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SCIENCE POLICY

WHO WILL BANKROLL THE NEXT BIG IDEA?

Miniature robots, personalized drugs and other potentially life-changing technologies lie waiting in the laboratory, lacking support. Here's how to fix the problem

By David J. Kappos

OUR MODERN WORLD is blessed with a wide array of products and services, health care options and medical treatments, gadgets and indulgences, all of which arrive on the scene with a rapidity that few of us can absorb. We find ourselves surprised and amazed by these wonderful innovations, and then we come to depend on them. What did we do before we had GPS, camera phones, brain scans and laser eye surgery?

The things that give us comfort and convenience and that improve our safety and health are the fruits of basic discoveries made decades ago in materials, software, computation, biology, chemistry and information technology, among other fields. And the rate at which new discoveries emerge from academic and government laboratories shows no sign of slowing. By such measures as academic papers and patent filings, science output continues to run as strong as or stronger than at any previous point in history. Moreover, with China, India and other nations coming onto the research scene in a big way, there is every reason to anticipate more great science in the future.

Great science does not automatically translate to world-beating technology, however. That transition requires time, money and patience -- commodities that are lately in short supply. Indeed, the traditional ways of moving discoveries out of labs and into real-world applications have come under a good deal of stress in the past generation. Unless we address this shortfall, our bright prospects will not come to pass. We are, in many ways, living off the success of yesterday's investments.

Sources of funding and effort have grown tenuous at two crucial and costly steps in the path from lab to marketplace: at the early stage, when new scientific concepts are being applied to promising (but speculative) practical uses, and at the late stage, when a technology is making the transition to an actual product that has to be tested and perfected for market introduction. The vehicles for moving basic research through these twin valleys of death used to be the province of big corporate labs, but these institutions have largely ceased to perform that role. Venture-capital firms have not picked up the slack but instead have opted for "de-risked" prospects that are significantly downstream from the output of basic research labs.

This trend has put a squeeze on innovation across the board. Raw technology requires substantial investment to shepherd it into the marketplace. The payoff is often uncertain. Communications and green technologies -- two key areas -- are particularly vulnerable to rapid copying in ways that intellectual-property laws often cannot address. Translational R&D in general presents a less attractive business proposition than do downstream investments, in which the major challenges have already been overcome. Unfortunately, shortcuts to pushing breakthroughs forward are few and far between.

The crisis we now face is an opportunity to build a more open, freewheeling and bottom-up support system for the long march from lab to marketplace -- one that may ultimately be more robust and better suited to the technologies of our age. Partnerships among governments, universities and corporations will have to replace the corporate largesse of old. To pull this off, we need a new culture of innovation, in which many smaller players work in concert to keep the pipeline of ideas flowing.

SIRI AND OTHER "LATENT OPPORTUNITIES"

AMERICAN SCIENCE and R&D constitute a dominant force on the world. From 1996 to 2011 the number of citable documents in scientific publications, including articles, reviews and conference proceedings produced by U.S. researchers, grew from roughly 310,000 a year to approximately 470,000 a year -- far more, in absolute terms, than those of any other nation and at a faster growth rate than those of any nation other than China. During the same period, the percentage of published papers that list collaborators from the U.S. and at least one other country has also climbed, from about 22 percent to nearly 30 percent, illustrating, in part, the growth of international joint development -- a product of better communication and data sharing. These numbers are strong, but behind them there is cause for worry.

To understand why, consider Siri, the cheeky iPhone assistant that emerged in 2011. Siri's roots go back to a $150-million, five-year, government-funded Defense Advanced Research Projects Agency initiative. Led by SRI International, it had 22 partners, including the Massachusetts Institute of Technology, Carnegie Mellon University and Stanford University. SRI continued to develop the technology before spinning it out as a stand-alone company with venture-capital backing. By the time Steve Jobs bought the firm for Apple in 2010, Siri had absorbed $175 million and seven years of development.

Siri is much more than a novelty for smartphones. The computing advances necessary to understand, process and respond to spoken-word queries regarding the location of the nearest Starbucks could soon be answering far more weighty questions. Imagine being able to consult a Sirilike tool about the lump you just found in your breast and having confidence in the answer. Such latent opportunities often become apparent during the course of moving a research idea through product development.

The case of Siri shows how what may seem like a simple path from R&D to marketplace can be long and winding. Larger-scale innovations in clean energy and pharmaceuticals often require decades of effort and a billion dollars or more in investment. Many of tomorrow's potential society-altering technologies currently lie waiting, full of promise but lacking support. Personalized drugs, which target individuals and their ailments, could one day alleviate great suffering. Yet the enormous cost and time to develop and test such specialized formulations under our regulatory regime make the investment a difficult sell. Advanced miniature robots, which could be inserted into the body to remove plaque from arteries, are another technology in waiting. Miniaturized, unmanned flying vehicles, currently a lab curiosity, could play a big role in advanced weather prediction or air-quality monitoring. As federal research dollars shrink and corporate labs focus on near-term product development, who will fund these technologies?

THE LEGACY OF BIG CORPORATE LABS

IN THE MID- TO LATE 20TH CENTURY the great corporate research labs served as a bridge from research to marketplace. One of the last important examples of corporate funding is strained silicon, the technology we have to thank for the amazing increase in performance of microprocessors in the past decade or two. Strained silicon is a technique for increasing the efficiency of silicon-based electronics; it involves depositing germanium onto silicon such that the space between silicon atoms grows, increasing circuit performance. Strained silicon started as an idea in a Cornell University lab in the late 1980s, then caught the attention of researchers at AT&T Bell Laboratories, who wanted better semiconductors for telephone switches. The company invested significant resources in this speculative technology even though the payoff was unclear. In 1996 the lead researcher, Gene Fitzgerald, then at M.I.T., formed Amberwave Technologies to commercialize it. From there it took another seven years and millions of dollars more before Intel unveiled its strained silicon -- based "Prescott" Pentium 4 processor.

Examples abound of technologies that shape our lives that would not have seen the light of day without support from big corporate labs. Hydraulic fracturing, or "fracking," dates back to the 1800s but only found widespread commercial use after Stanolind Oil, part of Standard Oil of Indiana, took up the technology in the 1940s. It took decades of further development before the technology could tap natural gas from previously unreachable reserves. The circuitous route of 3-D-printing technology started as ink-jet research at Siemens in the 1950s, which wound through Stanford's medical school, IBM, paper company Mead, and, eventually, Hewlett-Packard and other printer manufacturers.

The road from laboratory research breakthrough to practical implementation to marketplace success is long and unpredictable and requires numerous iterations. Today's product-focused companies cannot be expected to bear the expense of this undertaking. But it is crucial that we find a way to do so. Indeed, the withdrawal of big corporate research is already being felt, both in the U.S. and elsewhere.

SHORT-TERM PRESSURES

SHORT-TERM MARKET PRESSURES have already weakened investment in solar technologies and transportation electrification. In the information and communications technologies, the National Academy of Sciences has warned that "federal longterm basic research aimed at fundamental breakthroughs has declined in favor of shorter-term, incremental, and evolutionary products whose main purpose is to enable improvements in existing products and services." The U.S. no longer leads the world in "R&D intensity," the Telecommunications Industry Association notes, having fallen to eighth place among the Organization for Economic Co-operation and Development countries. "Over the past 35 years," it says, "the U.S. federal government has been the primary sponsor of basic research as all but a few corporate R&D laboratories no longer were able to afford the high costs and risks of basic research. Their corporate mandates required shorter-term R&D with faster paybacks."

The story is similar in Europe and Asia. Large corporate funding sources for translational research have diminished or remained flat in those countries, mostly from the same short-term pressures and belt tightening. At least the U.S. has some venture capital to cushion the blow -- Europe and Japan are not so lucky.

The rise of China and India has generated a new dynamic. Those countries could reinvigorate research, but they might also pose a threat to established technological nations. China could invest billions of dollars of state-controlled capital on product research stemming from basic research conducted in the U.S., Europe and Japan, thus reaping the resulting jobs and economic prosperity. Patent rights usually expire by the time such research reaches the marketplace, so China would not have to violate any intellectual-property rights. In fact, because commercializing basic research produces intellectual property in its own right, China could wind up demanding royalties from inventions stemming from research in other countries.

India's strategy is no more reassuring. It has effectively nationalized important patents to the benefit of its drug industry. Whether it will extend this approach beyond health care remains to be seen.

There is a positive view of the rise of China and India, however. Because those nations support a growing fraction of the world's scientists, it is only logical that they will produce more breakthroughs. Consumers everywhere will benefit. Even if China, say, takes U.S. research and turns it into products, that would be better than if no one did so.

FILLING THE RESEARCH GAP

IN THE ABSENCE of big corporate sponsors, the U.S., for one, must recalibrate its approach to support the transition of research from lab to marketplace. We will have to make some sacrifices in our long love affair with free-market competition and face up to the fact that parts of the hard, costly, uncertain process of innovation require major support from federal, state and local governments.

The recent furor over the failures of solar firm Solyndra and hybrid-battery maker A123 Systems has given federal investment in technology commercialization a bad name, but this kind of investment must continue. Washington needs to spread its bets and fund a wide range of entities -- from government research labs to privately funded technology start-ups that are well positioned to turn research into products and services. After all, the Internet grew out of research in the Department of Defense, GPS positioning came from military research, and flameresistant clothing now used by firefighters originated at NASA. When the National Science Foundation celebrated its 60th anniversary in 2010, it listed 60 discoveries supported from its coffers: magnetic resonance imaging, fiber optics, supercomputers and cryptography, to name just a few.

Federal support is only one step. We also must encourage partnerships that combine the public resources of our government agencies and major research universities with investments of time and funding from private industry.

This hybrid public-private approach is not new, but it has so far been mostly restricted to small, fringe projects, many of them underfunded. Technology-transfer offices at elite universities are not well integrated into the primary operations of the academic community. State-organized collaborations between publicly funded researchers and private industry to grow new companies -- and high-value jobs -- are not yet broad enough to encompass investments stretching to early stages.

Some useful models are emerging, however. Research for Advanced Manufacturing in Pennsylvania (RAMP) puts Carnegie Mellon and Lehigh University together with Pennsylvania companies with the aim of discovering new technologies and accelerating the flow of knowledge between university research institutions and private industry. RAMP investments include next-generation research on industrial applications of 3-D-printing technologies and a manufacturing process for blood plasma -- based biomaterials.

Other states are also creating frameworks to encourage partnering. For fiscal year 2012, Ohio allocated $25 million in funding for world-class public-private research labs that focus on advanced materials, regenerative medicine, fuel cells and energy storage, and alternative energy. In 2005 the state of Texas established the Emerging Technology Fund to provide matching funds to private firms that want to commercialize research originating from Texas universities or the nasa Johnson Space Center in Houston.

MONEY FOR THE LONG HAUL

WE NEED MORE such collaborations. How do we encourage both public and private actors to engage in them? The National Advisory Council on Innovation and Entrepreneurship, formed by the U.S. Department of Commerce, brought together thought leaders from industry, venture capital and universities to address this question. The council came up with a number of recommendations to encourage these groups to cooperate. Federal agencies can foster opportunities for high-risk innovative research. Industry and universities can strengthen their strategic investments in advancing technologies of mutual interest. And they can all start programs to connect university faculty and students to potential industry partners, entrepreneurial mentors and sources of "proof of concept" funding.

Federal agencies could help universities incorporate innovation components into grant applications. Universities that use their intellectual property in collaborations with industry could be granted preferential tax treatment. At the same time, university

technology-transfer offices could strive to maximize the benefit of discoveries to society rather than maximizing revenues to their university.
Our regulatory processes also need streamlining. In highly regulated but rapidly advancing industries such as green energy, regulations designed for the days when data were scarce and time-consuming to process put an unnecessary drag on innovators. Eliminating bottlenecks would speed things up and lower costs.

Europe and Asia have taken steps to establish incentives for innovators. France, China and Japan have adopted volume-based research tax credits, which reward companies for the sum total of their R&D activities. In contrast, the U.S. grants tax credits in piecemeal fashion, a cumbersome method that many American firms do not bother with. The continued development of the European Research Area, first launched in 2000 and relaunched in 2007 to focus efforts on a shared vision by 2020, has led to an increase in R&D investment and cooperation among European nations. Perhaps the U.S. could form a federated research organization for the Americas.

The idea behind these ideas is to change the culture into one that recognizes the value of investing for the long haul and creating sensible incentives. If we do this right, we will have built an innovation ecosystem that will continue to turn great science into transformative technology for another century.

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