indicators*: 2010; Technical Report for the National Science Board: Arlington, VA, 2010.

factors affecting the shift in innovation

What is underlying the shift in traditional innovation from large companies to entrepreneurs and startups? What effect are the current financial and tight credit climates having on innovation and on the nature of institutions capable of innovation? Will large companies look to entrepreneurs to contribute to industrial innovation?

The particular form of capitalism developed in the United States judges the value of large public companies based on financial performance over a relatively short term (at most, a few years and often less than one year). But research and development—particularly R&D leading to new classes of products—is intrinsically a long-term activity, typically 20 years.[24] It is not likely that large companies will choose to make substantial investments in long-term R&D in the current climate of intense financial oversight from short-term financial owners and their proxies unless there is a high degree of certainty that such long-term R&D investments are likely to lead to new products that increase shareholder value.

Replication of technology—whether by legitimate improvement, by licensing, or by theft of intellectual property— by global competitors is much easier and quicker today than 30 years ago due to advances in communications and to the permeability of international borders. International laws protecting intellectual property and their equitable enforcement are also lagging and often unenforceable. The result is severe shortening in the lifetimes of new products in proprietary, high-margin businesses. Companies must devote greater attention and resources to product life-cycle management in order to protect and extend profits for each innovation. Large companies are much better positioned for this process than small ones and are, therefore, favored for sustained innovation.

[24] *Measure for Measure: Chemical R&D Powers the U.S. Innovation Engine*; Technical Report for The Council for Chemical Research: Washington, DC, 2005.

Will large companies look to entrepreneurs to contribute to industrial innovation?

Shorter product life cycles also result in increased pressures to come up with the next big thing before current revenue streams decline or expire. This accelerated timeline is often incompatible with the pace of internal development of projects and favors a strategy of acquisition of new technology, either in the form of an established business or in well-defined low-risk technical options. Simply eking out incremental improvements ultimately results in a commodity business, in which margins are low.[25]

In the long term, the biggest threat to the successful companies of today is missing emerging disruptive innovations.[26] One example is the failure of Kodak to capitalize on the shift from film-based photography to digital formats. The company recognized the problem, and, in fact, developed good digital products, but was never able to establish a business sufficiently profitable to replace the film business. Another example of a costly failure to capitalize on innovation is AT&T. Despite being the first to test market mobile telephony, AT&T failed to explore the full potential market, ceding its lead instead to Ericsson and Nokia.

Companies must also be vigilant of external developments, so that they identify and capitalize on innovations regardless of their source. Organizations commonly fall into the trap of focusing predominantly on internal development of technologies, both to retain ownership and control of those technologies and to justify the expense of R&D organizations.

The issues facing the chemical industry mirror those in many other established U.S. industries. Input costs are rising as energy prices climb, and U.S. wages and benefit costs remain high. Yet companies often cannot pass on these costs to customers because of foreign competitors and commoditization of existing business. The result is a "commodity trap" that destroys margins and weakens the industry's ability to invest for the future.[27] These issues are similar to those faced by any maturing industry. If, however, "maturation" necessarily means focusing companies on commoditization, cash management, and other aspects of business in which disruptive innovation does not play an important role, there are three unfortunate consequences:

- Society benefits less from the introduction of new processes and products than it would if disruptive innovation still occurred;
- The availability of jobs for young scientists and engineers declines, as do jobs related to new product development in many other sectors of a business; and
- Corporate profitability ultimately suffers, as margins decrease.

Given the inability to compete in commodity chemicals against competitors with low-cost infrastructure, petrochemical complexes built adjacent to oil fields, or protected or asymmetrical markets, many large chemical companies have a clear strategic interest in rebuilding proprietary (higher-value) positions, but little understanding of how to accomplish this rebuilding.

[25]Anthony, S.D. *The Silver Lining: An Innovation Playbook for Uncertain Times*; Harvard Business Press: Boston, 2009; pp 1-21.
[26]Christensen, C. M. *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail*; Harvard Business School Publishing: Boston, 1997.
[27]Chesbrough, H. W. *Open Business Models: How to Thrive in the New Innovation Landscape*; Harvard Business School Publishing: Boston, 2006; pp 13.

Large companies have evolved from nationals, to multinationals, to globally integrated enterprises and seek growth in revenues wherever they can find it. They also seek innovation wherever it exists, and increasingly rely on open innovation and partnerships with other companies and academia, to acquire the commercial opportunities.[28] They can then take full advantage of their well-oiled development, manufacturing, marketing, and sales organizations to bring inventions to commercially successful, innovative technology. This, in turn, benefits stockholders, stakeholders, and society, and helps create jobs.

Some recent data and examples may be illuminating.

According to 2008 data from PatentSight, only two out of the top 10 chemical companies with the highest R&D investments are U.S.-based companies.[29]

Many service jobs in R&D (for example, synthesis of compounds used in the pharmaceutical industry) have left the U.S. for countries in which technical competence equals that of the U.S., but in which costs are lower. Some of the most rapidly growing markets are in developing economies, particularly in Brazil, Russia, India, China, and Indonesia. So it often makes economic sense to locate manufacturing facilities close to customers.

In principle, however, the U.S. will retain an advantage for some decades in its ability to innovate. One key asset is the U.S. academic enterprise, which educates and trains a most capable workforce and offers a rich source of invention.[30] A second is a culture of innovation that has produced world-leading technology in many areas including high-tech pharmaceuticals, biotechnology, electronics, social networking, entertainment, agriculture, and others. But significantly, in recent decades this trend has bypassed main-line chemistry.

National Renewable Energy Laboratory

[28]Chesbrough, H.W. *Open Innovation: The New Imperative for Creating and Profiting from Technology*; Harvard Business School Publishing: Boston, 2003.
[29]PatentSight, Chemical Industry Patent Benchmark.
http://patentsight.com/index.php/benchmarkchemical.html (accessed July 2010). The ten companies are BASF, Bayer, DuPont (U.S.), Dow Chemical (U.S.), Sumitomo Chemical, Mitsubishi Chemical, DSM, Solvay, Syngenta, and Akzo Nobel.
[30]The Bayh-Dole Act of 1980 is widely credited with the substantial amount of innovation emanating from U.S. academic institutions. See: Fabrizio, K. R. The Use of University Research in Firm Innovation. In *Open Innovation: Researching a New Paradigm*; Chesbrough, H.W.; Vanhaverbeke, W.; West, J., Eds.; Oxford University Press: New York, 2006; pp 134.

As one example of the latter statement, Table II-5 in Appendix II illustrates the pace of innovation in chemistry at MIT, which has been a hot spot for startup creation with 289 companies licensing technology from the university during the 19-year window from 1990 to 2009. The number of licenses extended to purely chemical technologies during this time period is 16, compared to 42 in chemical engineering startups, and 39 in life science chemistry startups.

In summary, as the chemical industry is consolidating, and as margins decline on commoditization, established chemical companies are looking for ways to maintain their profitability and to increase their revenues. One strategy — and one that has proved difficult in execution — is to use innovation to rebuild their proprietary positions in high-margin products and to create new markets in which they have a competitive advantage. An example is 3M's recent publicized success of its Cubitron II sanding disks. With decades of abrasives experience, 3M is regaining its abrasives leadership through this innovative product that cuts faster, lasts longer, and requires less application force than other market abrasives.

Relying on internal R&D has not reliably generated incremental innovation and has largely failed at disruptive innovation. These companies are acting globally by pursuing innovation where their customer base, raw materials, and talent are found. However, the pace of this activity may not be rapid enough to keep up with innovation from global competitors and may lead to the continued perception — and perhaps reality — that they are not able to manage innovation profitably. If their competitors *are* able to develop strategies for successful innovation, the difference between innovative and non-innovative companies will be a major risk for the latter.

funding for innovation

The source, availability, and cost of capital that fuel innovation varies widely. Capital can also vary considerably by purpose and use. Without capital, innovation cannot benefit society. Funding comes from a number of sources, which we describe below.

The Federal Government

Direct investment by the Federal government, of course, has an enormous influence on the type of research that is done at universities, and, to a smaller extent, in industry. Federal and state governments also have an enormous influence on how corporate dollars are invested, through law, regulatory structure, tax policy, and tariff structures.

The pharmaceutical industry is a major beneficiary of direct federal investment in university-based R&D (primarily through the NIH). The field of chemical science has benefitted from substantially lower levels of support from the National Science Foundation (NSF), the Department of Energy (DOE), the Department of Defense (DOD), and the Defense Advanced Research Projects Agency (DARPA). The non-healthcare related chemical industry has largely not taken advantage of the availability of low-cost capital in the form of Small Business Innovative Research (SBIR) grants and mission-directed projects from the government to decrease the cost of R&D, although DOD has been a major supporter of research in materials science and related fields and provided protected markets for new technologies (e.g., composites, airframes and aerospace technology, ceramics, electronic materials, software control systems, sensors, robotics, unmanned vehicles, and others).

In contrast to its funding of basic research, the Federal government has a more limited and targeted role in aiding translational research. Through various programs, the Federal government makes financing available to entrepreneurs and small businesses through specific loans and grants.

For example, through the Small Business Administration, small businesses can qualify for a variety of Federal government-guaranteed loans through participating lending institutions. More specifically, the Federal government guarantees loans for starting or expanding a business through its Basic 7(a) and Microloan programs. Entrepreneurs, though, are not eligible for an SBA-guaranteed loan if they have access to other financing on reasonable terms and — in any event — remain responsible under these programs for repayment of the loan.

As of October 2010, more than $16 billion has been awarded by the SBIR program to various small businesses.

Through a public-private partnership, the Federal government also provides equity funding for qualified small businesses through the SBA's Small Business Investment Company (SBIC) Program. SBICs are privately owned and administer funds acquired from private sources and funds borrowed at favorable rates from the SBA. Investments can be made in the form of either debt or equity. The Federal government's SBIR and Small Business Technology Transfer (STTR) Programs can be viable and cost-effective sources of capital for innovation. Each year, 11 federal agencies must set 2.5% of their respective extramural budgets aside to fund domestic small businesses engaged in translational research projects that hold commercial promise. As of October 2010, more than $16 billion has been awarded by the SBIR program to various small businesses.[31] Additionally, five of those same federal agencies must set aside an additional 0.3% of their budgets to fund translational research projects undertaken collaboratively by small businesses and research institutions under the STTR Program.

Achieving grants under either of these programs, however, is challenging. For example, in 2010, according to the NIH's Databook, just 15% of applicants for combined SBIR Phase I ($150,000) and Phase II ($1,000,000) grants were successful.[32]

[31]U.S. Department of Health & Human Services, Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) Programs, U.S. Department of Health & Human Services website. http://grants.nih.gov/grants/funding/sbirsttr_programs.htm (accessed Feb. 8, 2011).

[32]National Institutes of Health, NIH Databook IMPAC, Success Rate File, Small Business Research (SBIR/STTR), SBIR grants: Success rates by phase. http://report.nih.gov/NIHDatabook/Charts/Default.aspx?showm=Y&chartId=96&catId=12 (accessed Sept. 2010).

Foundations and Not-for-Profits

Foundations and not-for-profits (e.g., the Bill and Melinda Gates Foundation, business organizations such as the Shriners and Rotary Club, American Heart and American Cancer Societies, Alzheimer's Drug Discovery Foundation) are playing an increasingly important role in supporting research that is more focused on outcomes and less encumbered by the academic fashions expressed by the conventional peer review system and government grants. Foundation grants and contracts also must have social outcomes and are not constrained to return financial value to stockholders. These sources are not only underwriting new applications of chemistry and allied disciplines; they are also supporting the development of alternative business models to commercialize those applications. These foundations are, of course, focused on their own missions and are not primarily concerned with the health of the chemical enterprise.

Access to Capital Markets

Startups must have capital. Access to capital comes through financing via private sources (e.g., accredited investors and venture capitalists) and, perhaps later, through public equity (e.g., IPOs), by raising debt, or through corporate partnerships. While angels and venture capital firms have traditionally played a big role in advancing innovations for startups, especially in the biotech sector, the venture industry has become conservative. The venture capital model is broken as returns on investment have lengthened from the dot-com days and the community has not been able to sell their limited partners on this change. Rising numbers of corporate ventures, and many large companies are setting up venture arms or taking stakes in VC funds in part to encourage and access innovations at startups (Appendix III).[33]

[33]Voith, M. Rising Cleantech. *Chem. Eng. News*. **2010**, 88, 6.

Industry-Sponsored Research

The Federal government is projected to remain the largest single provider of R&D funding to academia in 2011: nearly 60% of academia's total R&D funding, or more than $36 billion.[34] Support for academia by large companies pales by comparison, providing nearly $2.8 billion but growing at slightly more than 5% in 2011.

Internally, large companies are projected to spend nearly $261 billion on R&D in 2011, up nearly 3% from 2010 spending levels. And, large companies are expected to perform nearly $26 billion of research for the Federal government.

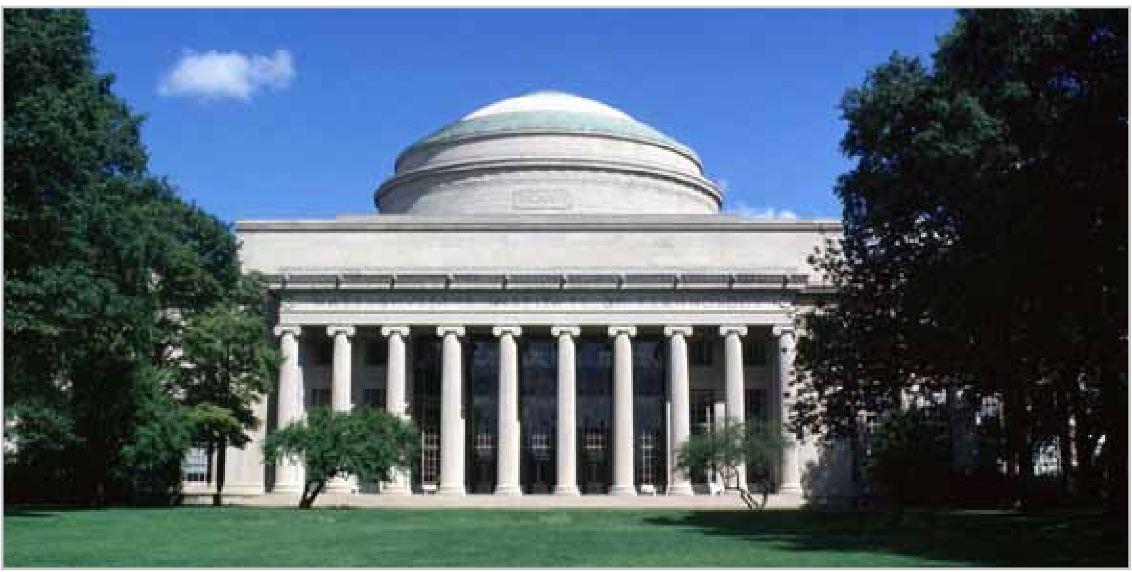
While industrial support for academic research is growing, it is not expected to grow appreciably or as fast as internal R&D funding rates for the foreseeable future. There are several main reasons for this situation. Even with an increased industrial support for academic research—perhaps due in part to the recent downsizing of R&D operations across the U.S.—mission differences, cultural challenges, intellectual property ownership issues, differences on the obligation to fund basic research, and conflict-of-interest concerns still loom within the on-going context of collaborative research. In some contexts, the business model for academia may have even changed with a perceived increased willingness to accept external, non-federal sources of funding. While efforts are on-going to address these and other concerns, there is generally more to do toward streamlining industry's support, including offering incentives, for academic research.

[34]*Science and Engineering Indicators: 2010*, Chapter 5, Academic Research and Development; Technical Report for the National Science Board: Arlington, VA, 2010.

is there a role for startups in chemistry?

In the last several decades, classical chemistry has not been an area that has been as active in technology transfer through startups as have been some other fields of science and technology. There have certainly been startups, some successful, some not.[35] Given the range of opportunities provided by societal needs, the rich flow of science coming out of the research universities, and the requirement of large companies that there be a range of technologies (or companies) for acquisition and growth, there seems to be no intrinsic reason why startups should not be more successful in chemistry than they are, and more successful in the future than they have been in the past. In many ways, in fact, the path from science to a recognizable product seems less encumbered by regulatory issues, and by very large costs such as those of clinical trials, than biomedical startups.

Why, then, are successful startups relative rarities in the chemical culture?



Donna Coveney /MIT

[35]Appendix IV is a highly selective and incomplete list of examples. These startups are included in this report to give a sense of the kinds of products on which these companies settled.

U.S. Academic Culture

The culture of university chemistry is certainly one reason. Professors in research universities typically work with industry as technical consultants, rather than as business collaborators or competitors. Generally, in chemistry departments (although not in chemical engineering and other fields), professors' words and actions promote the idea that basic research, and a career in academe, are the highest aspirations for topnotch students. This strategy is risky:

If universities are indifferent to what society needs, society may reciprocate that indifference.

In many universities, students graduate without ever being exposed to the idea that entrepreneurship might be a viable or desirable career option. They also receive little or no exposure to commercial science and technology. Educating the next generation of scientists and engineers to recognize and consider entrepreneurial opportunities that have impact on society is essential for future cultural changes in the chemical enterprise.

At the same time, the attitude toward entrepreneurism in academic chemistry is changing, albeit slowly, in some large research universities. While most faculty are still being evaluated exclusively on research and teaching for their tenure or promotion, some university administrators are noting entrepreneurial activities. A vanguard of research universities is providing proof-of-concept centers and the know-how and help required to attract the capital needed for startups.[36] Institutions that have created these entrepreneurial or proof-of-concept centers include Northwestern University, MIT, University of California (San Diego), University of Utah, Georgia Tech, University of Kansas, and the University of Southern California (Appendix V). In fact, the University of Alabama brought in a chemist with industry experience to head the school's Alabama Innovation and Mentoring of Entrepreneurs Center. The same movement is also observed in government policies, where there is increasing momentum in Congress, even in a time of tight budgets, to support commercialization of federally funded projects at universities and government laboratories.[37]

[36] Tedeschi, B. The Idea Incubator Goes to Campus. *New York Times*, Sunday Business section, New York edition, June 27, 2010, BU1.
[37] Wang, L. Improving Technology Transfer. *Chem. Eng. News*. **2010**, 88, 23.

Entrepreneurship as an Ecosystem

Entrepreneurship in the U.S. has been most successful in a limited number of geographical locations: Silicon Valley, South San Francisco, Cambridge and Boston, San Diego, Seattle, Austin, Chapel Hill, and other scattered pockets of innovation. Most studies of this phenomenon point out that entrepreneurial success reflects a complex ecosystem, not simply an energetic entrepreneur and a good idea. The most successful regions share some common traits:

- They are home to at least one university.
- There are a number of companies in various stages of development.
- There is a pool of scientists and engineers who are potential entrepreneurs, experienced startup CEOs, and supporting managers.
- There is also a pool of technicians able to move from company to company as jobs appear and disappear.
- Bankers are able to realistically evaluate risk.
- There are plenty of venture capitalists familiar with the characteristics of small businesses, facilities appropriate for the businesses.[38]

Chemistry startups have never firmly established themselves in such ecosystems, and although technical areas such as high-throughput screening and combinatorial synthesis have played roles in areas focused on by the pharmaceutical industry, they have never become large-scale technical activities. The current flurry of startup activities in energy-related industry has at least a modest chemical content.

Cost of Capital

One of the disadvantages of startup companies is the high cost of capital they require to do business. The venture capital industry — even in its heyday — was never comfortable with the risks and rewards of startups in chemistry; post-2008, they are more conservative and averse to business models with which they are not familiar. That is particularly true of those startups with a highly technical content, in which the track record of prior success is not good.

[38] *Measuring Regional Innovation: A Guidebook for Conducting Regional Innovation Assessments*; Technical Report for Council on Competitiveness: Washington, DC, 2005.

While chemical companies are not particularly attractive targets for venture capital funding, as the average margins tend to be thinner than other markets, recent investments in clean technologies like biofuels and bioproducts show that projects that ultimately require large capital projects can be started with venture capital.[39,40] Other areas that are attractive to the VC industry include those associated with water and solar energy, energy conservation, batteries, ultracapacitors, biofuels, fuel cells, carbon capture, and other energy-related areas.

Although the government—through SBIRs and similar programs—provides low-cost capital, understanding how to interact with the government through SBIRs and grants requires a familiarity with grant-writing and government processes (including specialized government accounting rules) that most chemistry startups lack. At the same time, one must recognize that SBIRs initially provide relatively small amounts of capital/cash ($50,000 to $100,000) with a high cost of time for accounting and management and low probabilities for successful award.

As noted, university proof-of-concept centers have been created to provide the know-how for startups, including how to find funding.[41] Regional governments are also exploring incentives to startups to spur creation of jobs and ultimately tax revenues.[42]

Sustaining Innovation Favors Large Companies

Beyond access to large financial resources, larger firms have a number of potential advantages in sustaining innovation. Their cost of capital is low. They have established patent portfolios and understand the intellectual property landscape. They have direct access to markets and customers, established reputations, and experienced management.

[39]National Venture Capital Association, Clean Tech Investment, VC Investments Q1-1998 to Q1-2010.
[40]Voith, M. Rising Cleantech. *Chem. Eng. News*. **2010**, 88, 6.
[41]Tedeschi, B. The Idea Incubator Goes to Campus. *New York Times*, Sunday Business section, New York edition, June 27, 2010, BU1.
[42]Jarvis, L. Seeding a Province. *Chem. Eng. News*. **2010**, 88, 20.

Intellectual Property and Products

Intellectual property in the pharmaceutical industry is relatively straightforward. A chemical compound with defined structure and composition is the product. For companies making reagents, or developing processes, intellectual property is more difficult: trade secret and proprietary know-how may be more important than patents. The type of law firm that is usually employed by universities to write patents is generally not skilled in writing chemical patents; professors and graduate students, and budding entrepreneurs employed in other organizations, typically have little understanding of intellectual property.

Although none of these matters precludes the development of a solid intellectual property foundation for a startup, it is a more complicated and expensive task than many would-be entrepreneurs recognize.

Unfamiliarity of Large Companies with Ways of Doing Business with Startups

Over the course of 30 years, the pharmaceutical industry has developed a sophisticated understanding of the characteristics of biomedical startups and has concluded that a healthy environment for startups is essential to the creativity of the pharmaceutical industry. Large classical chemistry companies have no such understanding. The "Not Invented Here" and "It's new, it can't work" syndromes are too prevalent.

Despite these challenges, there appears to be no intrinsic structural reason to believe that startups could not prosper in chemistry under the right circumstances. The business model would clearly be different from that in the more familiar pharmaceutical world: The capital required to develop a company would be smaller, the regulatory barriers would be smaller, and the size of the company (assuming an endpoint of acquisition) would be smaller than in the pharmaceutical model. There would seem, nonetheless, to be many opportunities for the development of small companies in chemistry.

the role of the American Chemical Society

The American Chemical Society serves, in principle, all parts of the chemical profession. In practice, that part of the chemical enterprise that might be involved most actively in startups and in technology transfer from research universities to industry (either large or small companies) is a financially small part of the chemical enterprise, and an even smaller part of the current focus of ACS.

And yet, one can argue (and there is evidence to support this proposition) that activities of a relatively small number of entrepreneurial scientists have the potential to have disproportionately large positive effects on the chemical enterprise and on society. We contend that ACS should focus more of its attention on these activities than it does.

The ACS might, in fact, be genuinely helpful in overcoming the barriers experienced by would-be entrepreneurs, students, and others wishing to work in startup companies, as well as members of universities and other organizations who wish to transfer their science into commercial technology. But, ACS must take this task seriously.

From idea to product, new technologies generally proceed through three stages: concept, development, and commercialization. Within each stage, certain technical, market, and business challenges must be successfully addressed. Enduring this process requires resolve amid a myriad of perplexing concerns. Does the technology yield products that offer a sustainable, competitive advantage over existing products? For what consumer need does the technology offer a solution? Can the product be cost-effectively produced, distributed, and sold? How will the venture commercializing the technology raise funds or make a profit? Is there an experienced and capable management team in place? What are the barriers and costs to registration, regulatory clearance, and market entry? These and other concerns, no doubt, will cause numerous sleepless nights for the real risk taker—the entrepreneur.

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ACS Policy
California
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ACS
Chemistry for Life®
ACS Network
Where Chemistry Connects.
Celebrate Chemistry
The International Year of Chemistry – 2011 will celebrate the achievements of chemistry and its contributions to the well-being of humankind.

Passion without resources and experience is simply not enough. ACS can do more to help.

ACS can play a vital role in providing much-needed resources to entrepreneurs. Among these resources are:

- Technical information,
- Members who are entrepreneurs and skilled, experienced business people,
- Administrative support,
- IT capabilities,
- Vendor relationships, and
- Industry partners that when leveraged strategically can and will make a major contribution to the entrepreneur's task of building a business and putting useful, safe, and environmentally sound chemistry-based products into the stream of commerce.

For the ACS, this effort can only translate into creating new, quality careers for chemists.

So, what can ACS do to help? Particularly at the concept stage, ACS's resources can supply the entrepreneur with access to a community that can provide technical expertise and management talent. In addition, ACS technical information is vital to refining the concept through its member base and information from its publishing units. These same resources could be used during early phases of the development to address more well-defined technical challenges that involve prototype development and pre-production process design. ACS's relationships with external vendors can be leveraged to obtain cost reductions or advantageous terms from professional firms to provide entrepreneurs with other critical services, such as legal, accounting, marketing, human resources, and information technology. ACS can also be instrumental in opening doors to sources of funding with accredited investors and venture capitalists having a specific chemistry-based technology and early-stage investment focus.

In addition, ACS can more actively advocate for policies at the Federal and state levels that foster innovation.

In summary, the Task Force's recommendations to ACS fall into four major thrusts:

1

ACS should develop a single organizational unit—a kind of "technological farmers' market"—offering affordable (or free) help to entrepreneurs.

This unit would support entrepreneurs by facilitating more affordable access to resources that should foster the creation of small companies from startups. Relevant resources might include information, management expertise, key services, and mentors. The unit could also support entrepreneurs in making introductions to much-needed capital and fostering partnerships with large companies.

2

ACS should increase its advocacy of policies at the federal and state level to improve the business environment for entrepreneurs and startup companies.

- It should urge reforms within the U.S. Patent and Trademark Office to assure more accurate patents and faster issuance.
- It should advocate financial policies in government that encourage large companies to partner with small ones. These include preferential tax treatment for repatriated income invested in U.S.-based developers of technology and making the R&D tax credit more simplified, permanent, and transferable.

3

ACS should work with academic institutions and other relevant organizations to promote awareness of career pathways and educational opportunities that involve or include entrepreneurship.

4

ACS should increase public awareness of the value of early-stage entrepreneurship with focused media coverage and information targeted to federal agencies that support chemistry. In addition, ACS should provide ways to recognize entrepreneurs publicly, to increase their visibility and enhance their opportunities for success.

ACS could choose as its goal becoming the first stop for chemistry-focused entrepreneurs, being careful not to duplicate what is already offered by other organizations (e.g., Kauffman Foundation, Deshpande Center or other university-affiliated organizations, regional entrepreneurial support organizations).

The next section of this report is the Task Force's thoughts on what ACS offers in each of the four categories listed above and how they could be applied to foster entrepreneurship and create jobs.

Access to Affordable Resources

1 Develop a Social-Network for Entrepreneurs

One of the challenges to starting a company is getting through the early growth phase of the startup. The ACS can aid those with an entrepreneurial mindset, who are typically limited in resources, by providing access to a network of talented and experienced scientists and engineers (some of whom might be retired) from a wide variety of backgrounds and disciplines who could support, advise, or consult.

One of the broadly held beliefs among successful entrepreneurs is that the only way to learn is to do; business schools may help you learn certain specific skills, but they do not, in general, teach you to be an entrepreneur. The ACS might find ways of providing a "dating service" connecting aspiring entrepreneurs with experienced, more senior managers of successful startup companies in apprenticeships of two to three years. ACS might also connect entrepreneurs currently starting businesses to one another in a peer-learning community, e.g., by using web-based technologies that allow real-time discussion, perhaps moderated by successful entrepreneurs.

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2 Facilitate Access to Resources for Entrepreneurs

Entrepreneurs are self-starters who will use all resources available to them. The ACS has access to a wide variety of resources that would be useful to entrepreneurs and their startups: consultants with specific chemical experience; service providers (lawyers, accountants, etc.) to aid in early business operations; examples of document and templates (NDAs, license agreements, financing terms sheets, etc.); grant assistance (identification, posting, and guidance); and introductions to financing sources (angels, VCs, etc.), among many other activities and services.

The ACS could also address the fact that although there are many resources to support innovation and would-be entrepreneurs, few of them are focused on the specific needs of chemistry. ACS could create opportunities for entrepreneurs to share services and provide reduced costs for ACS products. The ACS might consider helping to construct a pool providing legal, patent, and accounting services, which, by building the volume of business referred to law and accounting firms, could decrease its cost.

Researchers in startups often cannot afford to access important ACS resources such as SciFinder and ACS journals. CAS and ACS Publications should study whether they could provide reduced-price site licenses to incubators and/or startups for ACS publishing resources. ACS should also look into reduced prices for its short courses and other leadership and professional development courses. Even providing six months of these services free would greatly help startups, which are often cash poor.

ACS could also promote the formation of an integrated "Chemical Innovation Enterprise (CIE)."[43] The components of this enterprise already exist (as described in "The Chemical Enterprise" section of this report), but they are not an integrated resource for entrepreneurs.

[43]Elements of the Chemical Innovation Enterprise could adapt the approach used successfully to create and implement the ACS Leadership System, e.g., obtain broad-based input, including face-to-face interaction of representatives from all components of the chemical innovation enterprise, then create a small CIE Working Group to refine input and define a longer-term ACS plan. A CIE group could sponsor activities to promote understanding and respect among leaders from the components of the chemical innovation enterprise (academe, industry, government, other), and develop improved understanding of the best role(s) for each component in a holistic approach to the very large challenge of creating more jobs via chemical innovation. As part of the CIE, existing ACS legislative and grassroots advocacy programs could be expanded to include public outreach and to revise the public image of chemistry messaging to increase emphasis on the contributions of chemical entrepreneurs and the benefits to society of chemical entrepreneurial activity.

In the context of promoting an integrated Chemical Innovation Enterprise, the ACS could:

- Provide forums for leaders from the various components to interact to form a functioning enterprise,
- Provide chemistry professionals with resources focused on chemical innovation, and/or
- Provide a clearinghouse to connect chemistry professionals with helpful non-chemistry-focused resources, probably with an added chemist-friendly interface on the front-end.

A number of universities have established programs that are designed to give young scientists some familiarity with the skills they will need to operate in a startup environment (Appendix V lists some of these programs). In general, these programs are not directed toward chemists and do not provide many of the essential skills, exercises, or business training needed to operate a fledgling chemical enterprise. The ACS might help to catalyze the development of programs directed toward chemistry; since the costs of such programs are modest, industry might also understand the value of such programs for the industry as a whole, and be willing to participate financially.

3

Support and Mentor Aspiring Entrepreneurs

Many young chemists—especially those interested in R&D, and in the creation of new products—have limited interest in working for large companies. There is, unfortunately, no clear track that they can follow in thinking about entrepreneurial activity. There are a number of ways in which the ACS might be able to help to initiate the cycle of learning and success that is necessary to establish an entrepreneurial culture in chemistry.

ACS could target all chemical professionals—students, working chemists, and chemical engineers—in this effort. In particular, ACS could build on the already successful ACS Leadership Development System (LDS) by establishing an entrepreneur's track within LDS (e.g., a "So you think you want to be an entrepreneur?" overview course; other targeted courses could be focused on chemists and chemical engineers). It could enhance and add webinars (possibly interactive) with successful chemistry entrepreneurs or webinars on things you have to know to create a startup (intellectual property concerns, standards for new products[44], etc.). Among other ideas it could also:

- Provide inspiration: Create a video on the chemistry entrepreneurial experience (process, challenges, rewards ...via interviews with enthusiastic, successful chemical entrepreneurs).
- Make available (find existing, or develop) tools to help entrepreneurs self-identify (i.e., offer a checklist of required skills and behavioral characteristics for entrepreneurial success).

[44]Two programs that help small and medium businesses address related issues are the National Institute of Standards & Technology's (NIST) Standards in Trade Workshop and Notify U.S. service. The Standards in Trade workshop series helps U.S. businesses learn about standards, conformity assessment, and technical regulations in foreign countries to help them export to foreign markets. Notify U.S. service is an early warning mechanism by which U.S. stakeholders can learn about new or revised technical regulations in foreign markets that can impact product categories of interest to the stakeholder.

4 Connect Large Companies with Technical Expertise

Although much of the radical innovation in many fields has occurred in startup companies, in fact large-scale creation of jobs (or defensive prevention of job loss) occurs, in the short term, in large companies. The ACS might consider trying to help organizations that are fundamentally specialized in product line extensions, manufacturing, and customer service to be more efficient in doing so.

The information revolution is changing the way in which many companies search for information and technology that they need to maintain and expand their businesses. For the largest companies, these techniques may be familiar, if not efficiently used; for smaller companies, technical management may not be familiar with how to use these techniques. *Crowd sourcing* is one example.

Crowd sourcing is the act of outsourcing tasks, traditionally performed by an employee or contractor, to a large group of people or community—a crowd—through an open call. A prime example of this is P&G's innovative Connect & Develop initiative.[45] For example, the public may be invited to develop a new technology, carry out a design task (also known as community-based design and distributed participatory design), refine or carry out the steps of an algorithm, or help capture, systematize or analyze large amounts of data. The term has become popular with businesses, authors, and journalists as shorthand for the trend of leveraging the mass collaboration enabled by Web 2.0 technologies to achieve business goals. Both the term and its underlying business models have attracted controversy and criticisms.

Innocentive and Nine Sigma are two companies that use related models for crowd sourcing. There are many others that might be tried.[46] The ACS could play a role in helping small companies connect to large companies so together they could use these new techniques efficiently. And, through organizations such as CAS, perhaps the Society could help to develop new models that would work more efficiently for chemistry.

Recently retired ACS members are another valuable source of expertise. ACS could partner with YourEncore to create a repository of experienced chemists that could be hired on a freelance basis to solve important problems.

[45]Chesbrough, H.W. *Open Business Models: How to Thrive in the New Innovation Landscape*; Harvard Business School Publishing: Boston, 2006; pp 187-216.
[46]Chesbrough, H.W. *Open Business Models: How to Thrive in the New Innovation Landscape*; Harvard Business School Publishing: Boston, 2006; pp 141-149.

5 Foster Partnerships between Large Companies and Startups

Established chemical companies possess substantial resources—expertise, capital, and market presence, to name a few. But in order to thrive they need to develop higher margin products, based on disruptive technologies. Startups lack those resources, but have game-changing product opportunities that could benefit society if commercialized. Between these two extremes, opportunities exist to successfully collaborate, utilizing the strengths of each to overcome the weaknesses of the other.

For large companies, merger and acquisition could be a new form of R&D, while exits from business might be just as important to startups as initial investments.

In short, more can and should be done to facilitate introductions, remove distrust, find common strategic ground, and create "win-win" scenarios for these innovators.

6 Educate the Venture Capital Community

One of the factors that limit the availability of capital to startup enterprises in chemistry is that venture capitalists and investment bankers are fundamentally unfamiliar with chemistry startups. As the attractiveness of investments in pharmaceuticals has decreased and energy-related startups increased, there is a genuine interest on the part of the venture community in learning more about chemistry. The ACS could play a useful role—through short courses, or perhaps technology fairs—in helping to educate the venture community about opportunities in chemical technology. In addition, ACS can explore policy and advocacy options geared toward positively influencing venture capital laws to the benefit of chemical and allied sciences startups.

7

Provide Standards for Intellectual Property: Common Master Agreement

One of the stumbling blocks encountered in transferring a university invention into industry (whether large or small) is often intellectual property. Every university and every company seem to have their own idiosyncratic approach to valuation and licensing of IP. Universities typically overvalue their intellectual property; industry is typically opportunistic. The ACS could play a useful role—in collaboration with universities and companies — in drafting a "standard" set of agreements for confidentiality, disclosure, ownership, and licensing. These agreements would certainly not serve all purposes, but they might be extremely useful as a starting point for discussions. These agreements could be particularly valuable for startups in their potential for saving legal costs. (Appendix VI).

8

Organize Industry-Subsidized Incubators

One of the difficulties in starting up a new chemical company is that the facilities that are required are often different from those that might be available in the market. They also require a sophistication in permitting and safety that might not be present in the startup. To overcome this challenge, the ACS could help organize an industry-subsidized incubator (or incubators) in which these activities could be under shared, cost-effective management, under appropriate business terms.

Increase Advocacy of Policies that Promote a Better Business Climate for Entrepreneurs

The ACS has the political clout to speak effectively to Government. In the past, the view of "chemistry" in Washington was that it was "doing fine," and that "If it's not broken, do not fix it." As the balance of trade in the chemical industry has shifted, and as matters dealing with climate change, energy, and healthcare cost reduction have become more important, Washington has become more sensitive to the concerns of the chemical enterprise. The ACS might think more explicitly, as it carries out its advocacy activities, about policies that would encourage R&D (in companies of all sizes, but explicitly in startups). Examples of areas of focus include:

1

SBIR Policy

Majority venture-owned startups are prohibited from taking SBIR grants. This rule is scheduled to change, but continuous pressure—especially from a large, professional organization such as ACS—might accelerate the process, and thus lower the cost of capital for startups.

2

The Federal R&D Tax Credit

Since its passage in 1981, Congress has renewed the R&D tax credit 14 times. The uncertainty surrounding its renewal and the credit amount—due in large part to its complex formula— has created doubt in the business community about its benefit. With other industrialized nations providing more generous credits in support of private-sector research and development activities, making the U.S. R&D tax credit permanent would benefit essentially all large companies that carry out R&D. In some cases, it would encourage development of new products with longer time horizons. This, in turn, should encourage large companies to perform more R&D in the U.S., reducing layoffs of scientific and technical personnel.

An added advantage to making the Federal R&D tax credit permanent and more simplified is the positive net effect it should have on early-stage investment, particularly if the credit were transferable to large companies for their investment or refundable to the startup to improve its cash position. Under this scenario, private equity funds should be more willing to invest in startups, resulting in more skilled and highly paid jobs.

3 Carried Interest Provision

Another potential issue stems from emerging Congressional desire to propose changes to the tax rate regarding carried interest. The recent push in Congress for broad financial reform has opened this new front. ACS could investigate how it might influence this legislation. (Appendix VII). see text

4 Tax Incentives for Large Companies to Partner with Startups

Because of the short-term, bottom-line focus of large companies, startup entities have assumed the old roles of the R&D labs at many existing larger companies. In good times, risks are made with venture capital, and successful startup companies are often acquired or become self-sustaining larger independent entities. This model works moderately well, particularly in biotech. But other sectors, including the chemical industry, have and will continue to suffer as venture capital dries up or becomes prohibitively expensive. Large companies ordinarily prefer minority stakes in startups and couple their investments with a license right or purchase option. They have the capabilities to make bets like VCs, but they often do not do so at early stages; yet a partnership between a large company and small company (at an early stage) can dramatically increase the chances of success for the startup. Indeed, such partnerships can be the difference between success and failure for an early stage company. In addition to providing significant financial resources, the larger company often has the knowledge and infrastructure to manage the path from initial invention to innovation and translation. Perhaps, a push to facilitate such investment in startup companies by larger companies through the monetization of tax credits could contribute to solving this problem.

In addition to the Federal R&D tax credit program, at least 38 states utilize tax credit programs to stimulate economic development. State R&D tax credit programs have been said to have had "significant and positive effects" on the proliferation of high tech establishments within a state.[47] R&D tax credit programs vary by state, some offering transferability while others offer refunds. Some states allow credits to carry forward into the future and others cap the credit to a percentage of tax liability. Additionally some states allow for transferability or sale of the credits in the event the company has no tax liability.

[47] Wu, Y. In State R&D Tax Credits and High-Technology Establishments. *Economic Development Quarterly*. **2008**, 22, 136-148.

Tax considerations can create incentives for large companies considering investments in startups. Large companies ordinarily make investments in startups through newly created or existing venture arms or alongside other venture capitalists. Most Fortune 500 companies have venture arms, e.g., Intel, GE, GM, Dow, and DuPont. Life science companies are generally more active than chemical industry investors when investing in startups. While the investment motive is undoubtedly the same for any large company—an interest in the startup's promising technology and how it may fill a product portfolio gap or accelerate time to market—tax considerations play a part in the investment decision.

The often-cited Federal R&D tax credit, though, is ordinarily not a consideration. Because it cannot be monetized by the startup—either through transfer to the large company or by refund to the startup—it can never have more than an incidental effect upon the investment decision. For all intents and purposes, the Federal R&D tax credit may work, if at all, toward freeing capital for startups to further advance their promising technologies. In many cases, startups do not avail themselves of the credit due to its complexity or a failure to recognize their eligibility.

A permanent, simplified Federal R&D tax credit that is either transferable or refundable to the startup could have a profound effect upon the large company's decision to invest and dramatically increase their interest in the financing aspect of funding startups. This could, in turn, increase the pool of capital for startups, thereby improving access, terms, and affordability. Because most startups have little or no revenue for the credit to offset, the large company would likely have more immediate use for this tax credit if freely transferable. A modification of the R&D tax credit in this fashion will enable the Federal government to provide meaningful and major additional incentive to large companies to finance startups.

Interestingly, a few states have been experimenting with monetizing tax credits and appear to have experienced some success toward growing their core industry segments and some cottage industries altogether. New Jersey, Pennsylvania, North Dakota, and Minnesota legislatively provide for the sale or refund of R&D tax credits that offset revenue generated within their states. Startups in these states which are typically not yet profitable and do not have significant tax liability can sell unused R&D tax credits to large companies or receive tax refunds that improve their cash positions, allowing them to further advance and expand their business.

Tax credits for angel investing are another recent state-driven tax initiative to infuse capital into the startup community that is growing in popularity. Generally, angel investors within a particular state may qualify for a credit against their income tax for certain types of investments in targeted, emerging technology businesses. From the large company perspective, this tax credit may have unique application for investing in startups since angels – accredited investors as defined by Rule 501 of Regulation D – specifically includes corporations and partnerships with assets exceeding $5 million. Again, investment credits can be used by large companies to offset income tax.

Offshore funds are also an attractive source of investment capital. Current U.S. tax structure, however, discourages repatriating off-shore profits. As a result, many U.S. corporations keep and invest large amounts of capital outside the U.S. Initiatives that would provide favorable federal tax treatment for repatriating and investing these funds in U.S.-based startups could help create startups and jobs.

In summary, a simplified, transferable or refundable, permanent Federal R&D tax credit, coupled with transferable state R&D tax credits and angel tax credits, can provide a profound array of incentives for large companies to invest in startups. In addition, changes in policies on repatriating offshore profits and keeping long-term capital gains rates low will also encourage investment.

5 Immigration Reform

Current immigration policies are widely understood to limit the pool of talented scientists and engineers from which U.S. companies can draw. This type of limitation is particularly serious for startups. Changing the policy will be difficult right now in the United States because of great sensitivities about immigration. Yet, it is important that U.S. companies have access to the best global talent.

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6

Patent Office Reform

In 2009, David Kappos, the Director of the U.S. Patent and Trademark Office, acknowledged in a speech before the Independent Inventors Conference that "the USPTO is struggling; it's not working efficiently for inventors—corporate or independent." At the last count, the USPTO had a backlog of 700,000 patent applications. It often takes four years or more to obtain a patent. According to the U.S. Department of Commerce's recent White Paper, "Patent Reform, Unleashing Innovation, Promoting Economic Growth & Producing High-Paying Jobs," "this backlog and attendant delays cost the U.S. economy billions of dollars annually in 'foregone innovation.'"[48]

One current and widely held perception is that there are not enough highly qualified patent examiners in chemistry–related areas, which results in the issuance of patents that later become mired in legal disputes. Such legal disputes create enormous hardships for startups and small companies that are often cash poor. Also, the USPTO is the only government office that does not have satellite offices outside of the Washington, D.C., metropolitan area. With a large percentage of the graduating chemists and engineers located in the hotbeds of U.S. innovation, such as in California, Massachusetts, New York, and Texas, it would only make sense to open USPTO offices in these surrounding areas. The ACS should examine this problem and come up with recommendations for increasing the quality and retention of patent examiners in chemistry and allied fields.[49]

7

Innovation

ACS could explore ways to participate within President Obama's Startup America Partnership initiative to increase the number of startups developing chemistry-based innovation and creating quality chemistry jobs.

[48] Rai, A.; Graham, S.; Doms, M. *Patent Reform Unleashing Innovation, Promoting Economic Growth & Producing High-Paying Jobs*; Technical Report for the U.S. Department of Commerce: Washington, DC, April 2010 http://www.commerce.gov/sites/default/files/documents/migrated/Patent_Reform-paper.pdf (accessed Sept 2010).

[49] The ACS Committee on Patents and Related Matters has studied issues related to the USPTO, and ACS has issued a statement on patent reform that strongly supports a number of topics that would improve the current patent system.

Join with Academic Institutions to Promote Awareness of Career Pathways that Involve or Include Entrepreneurship

Most post-graduate programs in chemistry (those focused on individuals planning to make a career in R&D) are highly specialized in narrow technical fields. Students and other would-be entrepreneurs often are technically focused PhD.s who know nothing about money, or the operation of a business. As a result, they are unlikely to opt for startups when they choose careers, or to succeed if they do. With jobs becoming scarcer, the question of whether universities should help prepare students for careers beyond teaching and research–careers in startups or early-stage R&D companies, industry, intellectual property, or public service—needs to be revisited. For decades, this question has been contentious, with promoters of exclusive career tracks in teaching and research always prevailing in the argument. As academic science has moved closer to developmental engineering, and as jobs have become scarcer, now might be the time for the ACS to catalyze a fresh discussion of this subject.

ACS plays an active role in education, in particular through its Committee on Professional Training and Professional Education programs. Many of these resources could be harnessed to spur entrepreneurship.

1 Help Universities and Colleges Broaden Offerings in Education

The ACS should consider the question of whether accreditation should include at least minimal training in business-related activities. There is no plausible argument that a Ph.D. should be combined with an MBA for students other than those who explicitly wish that kind of background. However, a one-semester course in "conversational business" might open more options for students than a fourth course in organic synthetic methods; for example, the Management of Technology programs at schools like the University of California, Berkeley; Carnegie Mellon; and University of Washington are bringing graduate chemistry students together with MBA students in the classroom. These joint programs also foster the emergence of interesting startup ideas that compete successfully in many Business Plan competitions at these schools.

ACS's Committee on Professional Training could also consider offering a special accreditation to chemistry graduate departments that offer courses in entrepreneurship, business practices, etc., much in the way they offer approval for undergraduate chemistry departments that meet certain criteria. This "certification" or accreditation could become a source of pride and marketing for chemistry graduate programs.

2 Provide Incentives and Opportunities for Professors to Learn More About Industry

One way to promote growth of the startup culture in a university setting may be to encourage chemistry professors to learn more about opportunities in applied chemistry and perhaps to get more involved within the chemical industry in both big and small companies. This may be achieved by offering benefits to those professors who use their sabbatical time to take positions in the chemical industry and learn the requirements necessary to take a product from the lab bench to the commercial market. Some of the most prolific professors in marketing chemical solutions and building chemical companies have done just this, either working in industry for a period of time or sitting on chemical industry boards. In turn, industrial sabbaticals might stimulate further industry/academic collaboration and increase levels of funding support from industry.

Increase Public Awareness and Recognition of Entrepreneurship and Entrepreneurs

1

Utilize C&EN to Record and Recognize Successful Entrepreneurs

Chemical & Engineering News (C&EN) is the official weekly news magazine published by the American Chemical Society. It has wide circulation and potentially could be much more influential as a catalyst for change in chemistry than it is currently. Its internal view has been that its role is restricted to that of a news magazine for the chemical enterprise, and that it is not a teacher. Much more active coverage of successful and unsuccessful startups, with an emphasis on lessons learned, would be an example of the type of coverage that C&EN could use to bring attention to opportunities for entrepreneurial activity, and point—at least in general terms— toward directions and contacts that would be useful for a young scientist who is interested in entrepreneurship. Sponsored blogs and related activities could also be helpful. For example, C&EN could run an annual Top 100 Chemistry Entrepreneurs feature and provide periodic coverage of new careers in chemistry.

2

Recognize Chemical Entrepreneurship

ACS is in an excellent position to encourage and reward chemical entrepreneurship through its national and regional awards program. ACS should examine its current ACS national awards and consider whether it might wish to add one for innovation and entrepreneurship. It could also consider a competitive award (open to academe, industry, other organizations) to honor those who *encourage* chemistry-focused innovation. Being known as an ACS Entrepreneur — especially early in the life cycle of a company — might attract more interest from potential investors, partners, and government support.

An ACS business-plan competition for graduate students and postdocs could also be useful in attracting attention and encouraging entrepreneurship.

ACS has a unique opportunity to lead the facilitation of entrepreneurship and startups in the chemical enterprise and, in turn, spearhead the creation of quality jobs based on disruptive technologies.

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VII. CONCLUSION

The economic downturn of 2008-2009 and its lingering effects—persistent unemployment, tight credit, risk adverse capital markets—is more a reset than an adjustment. "Now", not 1999, is the new reality. For job growth to return to the chemical enterprise, new ways of promoting the commercialization of technological advances must be identified and implemented. Large companies can ill afford to assume "business as usual" and must, instead, consider entrepreneurism and startups as sources of innovation. Because economic and global competition will continue to apply downward pressure on margins in commodity chemicals, job growth for U.S.–based chemists in this sector appears unlikely.

There is an opportunity, however, for established chemical companies to rebuild their proprietary position in higher margin products and create new markets in which they have a competitive advantage through the commercialization of disruptive technologies. Opportunities exist for them to participate as partners with small companies and startups in the development of these new products. Since the chemical industry has not been as active in generating startups, developing an active culture of startups would be beneficial to society and the chemical profession. This, in turn, would create new jobs for innovative young chemists and seasoned professionals alike. Finally, there is an important opportunity for universities to broaden their outlook and educate chemists in a way that entrepreneurship and innovation become valued as part of an undergraduate and graduate education in chemistry.

VIII. TASK FORCE MEMBERS

Joseph S. Francisco

Dr. Joseph S. Francisco, 2010 ACS President, is the William E. Moore Distinguished Professor of Earth and Atmospheric Science and Chemistry at Purdue University. He appointed the Task Force which wrote this report. Francisco received a B.S. at the University of Texas, Austin, and his Ph.D. in chemical physics at the Massachusetts Institute of Technology. Francisco was a Research Fellow at Cambridge University in England, and a Provost Postdoctoral Fellow at MIT. In 1986, he joined the faculty at Wayne State University. In 1991, he was a Visiting Associate in Planetary Science at California Institute of Technology. He joined the faculty of Purdue University as Professor of Chemistry and Earth & Atmospheric Sciences in January 1995. Francisco has published more than 400 peer-reviewed publications in the fields of atmospheric chemistry, chemical kinetics, quantum chemistry, laser photochemistry, and spectroscopy. He was President for the National Organization for the Professional Advancement of Black Chemists and Chemical Engineers (NOBCChE) from 2005-2007. Francisco recently received the Alexander von Humboldt U.S. Senior Scientist Award by the German government and was appointed a Senior Visiting Fellow at the Institute of Advanced Studies at the University of Bologna, Italy.

George Whitesides

Dr. George M. Whitesides, chair of the ACS Task Force on Innovation, is the Woodford L. and Ann A. Flowers University Professor at Harvard University. Whitesides received an A.B. from Harvard University and a Ph.D. from the California Institute of Technology. He served on the chemistry faculty of the Massachusetts Institute of Technology from 1963 to 1982 and has been on the chemistry faculty of Harvard University since 1982. His wide-ranging research interests are in the areas of physical and organic chemistry, materials science, biophysics, complexity and emergence, surface science, microfluidics, optics, self-assembly, micro - and nanotechnology, science for developing economies, catalysis, energy production and conservation, origin of life, rational drug design, cell-surface biochemistry, simplicity, and infochemistry. He has extensive experience in entrepreneurship and has started a number of companies. Whitesides is a much honored chemist who is a member of both the National Academy of Sciences and the National Academy of Engineering and a foreign member or fellow of numerous international scientific societies. He is a member of the American Chemical Society.

Henry Chesbrough

Dr. Henry Chesbrough, Haas School of Business, University of California, Berkeley, created the theory behind and coined the term "open innovation." His insights into open innovation models have restructured the world of research and development and created new landscapes of business development and innovation strategy. Among his books are "Open Innovation: The New Imperative for Creating and Profiting from Technology" (Harvard Business Press, 2003), "Open Business Models: How to Thrive in the New Innovation Landscape" (Harvard Business Press, 2006), and "Open Services and Innovation" (Jossey-Bass, 2011). Chesbrough is executive director for The Center for Open Innovation at UC Berkeley. Prior to joining UC Berkeley in 2003, Chesbrough was an assistant professor of business administration and the Class of 1961 Fellow at the Harvard Business School. Chesbrough previously worked for 10 years in various Silicon Valley companies. Chesbrough has a Ph.D. in Business Administration from the UC Berkeley, an MBA from Stanford University, and a BA from Yale University.

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Dr. Pat N. Confalone is Vice President, Global R&D, DuPont Crop Protection. He received a B.S. from MIT and Ph.D. from Harvard. After a postdoctoral stint at Harvard, he joined the Chemical Research Department of Hoffmann-La Roche. Moving to DuPont in 1981, he contributed to the development of fluorescent DNA sequencing reagents employed in the human genome project; Cozaar™, a major anti-hypertensive based on angiotensin II antagonism; and Sustiva™, a highly successful drug used to treat AIDS. Confalone has published 140 papers and obtained 50 U.S. Patents. He serves on the Editorial Advisory Boards of *Current Drugs*, *Bioorganic and Medicinal Chemistry*, *Journal of Organic Chemistry*, *Synlett*, *Progress in Heterocyclic Chemistry*, *Synthesis*, *Medicinal Chemistry Research*, *Medicinal Chemistry Letters*, and *Drug Design and Discovery*. Confalone is a member of the ACS Board of Directors, and the governing boards of the Council for Chemical Research and the United States National Committee for IUPAC. He is a Fellow of the American Association for the Advancement of Science.

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Charles T. Kresge

Dr. Charles T. Kresge is the R&D vice president for Performance Plastics, Hydrocarbons and Chemicals & Energy Divisions at the Dow Chemical Company. Kresge joined Dow in 1999. Before joining Dow, he worked at Mobil Oil Company. Kresge holds over 100 patents dealing with novel catalysts and their applications and has published 50 scientific articles. Kresge is the co-recipient of The Donald W. Breck Award in Molecular Sieve Science. He also received an R&D 100 Award for Innovation and the Thomas Alva Edison Patent Award. He has served on the boards of the International Zeolite Association, Mesoporous Materials Association, the International Congress on Catalysis, and the Board of Chemical Sciences and Technology of the National Academies. He is President of Dow International Technology Corporation and serves on the Board of Directors of Univation Technologies LLC. Dr. Kresge is a member of the National Academy of Engineering. He received a B.S. from Swarthmore College and a Ph.D. from the University of California, Santa Barbara. Kresge is a member of the American Chemical Society.

Michael Lefenfeld

Michael Lefenfeld, President & CEO of SiGNa Chemistry, has dedicated his career to cutting-edge scientific research and developing innovative technologies that make people/industries safer, products greener and societies more sustainable. He holds an M.Phil. in Chemistry from Columbia University and a B.S. in Chemical Engineering from Washington University in St. Louis. At age 19, Lefenfeld created a medical sensor that became the basis for most pulse oximeters in use today. Lefenfeld's next discovery—a process to stabilize reactive metals—led to the formation of SiGNa to advance the technology. SiGNa has since created products that improved the safety, efficiency, and sustainability of many industries and is now commercializing its revolutionary hydrogen generation technology, which will make affordable and sustainable energy a reality for all. Lefenfeld has been recognized with the Presidential Green Chemistry Award, the WEF Technology Pioneer Award, among others. He is an adjunct faculty member at Michigan State University and a member of the Alzheimer's Drug Discovery Foundation's Board of Overseers. Lefenfeld is a member of the American Chemical Society.

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Dr. Chad A. Mirkin is the Director of the International Institute for Nanotechnology, the George B. Rathmann Professor of Chemistry, Professor of Chemical and Biological Engineering, Professor of Biomedical Engineering, Professor of Materials Science & Engineering, and Professor of Medicine at Northwestern University. Mirkin is known for development of nanoparticle-based biodetection schemes, the invention of Dip-Pen Nanolithography, and contributions to supramolecular chemistry. He is the author of over 450 manuscripts and over 380 patents and applications. He is the founder of three companies, Nanosphere, NanoInk, and AuraSense, which are commercializing nanotechnology applications in the life science and semiconductor industries. Mirkin has been recognized for his accomplishments with over 70 national and international awards, including the $500,000 MIT Lemelson Prize. He is a Member of President Obama's Council of Advisors on Science & Technology, and a member of the Institute of Medicine, the National Academy of Sciences, and the National Academy of Engineering. Dr. Mirkin received a B.S. from Dickinson College and a Ph.D. from Pennsylvania State University. He is a member of the American Chemical Society.

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Dr. Kathleen M. Schulz is President of Business Results Inc., a company based in Albuquerque, N.M., that provides coaching, consulting, and facilitation to help leaders get results. Dr. Schulz worked for more than 40 years in nearly every sector of the chemical enterprise, in positions including college professor, bench chemist, project manager, business unit director, and consultant. She has worked for organizations ranging from Hewlett-Packard and Lockheed-Martin to Midwest Research Institute and California State University-Fresno. Dr. Schulz earned a B.S. from Eastern New Mexico University and a Ph.D. from University of Missouri. She has received additional training in leading and communicating change, organization development, and human performance improvement. Dr. Schulz is a member of the ACS Board of Directors and was elected ACS Fellow. She has more than 30 years as a volunteer for ACS. Dr. Schulz is a founder of the ACS Leadership Development System (LDS) and certified to facilitate five LDS courses.

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Dr. Timothy M. Swager is the John D. MacArthur Professor of Chemistry at the Massachusetts Institute of Technology. He serves on multiple editorial, governmental, and corporate scientific advisory boards and is a member of the National Academy of Sciences. Swager's research interests are in design, synthesis, and study of organic-based electronic, optoelectronic, sensory, high-strength and liquid crystalline materials. Swager's demonstrations, that chemical sensory responses can be amplified by exciton and charge transport in electronic polymers, have resulted in new conceptual approaches to sensory materials. These methods are the basis of the Fido™ explosives detectors, which have the highest sensitivity of any explosives sensor every produced. These detectors were the flagship products of ICx Technologies, which was recently acquired by FLIR Systems for $274 million. Swager has recently co-founded DyNuPol Inc., which produces dynamic nuclear polarization materials for MRI imaging and biological structure determination. Swager received a B.S. from Montana State University and a Ph.D. from California Institute of Technology. He is a member of the American Chemical Society.

IX. APPENDICES (available on the web at www.acs.org/CreatingJobs)

Appendix I— Chemistry's Contributions to the U.S. Industrial Base
Appendix II— A Brief History of U.S. Innovation in Chemistry
Appendix III—Examples of Corporate and Academic Venture Funds
Appendix IV—Sample Start-Up Companies in the Chemical (allied) Industries
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NOTES

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