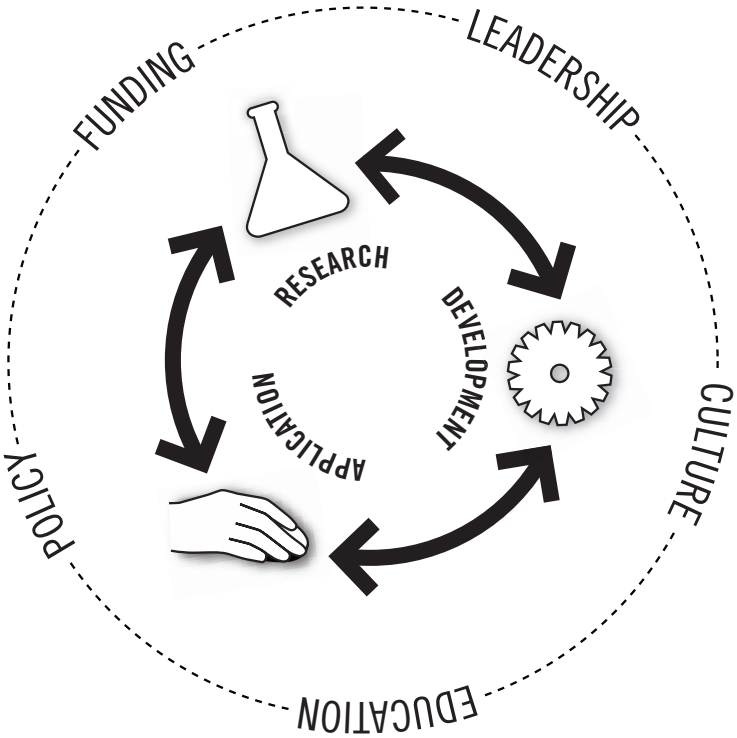

CHAPTER 2

THE INNOVATION ECOSYSTEM

I couldn't possibly keep track of my life without my "sticky notes." The story of how Post-its came to be is a classic tale of the communities of the Innovation Ecosystem collaborating to develop a world-changing product from a serendipitous discovery.

In 1968, a scientist named Spence Silver at 3M's lab in Minneapolis was researching ways to make the company's tape-based adhesives stronger. He failed to find what he was looking for, but instead he stumbled on something new: an adhesive that was strong enough to stick to many surfaces but could be easily removed and reused. Silver could have just moved on to try other ways of developing a stronger adhesive. But as a researcher in a lab that permitted a certain amount of open-ended exploration, he was not constrained by a predetermined outcome, and he was intrigued by the potential of his accidental invention.

Silver spent the next five years prototyping different forms of glue and working with others in the company to figure out how his discovery could be turned into successful products. Then one day, a scientist in 3M's product development department named Art Fry felt frustrated because the bookmarks kept falling out of his hymnal in church, and remembered hearing something about Silver's temporary adhesive. He wondered if it

could be used to create bookmarks that would stay put until you no longer needed them.

Transforming Silver's discovery and Fry's notion into the Post-it Notes we use today was not a painless process. Many naysayers in the company said things along the way like, "Who would pay for a little scrap of paper?" But Fry was tenacious in his pursuit, and 3M's leadership was supportive.

When Post-its finally hit the market in 1977, they didn't catch on immediately. Consumers couldn't imagine why they would need the product until 3M decided to widely distribute free samples. Once people saw how these versatile little sticky notes could be used, their imaginations ran wild. The Post-it brand is now a family of products for people of all ages to use at work, at home, and at school—including digital Post-it software for personal computers that uses no adhesive at all.

These all-important multicolored pieces of paper are a result of a thriving Innovation Ecosystem: Silver's research, which led to the discovery of a new form of glue; Fry's brainstorm to develop a line of Post-it products; and consumers who are continually finding new uses for them to this day. 3M's leadership understood the fundamentals of innovation and provided the right environment for talented, persistent employees to work together.

NATURAL INNOVATION

In the foothills west of Stanford University, there are 1,500 acres of land used for research in environmental restoration and habitat conservation. The locals have nicknamed this beautiful area "the Dish" after the radio telescope that sits at the top of the hill. For us, it is a prime recreation site for hiking and jogging. Each day, as I walk my familiar trail around the Dish, I am surrounded by nature's own restless creativity.

Trees, grasses, and wild mustard blanket the hills—golden brown in the heat of the summer, turning to a beautiful green and yellow after the rains come in the fall and new growth starts to appear in the spring. Hawks circle overhead, looking for food. Squirrels are everywhere, having grown comfortable with people in their midst. Snakes, lizards, gophers, jackrabbits, deer, bobcats, and the occasional mountain lion also consider the reserve their home. And among all of the wildlife are other people like me, walking and talking about personal, professional, or global problems, rain or shine, inspired by gorgeous views of the Stanford campus and Silicon Valley. Last summer, a fire burned 128 acres of the area, destroying plants and chasing away the inhabitants. But within weeks, with special care and nurturing by conservation biologists from the university, life on the Dish began to revive.

The Dish is an ecosystem: a dynamic interaction of living communities and their environment, working together to transfer the energy and nutrients necessary for survival. Every single tree that I pass is a living network unto itself, and the 1,500-acre reserve is only a small part of the larger ecosystem of the Bay Area. An ecosystem can be as narrow as a single stream or as wide as an ocean, but in all cases, ecosystems fail if they are not in balance, with the right environmental factors to support the species living within them.

The Innovation Ecosystem is made up of communities of people with different types of expertise and skill sets. Scientists, administrators, business leaders, engineers, writers, educators, health-care professionals, and other individuals all play a role. Each community must receive the nutrients it deserves through leadership, funding, and public attention.

Just as the health of a single tree in the Dish is dependent upon on the health of the ecosystem of the whole Bay Area, so the Innovation Ecosystem of any particular business or group

relies on the broader environment for innovation in the country and in the world. The various inhabitants of an Innovation Ecosystem can be classified into three communities: *research*, *development,* and *application*.

Activity in the research community benefits the entire Ecosystem in its quest for new knowledge; it is typically classified on a spectrum that runs from "basic" to "applied." Basic research thrives when the fewest external constraints are placed upon it. The search to understand the relationship between electricity and magnetism and the study of genetics and heredity are two examples of basic research that became critical building blocks for future innovations. Louis Pasteur, who developed the germ theory of disease, once remarked that "in the field of observation, chance favors only the prepared mind." Basic research prepares the mind of the scientific community as a whole and creates an environment for discovery.

Applied research, on the other hand, is framed by defining a particular problem to be solved. The invention of the transistor to replace expensive vacuum tubes was a triumph of applied research. The ongoing hunt for a specific set of genes that increases a child's chances of being born with autism is another example of applied research that is building on the discoveries of basic science. Although consideration of a potential market may play a role in applied research, addressing a specific business need is usually the role of the development community.

Researchers typically enjoy exploring the ambiguity of broad unanswered questions. They get positive feedback from the challenges of the process itself, sharing ideas and peer recognition. In view of its crucial role in the Ecosystem, research should be judged not by the number of patents obtained, but by the amount of new knowledge brought into the world by scientists, and by former students providing the foundation for innovation in other communities.

In a world that increasingly values commercial endeavors more highly than the quest for scientific knowledge, the importance of basic research is often taken for granted or forgotten entirely. What is often called corporate research is usually just advanced technological development, constrained by the needs of a specific business rather than being motivated by a desire to further general understanding. It does not benefit the rest of the Ecosystem in the same ways that the research community does, and it should not be seen as a substitute.

In the natural ecosystem of a tree, the branches and leaves won't get any water without a well-developed root system. In the Innovation Ecosystem, without a thriving research community at the roots, long-term, sustainable advancement is not possible.

The development community brings ideas to market; it includes the engineers, designers, marketers, and salespeople who turn new discoveries into usable (and hopefully user-friendly) products and services. A Pfizer scientist could leverage the discovery of a hormone that modulates insulin into a revolutionary drug for treating diabetes. Product developers may fashion new concepts from already-existing technologies, such as packaging a pregnancy test so that it's convenient for home use or creating a software application for organizing digital photos. Engineers may refine production methods toward a goal of greater efficiency, as those at Intel have been doing for decades at chip fabrication plants.

Those in the development community want to build something great and tend to favor breadth over depth. Rather than working on the same problem set for a decade, they are often anxious to move on and tackle the next challenge. Their rewards come from translating ideas into products, recognition of their contributions, and the positive feedback gained from seeing these products in use.

After one particularly frustrating meeting at Packet Design, chief scientist Van Jacobson observed that it was as if the researchers and developers were speaking different languages. The developers were like rock climbers—they wanted to find the tallest mountain and were excited about climbing to the top as quickly as possible. The researchers were like cartographers—their goal in climbing a mountain was to gain a better perspective of what interesting terrain lay ahead. This was an essential insight for us as a company. In understanding the perspectives of the different scientists and engineers, we could play to each person's strength and enable him or her to work better as a member of the team.

The application community drives activity throughout the Ecosystem by bringing science or technology to bear on the needs of individuals and organizations. In touch with the day-to-day needs of the world at large, the members of this community provide crucial information for researchers looking for problems to solve and developers navigating a swiftly changing technological landscape.

These are the scientists who choose to be internists, surgeons, or psychiatrists, doing clinical work as opposed to research in a lab. They're the engineers or developers who enable users to take advantage of what technology has to offer or the individuals who use the latest technological gadget to organize their lives. The application community is on the front lines of innovation, because it's not the mere existence of a technology, but rather the adoption of it, that creates change.

For Google to become the tech powerhouse that it is today required more than turning academic research on new algorithms into a nifty new search engine for the Web. The company also had to develop a business model that would provide it with a steady source of income for the long term. Google's

AdWords program—which displays unobtrusive paid advertisements alongside the algorithm's trustworthy search results—has proved to be as innovative and effective as the search engine itself. Furthermore, Google's application of state-of-the-art IT strategies to implement its widely distributed "cloud" of data centers has provided the necessary technical foundation for the ever-increasing scale of its business. Smart research, development, and application have all played indispensable roles in Google's success.

The sustainability of our national Innovation Ecosystem will depend upon maintaining a healthy balance between all three communities. We need a bold and well-funded research community to discover new knowledge and ideas looking far into the future. We need a prolific development community to make advances in the production and delivery of products and services. And we need a thriving application community to bring these advances to people throughout the world.

A well-balanced Ecosystem will be required to address the most serious challenges that we now face as a society. Reducing our dependence on oil and reversing the trends in climate change will require companies and individuals to find ways to conserve energy and use less petroleum-based fuel. We will need new kinds of hybrid cars, more efficient appliances, and groundbreaking ways of moderating energy demand. At the same time, we need to invest in basic and applied research to discover new sustainable energy sources and lessen our impact on the environment.

As in a natural ecosystem like the Dish, boosting the health of any part of the Innovation Ecosystem increases the vigor and adaptability of the whole. Organizations that reach outside of their primary community to tap the intelligence and resources of all three are leading the way to sustainable innovation.

AN INTERESTING EXPERIMENT

The Genomics Institute of the Novartis Research Foundation (GNF) is a new model for interdisciplinary research. Founded in 1999 with funding from the Swiss pharmaceutical giant, GNF focuses on solving complex medical problems by integrating advances in chemistry, biology, automation, and IT. Its passionate leader, Peter Schultz, is a unique combination of academic researcher and entrepreneur. He has cofounded seven start-ups, and is also a chemistry professor at the Scripps Research Institute in La Jolla, California.

The catalyst for the creation of GNF was the hope that the time required for drug discovery could be dramatically accelerated through the use of new techniques that enable genomics labs to conduct thousands of experiments in parallel, instead of analyzing one gene or molecule at a time. The typical investors in a biotech start-up would not have had the patience to fund the group as it explored various ways of accomplishing this. But Novartis took a longer view and funded GNF as a separate entity, enabling Schultz to attract scientists who have the skills to both build new technology platforms and apply them to the development of new products.

Schultz modestly describes GNF as "an interesting experiment" in building bridges between academia, the private sector, and basic and applied research. Some of the institute's programs are purely exploratory, but it also has the resources and expertise to develop practical health-care applications. "We have attracted people who are not afraid to go into new areas or assimilate ideas and data from a lot of different fields," says Schultz.

GNF is a provocative hybrid model for research: an independent lab that has the freedom to pursue basic science, while also having the wherewithal to translate its discoveries into

products. It is an experiment that is working because of a synergistic combination of visionary leadership, world-class talent, and patient financial backing.

INTUITIVE DEVELOPMENT

Determining the right trade-offs among technology, cost, and customer requirements is a key challenge for the development community. Companies that strike the right balance, like Intuitive Surgical, can really make a difference.

Most surgical operations today are performed with instruments that require an incision large enough to wedge a surgeon's hands into the body. *Laparoscopic,* or minimally invasive surgery—a huge medical advance of the 1980s—reduced the size of the incision, but the instruments were hard to use and did not have the range of motion of a surgeon's hand. Thus, while medical advances for procedures that involve the removal of an entire organ were made quickly, the state of the art for operations that require more delicate work stayed stagnant for a long time. Improving the clinical outcomes of these more complex operations was the development target of a start-up called Intuitive Surgical, based in Silicon Valley. The company has revolutionized medicine with a robotic system for assisting surgery called the da Vinci.

The da Vinci system is designed for maximum flexibility, with a wristlike mechanism that allows it to function like a human hand. The surgeon sits at a large console, viewing the patient through a 3D display, while maneuvering the instruments with precision hand controls. Computers embedded in the device make these movements feel completely natural to the surgeon, dramatically reducing training time. "It's like doing a normal operation," says company president Gary Guthart. "You see what you want, and you move to go get it—but it has the

benefits of minimally invasive surgery to the patient." When I visited the company's headquarters, Guthart took me into the demo room to show me just how intuitive the process really is. To my surprise, I was able to manipulate the instruments within minutes.

In the mid-1980s, a physician and entrepreneur named Fred Moll visited the Stanford Research Institute for a demo of computer-aided surgery, which was part of a research program funded by DARPA and the National Institutes of Health (NIH). Able to foresee the potential impact of the technology, Moll licensed it in 1995 and launched Intuitive Surgical, hiring some of the original SRI researchers, including Gary Guthart.

Developing the da Vinci required the evolution of several different technologies in parallel. The robotics component is based on tools developed in the 1950s and 1960s for handling hazardous materials. The video component and the use of insufflation—the technique of injecting gas to expand the body cavity—came from refinements made in laparoscopic surgery. Research into virtual-reality displays and navigating immersive environments also played a role. Advancements in high-resolution imagery and optics were critical to ensuring that the surgeon experiences the operation just as if he or she were standing over the patient.

The company stumbled several times on its road to success. Getting the da Vinci ready required integrating more than 3,000 microcomponents and having them function seamlessly together. Commercially available endoscopy turned out to be inadequate for the company's imaging needs, so it had to develop its own video technology. Early ideas about how da Vinci could be incorporated into the routines of an operating room had to be scrapped.

But once the system became available, surgeons not only embraced it but found new ways to use it. A doctor in Ger-

many suggested that da Vinci might be ideal for performing prostate operations. Soon he was training other surgeons in the procedure, and now 70 percent of all prostate operations are performed using the system. Patients needing gastric bypasses, hysterectomies, and mitral-valve repair have also benefited from less invasive operations and shorter recovery times.

After becoming the first robotic system for laparoscopic surgery approved by the FDA, da Vinci is now employed in more than 600 operating rooms, and the company has a $5 billion market cap. Yogen Dalal, an early investor in the company, says, "If you look at their system, it wasn't incremental in any way. It was completely and totally disruptive."

Intuitive Surgical is an excellent example of cross-pollination between the research, development, and application communities. DARPA-funded research inspired the launch of a product start-up that collaborated with its customers to apply radical new technology to save lives.

ABSOLUTELY, POSITIVELY INNOVATIVE

At midnight the planes begin arriving from all over the world, and by 2 a.m. the last one has departed. For two hours, the main FedEx hub in Memphis is filled with activity—unloading, sorting, and then reloading the planes. Achieving almost perfect service levels as FedEx transports millions of packages a day throughout the world by air and ground requires an enormous amount of discipline and attention to process. But from the day the company was founded by Fred Smith, FedEx has not wavered from its commitment to applying technology to best serve its customers.

It has developed new noise-suppression technology for aircraft, and partnered with the University of Maryland to produce

heads-up displays that improve safety and enable pilots to land in limited-visibility conditions. The company designs new ways of making its transport vehicles more fuel-efficient and safe, with onboard cameras and sensors. Advanced operations research allows FedEx to optimally schedule flight times, truck routes, and deliveries; and new sorting technologies automate the flow of packages efficiently. The company's commitment to leading in IT has grown out of Smith's realization that, as he puts it, "Information about a package is as important as delivery of the package itself."

One of the company's most visible innovations is its Web site, fedex.com, which today is used to ship more than 1 million packages daily and track more than 5 million more. It saves FedEx millions of dollars, and customers avoid the time and frustration of waiting on hold to talk to a customer service representative.

An interactive Web site that brings a business closer to its customers seems commonplace today. But in 1994, when the company registered the fedex.com domain name, it was not. FedEx was one of the first commercial companies to use the Web for something other than repurposing marketing brochures. We are now accustomed to companies such as Amazon, Yahoo, eBay, Google, Facebook, and LinkedIn that have leveraged the Internet to enable new business and consumer applications. Few remember that the first wave of Internet early adopters was primarily academic researchers looking for a way to share information faster and more widely.

At a 1994 briefing on future technologies, Bill Joy, Sun Microsystems' cofounder and a technical visionary, spent most of the day talking about the ramifications of the Internet and a new technology called the World Wide Web that had been developed at CERN in Switzerland. Rob Carter, FedEx's CIO, left the meeting knowing that the company had to have a pres-

ence on the Internet, but he wasn't quite sure in what way, so he asked IT director Miley Ainsworth to learn more.

Always keen to play with the latest technology, Ainsworth flew to Silicon Valley for a class at Stanford on HTML, the coding language of the Web. He came back with a copy of Mosaic, the first easy-to-use Web browser, developed by Marc Andreessen, then a student at the University of Illinois. Ainsworth figured that customers visiting FedEx's Web site would want to do more than just read an advertisement for the company's services, so he furnished the site with a simple form that said, "Enter your tracking number here to track a package." Once the company connected its Web software to its back-end databases, anyone with a browser was able to see if a package had been delivered without picking up the phone.

Enthusiasm for this new way of doing business spread rapidly throughout the company by word of mouth. The news that packages could be tracked at fedex.com spread virally through the emerging Internet. "It was an overnight sensation that quickly got a good reputation," Carter said. "It saved money. It was flexible. Its benefits were clear to us and were quickly recognized by our customers as well."

The site has grown far beyond even Ainsworth's hopes for it. Today more customers rely on fedex.com than use the company's 800 number. It has become a comprehensive interface to doing business with the company. FedEx's early embrace of the Web would not have been possible without the core values of innovation thriving at the company, and without close interaction between all of the communities of the Ecosystem.

CROSS-POLLINATING THE FUTURE

Each of these organizations demonstrates the importance of the individual communities of the Ecosystem, as well as the

power resulting from the right flow of questions, knowledge, and technology between them. Researchers and developers benefit from having access to real-world data, and private industry is kept vital by having a steady stream of ideas and talent from labs.

Usually research inspires the development of products that are used in innovative applications. But end users often discover applications that developers never dream of, and research can result from a desire to understand more about how current products work. "Most of the original engines were developed by people without a knowledge of the relationship between heat and mechanical energy," says Joel Birnbaum, retired senior vice president at Hewlett-Packard, "but once the science of thermodynamics evolved to explain why engines had different efficiencies, it became possible to make great advances in engine design."

Organizations need people who are capable of translating among the three branches of the Ecosystem. Engineers and scientists working on advanced technology provide a critical bridge between the research and development communities. Those working in development may not have the time, the type of education, or the training to cull the information they require from advanced research. Resources are also needed to provide a bridge from the application community to development—people who probe the capabilities of new technologies and products, studying their potential impact on the organization.

As we look to address growing concerns over potential conflicts of interest arising between pharmaceutical companies and doctors or energy companies funding academic research, we must make sure that we do not stop the free flow of information between the communities of the Ecosystem that exerts a synergistic effect on innovation.

NURTURING THE INNOVATIVE ENVIRONMENT

Just as plants require water and sunlight if they are to grow, sustaining innovation requires the right *leadership*, *funding*, *policy*, *education,* and *culture*.

Business, political, and individual leadership all have an impact on the Ecosystem. Nurturing innovation in any organization is ultimately the responsibility of those at the top. "I have to ensure that we are a company that allows room for innovation and rewards it," says Disney CEO Bob Iger. "A big established company can still innovate. It is incumbent on the leadership not only to figure out how that can happen, but to make sure that it does happen." Company leaders and board members need to instill the capacity for change in their organizations and communicate a sense of shared mission to all employees.

Our nation's leaders decisively influence the health of the country's Innovation Ecosystem. Politicians influence day-to-day business processes through laws and regulations. They control funding and policy that directly affect our educational system and the research community. "How much a country invests in research will determine its business cycles two or three decades out," says Cisco CEO John Chambers.

Parents, educators, and the media are responsible for developing and inspiring the next generation of American innovators. Each of us, as an employee or a member of society, has the responsibility to lead within our own sphere of influence.

Competition for funding can bring out the best in innovators, but it can have the opposite impact if the resources are *too* scarce. It is not just the magnitude of funds that is important, but also how they are allocated. Stability and consistency of resources are critical for projects that span long periods of time.

"The government funded the development of the Internet for roughly 24 years, which is stunningly remarkable for any program like that," says Vint Cerf, now Google's chief Internet evangelist. "That sustained funding made a huge difference." If funding cannot be relied upon, innovators and leaders end up spending more time fund-raising than they spend working. This holds true for research grants, venture capital for entrepreneurs, or internal funding in larger organizations. Requirements to demonstrate progress too frequently can lead to short-term trade-offs.

Federal and state policies have a significant impact on the Ecosystem. Legislation, SEC regulations, litigation rules, healthcare requirements, and tax incentives all affect the ability of businesses to innovate effectively.

Education is equally important. We are all born with the potential to innovate. Kids are naturally curious, open-minded, trusting, and persistent. K-12 and higher education can develop this naturally innovative spirit or stifle it. The quality and accessibility of higher education influence the talent pool available to drive innovation throughout the Ecosystem.

The larger cultural context also makes a significant impact on our capacity for change. The promise of achieving the American Dream set the tone for entrepreneurialism and innovation in this country. The implicit values of our organizations and our nation can either reinforce or dilute the core values of innovation.

A complex shift in these environmental factors has thrown America's Innovation Ecosystem off balance, threatening the way of life that we now take for granted. Should we accept the idea that the United States is in decline as an economic power and that there's nothing we can do about it? Can we leave it up to capitalism, assuming that this shift is just a cycle that will be taken care of by the markets? No. To regain our balance will

require everyone's focus. People and organizations must work on the problem from the bottom up, while demanding that our legislators take the lead on issues that require their involvement.

We must all think about the consequences for innovation of our business and policy decisions. If we don't, America is in danger of losing its Innovation Ecosystem completely—and thus, its leadership role in the emerging global economy.

First, we have to understand how we got to this point. For decades, our industries, government agencies, and universities produced a wealth of life-changing products and services, as well as a steady stream of people who were well prepared and eager to innovate in a wide range of fields. What happened to the brave nation that dared to put a man on the moon, launch a worldwide communications network, and crack the genetic code?