Strategic Management of Technological Innovation

SEVENTH EDITION

Melissa A. Schilling

Mc Graw Hill

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New York University

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STRATEGIC MANAGEMENT OF TECHNOLOGICAL INNOVATION, SEVENTH EDITION

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About the Author

Melissa A. Schilling, Ph.D.

Melissa Schilling is the John Herzog family professor of management and organizations at New York University's Stern School of Business. Professor Schilling teaches courses in strategic management, corporate strategy and technology, and innovation management. Before joining NYU, she was an Assistant Professor at Boston University (1997–2001), and has also served as a Visiting Professor at INSEAD and the Bren School of Environmental Science & Management at the University of California at Santa Barbara. She has also taught strategy and innovation courses at Siemens Corporation, IBM, the Kauffman Foundation Entrepreneurship Fellows program, Sogang University in Korea, and the Alta Scuola Polytecnica, a joint institution of Politecnico di Milano and Politecnico di Torino.

Professor Schilling's research focuses on technological innovation and knowledge creation. She has studied how technology shocks influence collaboration activity and innovation outcomes, how firms fight technology standards battles, manage platform ecosystems, and utilize collaboration, protection, and timing of entry strategies. She also studies how product designs and organizational structures migrate toward or away from modularity. Her most recent work focuses on knowledge creation, including how breadth of knowledge and search influences insight and learning, and how the structure of knowledge networks influences their overall capacity for knowledge creation. Her research in innovation and strategy has appeared in the leading academic journals such as *Academy of Management Journal, Academy of Management Review, Management Science, Organization Science, Strategic Management Journal,* and *Journal of Economics and Management Strategy* and *Research Policy*. She also sits on the editorial review boards of *Academy of Management Journal, Academy of Management Discoveries, Organization Science, Strategy Science,* and *Strategic Organization.* She is the author of *Quirky: The Remarkable Story of the Traits, Foibles, and Genius of Breakthrough Innovators Who Changed the World,* and she is coauthor of *Strategic Management: An Integrated Approach.* Professor Schilling won the Organization Science and Management Science Best Paper prize in 2007, an NSF CAREER award in 2003, and Boston University's Broderick Prize for research in 2000.

Preface

Innovation is a beautiful thing. It is a force with both aesthetic and pragmatic appeal: It unleashes our creative spirit, opening our minds to hitherto undreamed of possibilities, while accelerating economic growth and providing advances in such crucial human endeavors as medicine, agriculture, and education. For industrial organizations, the primary engines of innovation in the Western world, innovation provides both exceptional opportunities and steep challenges. While innovation is a powerful means of competitive differentiation, enabling firms to penetrate new markets and achieve higher margins, it is also a competitive race that must be run with speed, skill, and precision. It is not enough for a firm to be innovative—to be successful it must innovate better than its competitors.

As scholars and managers have raced to better understand innovation, a wide range of work on the topic has emerged and flourished in disciplines such as strategic management, organization theory, economics, marketing, engineering, and sociology. This work has generated many insights about how innovation affects the competitive dynamics of markets, how firms can strategically manage innovation, and how firms can implement their innovation strategies to maximize their likelihood of success. A great benefit of the dispersion of this literature across such diverse domains of study is that many innovation topics have been examined from different angles. However, this diversity also can pose integration challenges to both instructors and students. This book seeks to integrate this wide body of work into a single coherent strategic framework, attempting to provide coverage that is rigorous, inclusive, and accessible.

Organization of the Book

The subject of innovation management is approached here as a strategic process. The outline of the book is designed to mirror the strategic management process used in most strategy textbooks, progressing from assessing the competitive dynamics of the situation, to strategy formulation, and then to strategy implementation. The first part of the book covers the foundations and implications of the dynamics of innovation, helping managers and future managers better interpret their technological environments and identify meaningful trends. The second part of the book begins the process of crafting the firm's strategic direction and formulating its innovation strategy, including project selection, collaboration strategies, and strategies for protecting the firm's property rights. The third part of the book covers the process of implementing innovation, including the implications of organization structure on innovation, the management of new product development processes, the construction and management of new product development teams, and crafting the firm's deployment strategy. While the book emphasizes practical applications and examples, it also provides systematic coverage of the existing research and footnotes to guide further reading.

Complete Coverage for Both Business and Engineering Students

This book is designed to be a primary text for courses in the strategic management of innovation and new product development. Such courses are frequently taught in both business and engineering programs; thus, this book has been written with the needs of business and engineering students in mind. For example, Chapter Six (Defining the Organization's Strategic Direction) provides basic strategic analysis tools with which business students may already be familiar, but which may be unfamiliar to engineering students. Similarly, some of the material in Chapter Eleven (Managing the New Product Development Process) on computer-aided design or quality function deployment may be review material for information system students or engineering students, while being new to management students. Though the chapters are designed to have an intuitive order to them, they are also designed to be self-standing so instructors can pick and choose from them "buffet style" if they prefer.

New for the Seventh Edition

This seventh edition of the text has been comprehensively revised to ensure that the frameworks and tools are rigorous and comprehensive, the examples are fresh and exciting, and the figures and cases represent the most current information available. Some changes of particular note include:

Six New Short Cases

Netflix and the Battle of the Streaming Services. The new opening case for Chapter Four is about a battle unfolding for dominance in movie and television streaming. Though the case focuses on Netflix, it also details the moves made by competitors such as Amazon Prime Video, Disney, Hulu, and HBO. The case reveals the very interesting synergies Netflix has reaped in being both a content developer and a distributor, and it highlights the tradeoffs content developers make in choosing to have their content exclusive to a particular streaming service.

Failure to Launch at Uber Elevate. The opening case for Chapter Five in the sixth edition was about UberAIR, Uber's plan for launching an air taxi service; the opening case for Chapter Five for the seventh edition is about Uber's withdrawal of plans to launch its own air taxi service and the other companies that are still moving forward. This case highlights the range of challenges in launching something as new as air taxi service. While battery life and flight time are still considered areas that need improvement, the primary challenges to this market are now regulatory and infrastructure oriented: Where will the eVTOLs land? Who will regulate air traffic and how? Will the eVTOLs be too noisy? Will the eVTOLs be manned by pilots or autonomous? It is pretty easy to conclude from the case that Uber probably tried to enter this market too early, but it remains unclear whether the remaining players (who are almost all manufacturing startups dedicated wholly to producing eVTOLs) will fare better.

Zeta Energy and The "Holy Grail" of Batteries. Chapter Eight now opens with a case about Zeta Energy, a young battery technology startup that is in the process of developing a lithium metal sulfur battery. The technology is impressive and the potential markets are huge and diverse (e.g., electric vehicles, grid storage, consumer devices, and drones), but Zeta faces a dilemma of how to reach the stage of commercialization. Battery development is expensive and risky; Zeta has had problems raising enough funding to build the kind of facility it needs to produce the batteries at scale. The case highlights the various partnering strategies Zeta is considering, setting up a nice opportunity for students to analyze the pros and cons of types of collaboration agreements and types of partners.

The Patent Battle Over CRISPR Cas-9 Gene Editing. The new opening case for Chapter Nine is on what has been described as one of the most important patent battles in the last 50 years. CRISPR Cas-9 is a breakthrough technology that enables live animals (including humans) to be gene edited—potentially enabling us to eliminate and/or treat a wide range of diseases. Even more exciting is the fact that the technology itself is relatively inexpensive and simple, prompting a flood of students, researchers, and manufacturers to enthusiastically begin using it. The ownership of the intellectual property rights, however, are contested between a group at Berkeley and a group at MIT. The way each group's patents were filed, concomitant with the change of patent law, collectively created one of the most interesting—and high-stakes—battles patent lawyers have seen in decades.

How Apple Organizes for Innovation. Chapter Ten now opens with a case that describes how Apple is organized. The case tells the story of when Steve Jobs returned to Apple and dramatically reorganized the firm, yielding a big firm that has a structure that is much more commonly seen in small firms. The case provides detail on why Jobs felt the structure was appropriate, what its tradeoffs are, notably highlighting how much power the structure gives to its top leader. While this was probably a very desirable feature for Jobs, the case raises the question of whether or not the same structure makes sense for Apple under Tim Cook and whether it would make sense for different kinds of firms.

Magna International's Carbon Fiber "Lightweighting" Project. The opening case for Chapter Twelve describes in detail how Magna International, a Tier 1 automotive supplier, developed a scalable manufacturing method for carbon fiber auto parts in response to BMW's announcement of its intentions to build cars with the new material. With details and quotes from Tom Pilette, the VP of Product and Process Development of Magna who led the project, we learn about how the team was assembled and managed, how the team culture evolved, how team members were compensated, and more. BMW ends up deciding to make carbon fiber composites in house rather than buying from a supplier, but Magna's efforts transform it into an award-winning world leader in carbon fiber composite manufacturing.

Cases, Data, and Examples from around the World

Careful attention has been paid to ensure that the text is global in its scope. The opening cases and examples feature companies from China, India, Israel, Japan, The Netherlands, Kenya, the United States, and more. Wherever possible, statistics used in the text are based on worldwide data.

More Comprehensive Coverage and Focus on Current Innovation Trends

In response to reviewer suggestions, the new edition now provides an extensive discussion of the use of "Big Data" in guiding innovation, the strengths and weaknesses of grand prizes (like the XPRIZE) in generating innovation, characteristics of breakthrough innovators, the role of organization culture in innovation, a detailed example of Failure Modes and Effects Analysis that helps students set up their own FMEA spreadsheet, and more. The suggested readings for each chapter have also been updated to identify some of the more recent publications that have gained widespread attention in the topic area of each chapter. Despite these additions, great effort has also been put into ensuring the book remains concise—a feature that has proven popular with both instructors and students.

Supplements

The teaching package for *Strategic Management of Technological Innovation* is available online from Connect at connect.mheducation.com and includes:

- An instructor's manual with suggested class outlines, responses to discussion questions, and more.
- Complete PowerPoint slides with lecture outlines and all major figures from the text. The slides can also be modified by the instructor to customize them to the instructor's needs.
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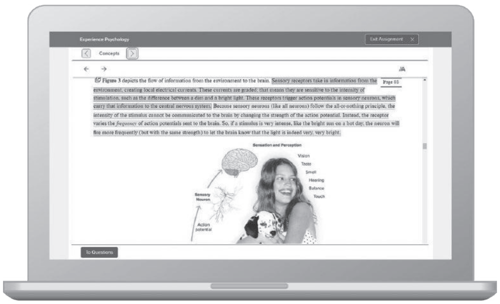

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Melissa A. Schilling

Briefs Contents

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Contents

Chapter One

Introduction

THE IMPORTANCE OF TECHNOLOGICAL INNOVATION

technological innovation
The act of introducing a new device, method, or material for application to commercial or practical objectives.

In many industries, **technological innovation** is now the most important driver of competitive success. Firms in a wide range of industries rely on products developed within the past five years for almost one-third (or more) of their sales and profits. For example, at Johnson & Johnson, products developed within the last five years account for over 30 percent of sales, and sales from products developed within the past five years at 3M have hit as high as 45 percent in recent years.

The increasing importance of innovation is due in part to the globalization of markets. Foreign competition has put pressure on firms to continuously innovate in order to produce differentiated products and services. Introducing new products helps firms protect their margins, while investing in process innovation helps firms lower their costs. Advances in information technology also have played a role in speeding the pace of innovation. Computer-aided design and computer-aided manufacturing have made it easier and faster for firms to design and produce new products, while flexible manufacturing technologies have made shorter production runs economical and have reduced the importance of production economies of scale.[1] These technologies help firms develop and produce more product variants that closely meet the needs of narrowly defined customer groups, thus achieving differentiation from competitors. For example, in 2021, Toyota offered dozens of different passenger vehicle lines under the Toyota brand (e.g., Camry, Prius, Highlander, Yaris, Land Cruiser, and Tundra). Within each of the vehicle lines, Toyota also offered several different models (e.g., Camry L, Camry LE, Camry SE, and Camry Hybrid SE) with different features and at different price points. In total, Toyota offered over 200 car models ranging in price from $16,605 (for the Yaris sedan) to $85,665 (for the Land Cruiser), and seating anywhere from three passengers (e.g., Tacoma Regular Cab truck) to eight passengers (Sienna Minivan). On top of this, Toyota also produced a range of luxury vehicles under its Lexus brand. Similarly, in 2021, Samsung produced more than 43 unique smartphones, from the Galaxy A01 priced at roughly $100 to the Galaxy Fold priced at roughly $2000. Companies can use broad portfolios of product models to help ensure they can penetrate almost every conceivable market niche. While producing multiple product variations used to be expensive and time-consuming, flexible manufacturing technologies now enable firms to seamlessly transition from producing one product model to the next, adjusting production schedules with real-time information on demand. Firms further reduce production costs by using common components in many of the models.

As firms such as Toyota, Samsung, and others adopt these new technologies and increase their pace of innovation, they raise the bar for competitors, triggering an industry-wide shift to shortened development cycles and more rapid new product introductions. The net results are greater market segmentation and rapid product obsolescence.[2] Product life cycles (the time between a product's introduction and its withdrawal from the market or replacement by a next-generation product) have become as short as 4 to 12 months for software, 12 to 24 months for computer hardware and consumer electronics, and 18 to 36 months for large home appliances.[3] This spurs firms to focus increasingly on innovation as a strategic imperative—a firm that does not innovate quickly finds its margins diminishing as its products become obsolete.

THE IMPACT OF TECHNOLOGICAL INNOVATION ON SOCIETY

If the push for innovation has raised the competitive bar for industries, arguably making success just that much more complicated for organizations, its net effect on society is more clearly positive. Innovation enables a wider range of goods and services to be delivered to people worldwide. It has made the production of food and other necessities more efficient, yielded medical treatments that improve health conditions, and enabled people to travel to and communicate with almost every part of the world. To get a real sense of the magnitude of the effect of technological innovation on society, look at Figure 1.1, which shows a timeline of some of the most important technological innovations developed over the last 200 years. Imagine how different life would be without these innovations!

gross domestic product (GDP)
The total annual output of an economy as measured by its final purchase price.

The aggregate impact of technological innovation can be observed by looking at **gross domestic product (GDP)**. The gross domestic product of an economy is its total annual output, measured by final purchase price. Figure 1.2 shows the average GDP per capita (i.e., GDP divided by the population) for the world from 1980 to 2019. The figures have been converted into U.S. dollars and adjusted for inflation. As shown in the figure, the average world GDP per capita has risen pretty steadily since 1980. In a series of studies of economic growth conducted at the National Bureau of Economic Research, economists showed that the historic rate of economic growth in GDP could not be accounted for entirely by growth in labor and capital inputs. Economist Robert Merton Solow argued that this unaccounted-for residual growth represented technological change: Technological innovation increased the amount of output achievable from a given quantity of labor and capital. This explanation was not immediately accepted; many researchers attempted to explain the residual away in terms of measurement error, inaccurate price deflation, or labor improvement.

FIGURE 1.1
Timeline of Some of the Most Important Technological Innovations in the Last 200 Years

1800	-	1800—Electric battery
	-	1804—Steam locomotive
	-	1807—Internal combustion engine
	-	1809—Telegraph
	-	1817—Bicycle
1820	-	1821—Dynamo
	-	1824—Braille writing system
	-	1828—Hot blast furnace
	-	1831—Electric generator
	-	1836—Five-shot revolver
1840	-	1841—Bunsen battery (voltaic cell)
	-	1842—Sulfuric ether-based anesthesia
	-	1846—Hydraulic crane
	-	1850—Petroleum refining
	-	1856—Aniline dyes
1860	-	1862—Gatling gun
	-	1867—Typewriter
	-	1876—Telephone
	-	1877—Phonograph
	-	1878—Incandescent lightbulb
1880	-	1885—Light steel skyscrapers
	-	1886—Internal combustion automobile
	-	1887—Pneumatic tire
	-	1892—Electric stove
	-	1895—X-ray machine
1900	-	1902—Air conditioner (electric)
	-	1903—Wright biplane
	-	1906—Electric vacuum cleaner
	-	1910—Electric washing machine
	-	1914—Rocket
1920	-	1921—Insulin (extracted)
	-	1927—Television
	-	1928—Penicillin
	-	1936—First programmable computer
	-	1939—Atom fission
1940	-	1942—Aqua lung
	-	1943—Nuclear reactor
	-	1947—Transistor
	-	1957—Satellite
	-	1958—Integrated circuit
1960	-	1967—Portable handheld calculator
	-	1969—ARPANET (precursor to Internet)
	-	1971—Microprocessor
	-	1973—Mobile (portable cellular) phone
	-	1976—Supercomputer
1980	-	1981—Space shuttle (reusable)
	-	1987—Disposable contact lenses
	-	1989—High-definition television
	-	1990—World Wide Web protocol
	-	1996—Wireless Internet
2000	-	2002—CRISPR Cas9 gene editing
	-	2003—Map of human genome
	-	2008—Blockchain
	-	2010—Synthetic life form
	-	2017—SpaceX reusable rocket

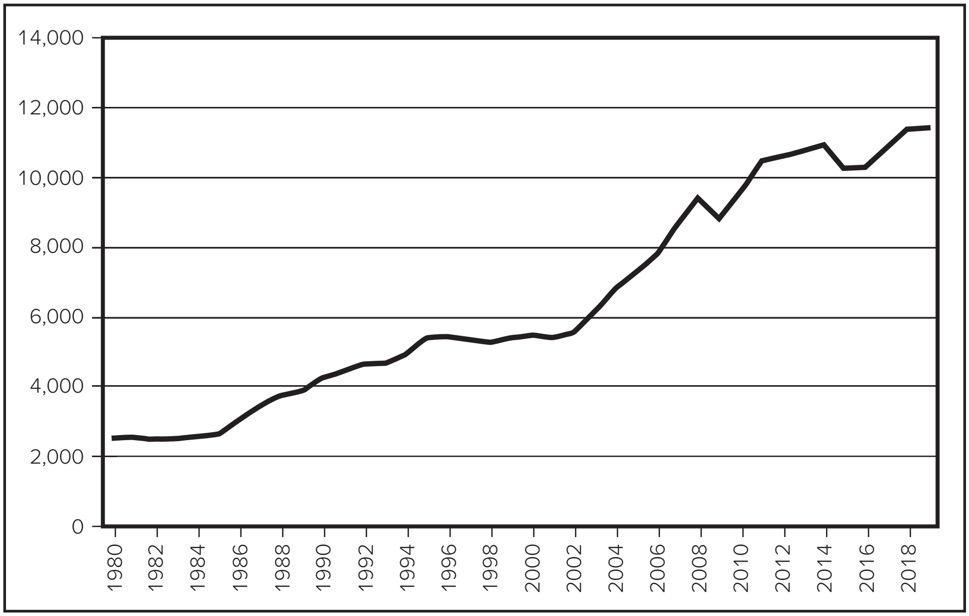
But in each case the additional variables were unable to eliminate this residual growth component. A consensus gradually emerged that the residual did in fact capture technological change. Solow received a Nobel Prize for his work in 1981, and the residual became known as the Solow Residual.[4] While GDP has its shortcomings as a measure of standard of living, it does relate very directly to the amount of goods consumers can purchase. Thus, to the extent that goods improve quality of life, we can ascribe some beneficial impact of technological innovation.

Sometimes technological innovation results in negative **externalities**. Production technologies may create pollution that is harmful to the surrounding communities; agricultural and fishing technologies can result in erosion, elimination of natural habitats, and depletion of ocean stocks; medical technologies can result in unanticipated consequences such as antibiotic-resistant strains of bacteria or moral dilemmas regarding the use of genetic modification. However, technology is, in its purest essence, knowledge—knowledge to solve our problems and pursue our goals.[5] Technological innovation is thus the creation of new knowledge that is applied to practical problems. Sometimes this knowledge is applied to problems hastily, without full consideration of the consequences and alternatives, but overall it will probably serve us better to have more knowledge than less.

externalities
Costs (or benefits) that are borne (or reaped) by individuals other than those responsible for creating them. Thus, if a business emits pollutants in a community, it imposes a negative externality on the community members; if a business builds a park in a community, it creates a positive externality for community members.

FIGURE 1.2
World Gross Domestic Product per Capita, 1980–2019 (in real 2019 U.S. dollars)

Source: "World GDP Per Capita 1960–2021," Macrotrends, https://www.macrotrends.net/countries/WLD/world/gdp-per-capita.



INNOVATION BY INDUSTRY: THE IMPORTANCE OF STRATEGY

As will be shown in Chapter Two, the majority of effort and money invested in technological innovation comes from industrial firms. However, in the frenetic race to innovate, many firms charge headlong into new product development without clear strategies or well-developed processes for choosing and managing projects. Such firms often initiate more projects than they can effectively support, choose projects that are a poor fit with the firm's resources and objectives, and suffer long development cycles and high project failure rates as a consequence (see the accompanying Research Brief for a recent study of the length of new product development cycles). While innovation is popularly depicted as a freewheeling process that is unconstrained by rules and plans, study after study has revealed that successful innovators have clearly defined innovation strategies and management processes.[6]

The Innovation Funnel

Most innovative ideas do not become successful new products. Many studies suggest that only one out of several thousand ideas results in a successful new product: Many projects do not result in technically feasible products and, of those that do, many fail to earn a commercial return. According to a 2012 study by the Product Development and Management Association, only about one in nine projects that are initiated is successful, and of those that make it to the point of being launched to the market, only about half earn a profit.[7] Furthermore, many ideas are sifted through and abandoned before a project is even formally initiated. According to one study that combined data from

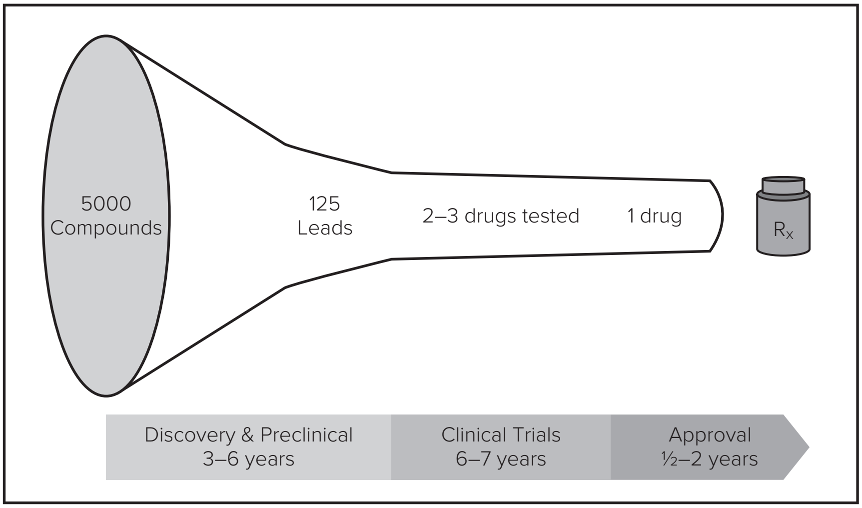
Research Brief How Long Does New Product Development Take?[a]

In a large-scale survey administered by the Product Development and Management Association (PDMA), in 2012, researchers examined the length of time it took firms to develop a new product from initial concept to market introduction. The study divided new product development projects into categories representing their degree of innovativeness: "radical" projects, "more innovative" projects, and "incremental" projects. On average, *incremental* projects took only 33 weeks from concept to market introduction. *More innovative* projects took significantly longer, clocking in at 57 weeks. The development of *radical* products or technologies took the longest, averaging 82 weeks. The study also found that on average, for *more innovative* and *radical* projects, firms reported significantly shorter cycle times than those reported in the previous PDMA surveys conducted in 1995 and 2004.

[a] Adapted from Stephen K. Markham and Hyunjung Lee, "Product Development and Management Association's 2012 Comparative Performance Assessment Study," *Journal of Product Innovation Management* 30, no. 3 (2013): 408–29.

prior studies of innovation success rates with data on patents, venture capital funding, and surveys, it takes about 3000 raw ideas to produce one significantly new and successful commercial product.[8] The pharmaceutical industry demonstrates this well—only one out of every 5000 compounds makes it to the pharmacist's shelf, and only one-third of those will be successful enough to recoup their R&D costs.[9] Furthermore, most studies indicate that it costs at least $1.4 billion and a decade of research to bring a new Food and Drug Administration (FDA)–approved pharmaceutical product to market![10] The innovation process is thus often conceived of as a funnel, with many potential new product ideas going in the wide end, but very few making it through the development process (see Figure 1.3).

FIGURE 1.3
The New Product Development Funnel in Pharmaceuticals



The Strategic Management of Technological Innovation

Improving a firm's innovation success rate requires a well-crafted strategy. A firm's innovation projects should align with its resources and objectives, leveraging its core competencies and helping it achieve its strategic intent. A firm's organizational structure and control systems should encourage the generation of innovative ideas while also ensuring efficient implementation. A firm's new product development process should maximize the likelihood of projects being both technically and commercially successful. To achieve these things, a firm needs (*a*) an in-depth understanding of the dynamics of innovation, (*b*) a well-crafted innovation strategy, and (*c*) well-designed processes for implementing the innovation strategy. We will cover each of these in turn (see Figure 1.4).

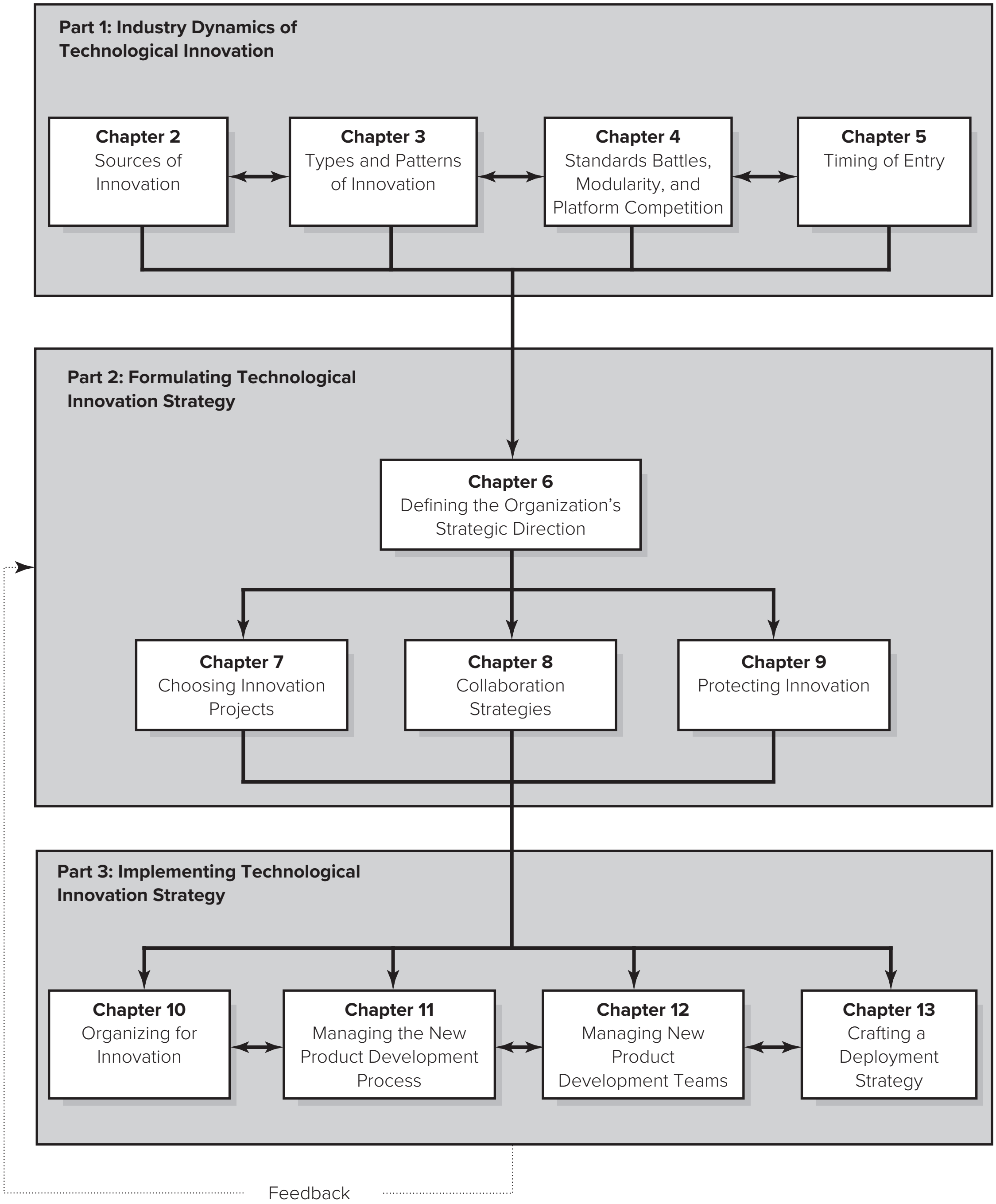
In Part One, we will cover the foundations of technological innovation, gaining an in-depth understanding of how and why innovation occurs in an industry, and why some innovations rise to dominate others. First, we will look at the sources of innovation in Chapter Two. We will address questions such as: Where do great ideas come from? How can firms harness the power of individual creativity? What role do customers, government organizations, universities, and alliance networks play in creating innovation? In this chapter, we will first explore the role of creativity in the generation of novel and useful ideas. We then look at various sources of innovation, including the role of individual inventors, firms, publicly sponsored research, and collaborative networks.

In Chapter Three, we will review models of types of innovation (such as radical versus incremental and architectural versus modular) and patterns of innovation (including s-curves of technology performance and diffusion, and technology cycles). We will address questions such as: Why are some innovations much harder to create and implement than others? Why do innovations often diffuse slowly even when they appear to offer a great advantage? What factors influence the rate at which a technology tends to improve over time? Familiarity with these types and patterns of innovation will help us distinguish how one project is different from another and the underlying factors that shape the project's likelihood of technical or commercial success.

In Chapter Four, we will turn to the particularly interesting dynamics that emerge in industries characterized by network externalities and other sources of increasing returns that can lead to standards battles and winner-take-all markets. We will address questions such as: Why do some industries choose a single dominant standard rather than enabling multiple standards to coexist? What makes one technological innovation rise to dominate all others, even when other seemingly superior technologies are offered? How can a firm avoid being locked out? Is there anything a firm can do to influence the likelihood of its technology becoming the dominant design? When are platform ecosystems likely to displace other forms of competition in an industry?

In Chapter Five, we will discuss the impact of entry timing, including first-mover advantages, first-mover *dis*advantages, and the factors that will determine the firm's optimal entry strategy. This chapter will address such questions as: What are the advantages and disadvantages of being first to market, early but not first, and late? What determines the optimal timing of entry for a new innovation? This chapter reveals a number of consistent patterns in how timing of entry impacts innovation success, and it

FIGURE 1.4
The Strategic Management of Technological Innovation



outlines what factors will influence a firm's optimal timing of entry, thus beginning the transition from understanding the dynamics of technological innovation to formulating technology strategy.

In Part Two, we will turn to formulating technological innovation strategy. Chapter Six reviews the basic strategic analysis tools managers can use to assess the firm's current position and define its strategic direction for the future. This chapter will address such questions as: What are the firm's sources of sustainable competitive advantage? Where in the firm's value chain do its strengths and weaknesses lie? What are the firm's core competencies, and how should it leverage and build upon them? What is the firm's strategic intent—that is, where does the firm want to be 10 years from now? Only after the firm has thoroughly appraised where it is currently can it formulate a coherent technological innovation strategy for the future.

In Chapter Seven, we will examine a variety of methods of choosing innovation projects. These include quantitative methods such as discounted cash flow and options valuation techniques, qualitative methods such as screening questions and balancing the research and development portfolio, as well as methods that combine qualitative and quantitative approaches such as conjoint analysis and data envelopment analysis. Each of these methods has its advantages and disadvantages, leading many firms to use a multiple-method approach to choosing innovation projects. This chapter also includes some of the sources of funding an innovative startup might use to finance their projects.

In Chapter Eight, we will examine collaboration strategies for innovation. This chapter addresses questions such as: Should the firm partner on a particular project or go solo? How does the firm decide which activities to do in-house and which to access through collaborative arrangements? If the firm chooses to work with a partner, how should the partnership be structured? How does the firm choose and monitor partners? We will begin by looking at the reasons a firm might choose to go solo versus working with a partner. We then will look at the pros and cons of various partnering methods, including joint ventures, alliances, licensing, outsourcing, and participating in collaborative research organizations. The chapter also reviews the factors that should influence partner selection and monitoring.

In Chapter Nine, we will address the options the firm has for appropriating the returns to its innovation efforts. We will look at the mechanics of patents, copyright, trademarks, and trade secrets. We will also address such questions as: Are there ever times when it would benefit the firm to not protect its technological innovation so vigorously? How does a firm decide between a wholly proprietary, wholly open, or partially open strategy for protecting its innovation? When will open strategies have advantages over wholly proprietary strategies? This chapter examines the range of protection options available to the firm, and the complex series of trade-offs a firm must consider in its protection strategy.

In Part Three, we will turn to implementing the technological innovation strategy. This begins in Chapter Ten with an examination of how the organization's size and structure influence its overall rate of innovativeness. The chapter addresses such questions as: Do bigger firms outperform smaller firms at innovation? How do formalization, standardization, and centralization impact the likelihood of generating innovative ideas and the organization's ability to implement those ideas quickly and efficiently? Is it possible to achieve creativity and flexibility at the same time as efficiency and reliability? How does the firm's culture influence its innovation? How do multinational firms decide where to perform their development activities? How do multinational firms coordinate their development activities toward a common goal when the activities occur in multiple countries? This chapter examines how organizations can balance the benefits and trade-offs of flexibility, economies of scale, standardization, centralization, and tapping local market knowledge.

In Chapter Eleven, we will review a series of "best practices" that have been identified in managing the new product development process. This includes such questions as: Should new product development processes be performed sequentially or in parallel? What are the advantages and disadvantages of using project champions? What are the benefits and risks of involving customers and/or suppliers in the development process? What tools can the firm use to improve the effectiveness and efficiency of its new product development processes? How does the firm assess whether its new product development process is successful? This chapter provides an extensive review of methods that have been developed to improve the management of new product development projects and to measure their performance.

Chapter Twelve builds on the previous chapter by illuminating how team composition and structure will influence project outcomes. This chapter addresses questions such as: How big should teams be? What are the advantages and disadvantages of choosing highly diverse team members? Do teams need to be colocated? When should teams be full time and/or permanent? What type of team leader and management practices should be used for the team? This chapter provides detailed guidelines for constructing new product development teams that are matched to the type of new product development project under way.

Finally, in Chapter Thirteen, we will look at innovation deployment strategies. This chapter will address such questions as: How do we accelerate the adoption of the technological innovation? How do we decide whether to use licensing or OEM agreements? Does it make more sense to use penetration pricing or a market-skimming price? When should we sell direct versus using intermediaries? What strategies can the firm use to encourage distributors and complementary goods providers to support the innovation? What are the advantages and disadvantages of major marketing methods? This chapter complements traditional marketing, distribution, and pricing courses by looking at how a deployment strategy can be crafted that especially targets the needs of a new technological innovation.

Summary of Chapter

1. Technological innovation is now often the single most important competitive driver in many industries. Many firms receive more than one-third of their sales and profits from products developed within the past five years.
2. The increasing importance of innovation has been driven largely by the globalization of markets and the advent of advanced technologies that enable more rapid product design and allow shorter production runs to be economically feasible.
3. Technological innovation has a number of important effects on society, including fostering increased GDP, enabling greater communication and mobility, and improving medical treatments.

4. Technological innovation may also pose some negative externalities, including pollution, resource depletion, and other unintended consequences of technological change.
5. While government plays a significant role in innovation, industry provides the majority of R&D funds that are ultimately applied to technological innovation.
6. Successful innovation requires an in-depth understanding of the dynamics of innovation, a well-crafted innovation strategy, and well-developed processes for implementing the innovation strategy.

Discussion Questions

1. Why is innovation so important for firms to compete in many industries?
2. What are some advantages and disadvantages of technological innovation?
3. Why do you think so many innovation projects fail to generate an economic return?

Suggested Further Reading

Classics

Edwin Mansfield, "Contributions of R and D to Economic Growth in the United States," *Science* CLXXV (1972): 477–86.

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7. Stephen K. Markham and Hyunjung Lee, "Product Development and Management Association's 2012 comparative performance assessment study," *Journal of Product Innovation Management* 30, no. 3 (2013): 408–29.
8. Greg Stevens and James Burley, "3,000 Raw Ideas Equals 1 Commercial Success!" *Research Technology Management* 40, no. 3 (1997): 16–27.
9. Standard & Poor's Industry Surveys, Pharmaceutical Industry, 2008.
10. Joseph A. DiMasi, Henry G. Grabowski, and Ronald W. Hansen, "Innovation in the Pharmaceutical Industry: New Estimates of R&D Costs," *Journal of Health Economics* 47 (May 2016): 20–33.

Part **One**

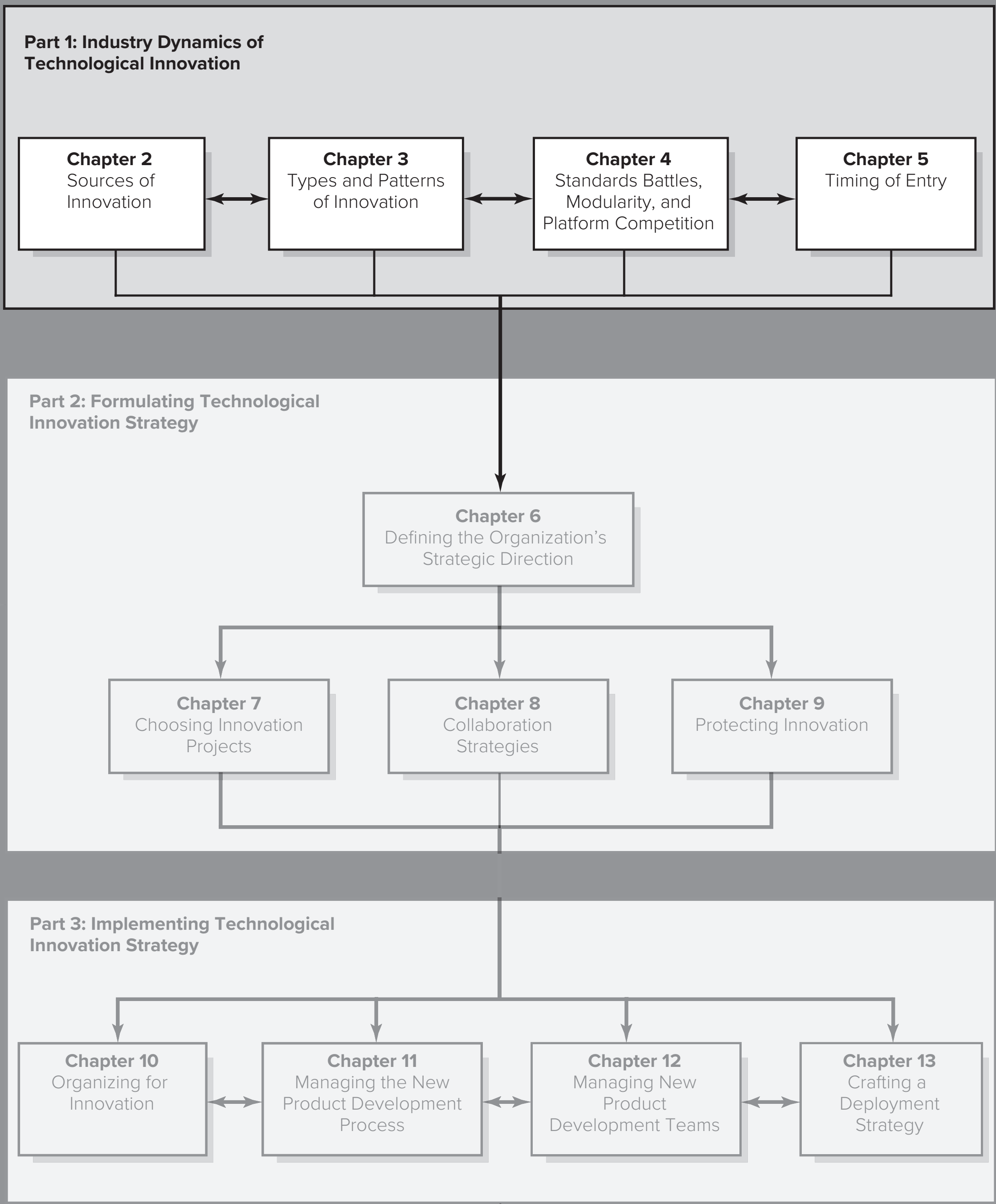
Industry Dynamics of Technological Innovation

In this section, we will explore the industry dynamics of technological innovation, including:

- The sources from which innovation arises, including the roles of individuals, organizations, government institutions, and networks.
- The types of innovations and common industry patterns of technological evolution and diffusion.
- The factors that determine whether industries experience pressure to select a dominant design, and what drives which technologies to dominate others.
- The effects of timing of entry, and how firms can identify (and manage) their entry options.

This section will lay the foundation that we will build upon in Part Two, Formulating Technological Innovation Strategy.

Industry Dynamics of Technological Innovation



Chapter **Two**

Sources of Innovation

The Rise of Cultured Meat[a]

In late 2017, Microsoft founder Bill Gates and a group of other high-powered investors—who comprise Breakthrough Energy Ventures, such as Amazon's Jeff Bezos, Alibaba's Jack Ma, and Virgin's Richard Branson—announced their intention to fund a San Francisco–based start-up called Memphis Meats with an unusual business plan: It grew "clean" meat using stem cells, eliminating the need to breed or slaughter animals. The company had already produced beef, chicken, and duck, all grown from cells.[b]

There were many potential advantages of growing meat without animals. First, growth in the demand for meat was skyrocketing due to both population growth and development. When developing countries become wealthier, they increase their meat consumption. While humanity's population had doubled since 1960, consumption of animal products had risen fivefold and was still increasing. Many scientists and economists had begun to warn of an impending "meat crisis." Even though plant protein substitutes like soy and pea protein had gained enthusiastic followings, the rate of animal protein consumption had continued to rise. This suggested that meat shortages were inevitable unless radically more efficient methods of production were developed.

Large-scale production of animals also had a massively negative effect on the environment. The worldwide production of cattle, for example, resulted in a larger emissions of greenhouse gases than the collective effect of the world's automobiles. Animal production is also extremely water intensive: To produce each chicken sold in a supermarket, for example, requires more than 1000 gallons of water, and each egg requires 50 gallons. Each gallon of cow's milk required 900 gallons of water. A study by Oxford University indicated that meat grown from cells would produce up to 96 percent lower greenhouse gas emissions, use 45 percent less energy, 99 percent less land, and 96 percent less water.[c]

Scientists also agreed that producing animals for consumption was simply inefficient. Estimates suggested, for example, that it required roughly 23 calories worth of inputs to produce one calorie of beef. Cultured meat promised to bring that ratio down to three calories of inputs to produce a calorie of beef—more than seven times greater efficiency. Cultured meat also would not contain antibiotics, steroids, or bacteria such as *E. coli*—it was literally "cleaner," and that translated into both greater human health and lower perishability.

The Development of Clean Meat

In 2004, Jason Matheny, a 29-year-old recent graduate from the John Hopkins Public Health program decided to try to tackle the problems with production of animals for food. Though Matheny was a vegetarian himself, he realized that convincing enough people to adopt a plant-based diet to slow down the meat crisis was unlikely. As he noted, "You can spend your time trying to get people to turn their lights out more often, or you can invent a more efficient light bulb that uses far less energy even if you leave it on. What we need is an enormously more efficient way to get meat."[d]

Matheny founded a nonprofit organization called New Harvest that would be dedicated to promoting research into growing real meat without animals. He soon discovered that a Dutch scientist, Willem van Eelen was exploring how to culture meat from animal cells. Van Eelen had been awarded the first patent on a cultured meat production method in 1999. However, the eccentric scientist had not had much luck in attracting funding to his project, nor in scaling up his production. Matheny decided that with a little prodding, the Dutch government might be persuaded to make a serious investment in the development of meat-culturing methods. He managed to get a meeting with the Netherland's minister of agriculture where he made his case. Matheny's efforts paid off: The Dutch government agreed to invest two million euros in exploring methods of creating cultured meat at three different universities.

By 2005, cultured meat was starting to gather attention. The journal *Tissue Engineering* published an article entitled "In Vitro-Cultured Meat Production," and in the same year, the *New York Times* profiled cultured meat in its annual "Ideas of the Year." However, while governments and universities were willing to invest in the basic science of creating methods of producing cultured meat, they did not have the capabilities and assets needed to bring it to commercial scale. Matheny knew that to make cultured meat a mainstream reality, he would need to attract the interest of large agribusiness firms.

Matheny's initial talks with agribusiness firms did not go well. Though meat producers were open to the idea conceptually, they worried that consumers would balk at cultured meat and perceive it as unnatural. Matheny found this criticism frustrating; after all, flying in airplanes, using air conditioning, or eating meat pumped full of steroids to accelerate its growth were also unnatural.

Progress was slow. Matheny took a job at the Intelligence Advanced Research Projects Activity (IARPA) of the U.S. Federal Government while continuing to run New Harvest on the side. Fortunately, others were also starting to realize the urgency of developing alternative meat production methods.

Enter Sergey Brin of Google

In 2009, the foundation of Sergey Brin, cofounder of Google, contacted Matheny to learn more about cultured meat technologies. Matheny referred

Brin's foundation to Dr. Mark Post at Maastricht University, one of the leading scientists funded by the Dutch government's cultured meat investment. Post had succeeded in growing mouse muscles in vitro and was certain his process could be replicated with the muscles of cows, poultry, and more. As he stated, "It was so clear to me that we could do this. The science was there. All we needed was funding to actually prove it, and now here was a chance to get what was needed."[e] It took more than a year to work out the details, but in 2011, Brin offered Post roughly three quarters of a million dollars to prove his process by making two cultured beef burgers, and Post's team set about meeting the challenge.

In early 2013, the moment of truth arrived: Post and his team had enough cultured beef to do a taste test. They fried up a small burger and split it into thirds to taste. It tasted like meat. Their burger was 100 percent skeletal muscle and they knew that for commercial production they would need to add fat and connective tissue to more closely replicate the texture of beef, but those would be easy problems to solve after passing this milestone. The press responded enthusiastically, and the *Washington Post* ran an article headlined, "Could a Test-Tube Burger Save the Planet?"[f]

Going Commercial

In 2015, Uma Valeti, a cardiologist at the Mayo Clinic founded his own cultured-meat research lab at the University of Minnesota. "I'd read about the inefficiency of meat-eating compared to a vegetarian diet, but what bothered me more than the wastefulness was the sheer scale of suffering of the animals."[g] As a heart doctor, Valeti also believed that getting people to eat less meat could improve human health: "I knew that poor diets and the unhealthy fats and refined carbs that my patients were eating were killing them, but so many seemed totally unwilling to eat less or no meat. Some actually told me they'd rather live a shorter life than stop eating the meats they loved." Valeti began fantasizing about a best-of-both-worlds alternative—a healthier and kinder meat. As he noted, "The main difference I thought I'd want for this meat I was envisioning was that it'd have to be leaner and more protein-packed than a cut of supermarket meat, since there's a large amount of saturated fat in that meat. . . . Why not have fats that are proven to be better for health and longevity, like omega-3s? We want to be not just like conventional meat but healthier than conventional meat."[h]

Valeti was nervous about leaving his successful position as a cardiologist—after all, he had a wife and two children to help support. However, when he sat down to discuss it with his wife (a pediatric eye surgeon), she said, "Look, Uma. We've been wanting to do this forever. I don't ever want us to look back on why we didn't have the courage to work on an idea that could make this world kinder and better for our children and their generation."[i] And thus Valeti's company, which would later be named Memphis Meats, was born.

Building on Dr. Post's achievement, Valeti's team began experimenting with ways to get just the right texture and taste. After much trial and error, and a growing number of patents, they hosted their first tasting event in

December 2015. On the menu: a meatball. This time the giant agribusiness firms took notice.

At the end of 2016, Tyson Foods, the world's largest meat producer, announced that it would invest $150 million in a venture capital fund that would develop alternative proteins, including meat grown from self-reproducing cells. In August of 2017, agribusiness giant Cargill announced it was investing in Memphis Meats, and a few months later in early 2018, Tyson Foods also pledged investment.

That first meatball cost $1200; to make cultured meat a commercial reality required bringing costs down substantially. But analysts were quick to point out that the first iPhone had cost $2.6 billion in R&D—much more than the first cultured meats. Scale and learning curve efficiencies would drive that cost down. Valeti had faith that the company would soon make cultured meat not only competitive with traditional meat, but also more affordable. Growing meat rather than whole animals had, after all, inherent efficiency advantages.

In December of 2020, cultured chicken made by Eat Just became the first cultured meat product in the world to be approved for commercial sale when it was approved by the Singapore Food Agency. The chicken was expected to go on sale in Singaporean restaurants in early 2021. Eat Just had found earlier success by selling Just Eggs (made from mung beans). Its founder, Josh Tetrick, was also in talks with U.S. and European food regulators and noted, "I would imagine what will happen is the U.S., Western Europe and others will see what Singapore has been able to do, the rigors of the framework that they put together. And I would imagine that they will try to use it as a template to put their own framework together."[j]

Some skeptics believed the bigger problem was not production economies or regulatory approval, but consumer acceptance: Would people be willing to eat meat grown without animals? Sergey Brin, Bill Gates, Jeff Bezos, Jack Ma, and Richard Branson were willing to bet that they would. As Branson stated in 2017, "I believe that in 30 years or so we will no longer need to kill any animals and that all meat will either be clean or plant-based, taste the same and also be much healthier for everyone."[k] Bruce Friedrich, executive director of the nonprofit The Good Food Institute agrees, noting "As nations race to divorce meat production from industrial animal agriculture, countries that delay their investment in this bright food future risk getting left behind."[l]

Discussion Questions

1. What were the potential advantages of developing cultured meat? What were the challenges of developing it and bringing it to market?
2. What kinds of organizations were involved in developing cultured meat? What were the different resources that each kind of organization brought to the innovation and what were their motives?
3. What are the challenges to gaining wide market acceptance of cultured meat, and how could these organizations facilitate that? Can you think of other products or services that faced similar adoption challenges?

[a] Adapted from a New York University teaching case by Paul Shapiro and Melissa Schilling.
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[d] Paul Shapiro, *Clean Meat: How Growing Meat without Animals Will Revolutionize Dinner and the World* (New York: Gallery Books, 2018), 35.
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[f] "Could a Test-Tube Burger Save the Planet?" *Washington Post,* August 5, 2013.
[g] Paul Shapiro, *Clean Meat: How Growing Meat without Animals Will Revolutionize Dinner and the World* (New York: Gallery Books, 2018), 113.
[h] Paul Shapiro, *Clean Meat: How Growing Meat without Animals Will Revolutionize Dinner and the World* (New York: Gallery Books, 2018), 115.
[i] Paul Shapiro, *Clean Meat: How Growing Meat without Animals Will Revolutionize Dinner and the World* (New York: Gallery Books, 2018), 118.
[j] Ryan W. Miller, "Lab-Grown 'Chicken Bites'? Cultured Meat Product Gets World's First Regulatory Approval," *USA Today*, December 2, 2020.
[k] Zack Friedman, "Why Bill Gates and Richard Branson Invested in 'Clean' Meat," *Forbes*, August 2017.
[l] Ryan W. Miller, "Lab-Grown 'Chicken Bites'? Cultured Meat Product Gets World's First Regulatory Approval," *USA Today*, December 2, 2020.

OVERVIEW

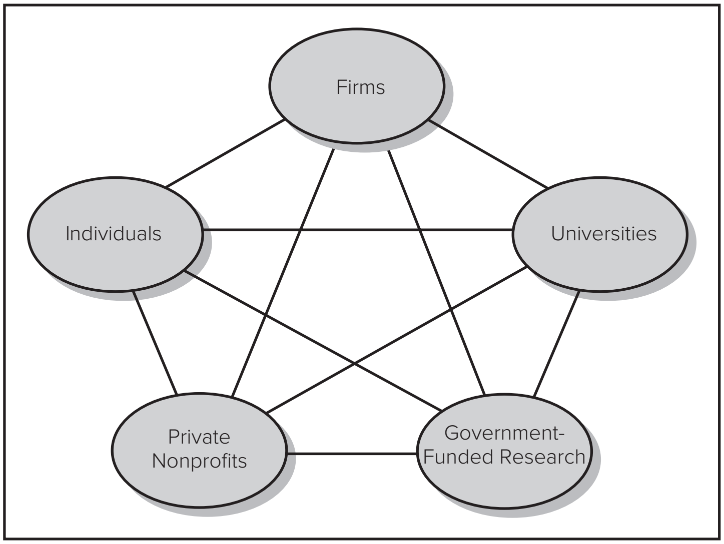
innovation
The practical implementation of an idea into a new device or process.

Innovation can arise from many different sources. It can originate with individuals, as in the familiar image of the lone inventor or users who design solutions for their own needs. Innovation can also come from the research efforts of universities, government laboratories and incubators, or private nonprofit organizations. One primary engine of innovation is firms. Firms are well suited to innovation activities because they typically have greater resources than individuals and a management system to marshal those resources toward a collective purpose. Firms also face strong incentives to develop differentiating new products and services, which may give them an advantage over nonprofit or government-funded entities.

An even more important source of innovation, however, does not arise from any one of these sources, but rather the linkages between them. Networks of innovators that leverage knowledge and other resources from multiple sources are one of the most powerful agents of technological advance.[1] We can thus think of sources of innovation as composing a complex system wherein any particular innovation may emerge primarily from one or more components of the system or the linkages between them (see Figure 2.1).

In the sections that follow, we will first consider the role of creativity as the underlying process for the generation of novel and useful ideas. We will then consider how creativity is transformed into innovative outcomes by the separate components of the innovation system (individuals, firms, etc.), and through the linkages between different components (firms' relationships with their customers, technology transfer from universities to firms, etc.).

FIGURE 2.1
Sources of Innovation as a System



CREATIVITY

idea
Something imagined or pictured in the mind.

creativity
The ability to produce novel and useful work.

Innovation begins with the generation of new **ideas**. The ability to generate new and useful ideas is termed creativity. **Creativity** is defined as the ability to produce work that is useful and novel. Novel work must be different from work that has been previously produced and surprising in that it is not simply the next logical step in a series of known solutions.[2] The degree to which a product is novel is a function both of how different it is from prior work (e.g., a minor deviation versus a major leap) and of the audience's prior experiences.[3] A product could be novel to the person who made it, but known to most everyone else. In this case, we would call it reinvention. A product could be novel to its immediate audience, yet be well known somewhere else in the world. The most creative works are novel at the individual producer level, the local audience level, and the broader societal level.[4]

Individual Creativity

An individual's creative ability is a function of his or her *intellectual abilities, knowledge, personality, motivation*, and *environment*.

The most important *intellectual abilities* for creative thinking include intelligence, memory, the ability to look at problems in unconventional ways, the ability to analyze which ideas are worth pursuing and which are not, and the ability to articulate those ideas to others and convince others that the ideas are worthwhile. One important intellectual ability for creativity is a person's ability to let their mind engage in a visual mental activity termed *primary process thinking.*[5] Because of its unstructured nature, primary process thinking can result in combining ideas that are not typically related, leading to what has been termed *remote associations* or *divergent thinking.* Sigmund Freud noted that primary process thinking was most likely to occur just before sleep or while dozing or daydreaming; others have observed that it might also be common when distracted by physical exercise, music, or other activities. Creative people may make their minds more open to remote associations and then mentally sort through these associations, selecting the best for further consideration. Having excellent working memory is useful here too—individuals with excellent working memory may be more likely or more able to search longer paths through the network of associations in their mind, enabling them to arrive at a connection between two ideas or facts that seem unexpected or strange to others.[6] A connection that appears to be random may not be random at all—it is just difficult for other people to see the association because they are not following as long of a chain of associations.

Consistent with this, studies by professors Mathias Benedek and Aljoscha Neubauer found that highly creative people usually follow the same association paths as less creative people—but they do so with such greater speed that they exhaust the common associations sooner, permitting them to get to less common associations earlier than others would.[7] Benedek and Neubauer's research argues that highly creative people's speed of association is due to exceptional working memory and executive control. In other words, the ability to hold many things in one's mind simultaneously and maneuver them with great facileness enables a person to rapidly explore many possible associations.[8]

The impact of *knowledge* on creativity is somewhat double-edged. If an individual has too little knowledge of a field, he or she is unlikely to understand it well enough to contribute meaningfully to it. On the other hand, if an individual knows a field too well, that person can become trapped in the existing logic and paradigms, preventing him or her from coming up with solutions that require an alternative perspective. Thus, an individual with only a moderate degree of knowledge of a field might be able to produce more creative solutions than an individual with extensive knowledge of the field, and breakthrough innovations are often developed by outsiders to a field.[9]

Consider, for example, Elon Musk. Elon Musk developed a city search Web portal called Zip2 in college, then founded an Internet financial payments company that merged with a rival and developed the PayPal financial payment system. Then after selling PayPal, Musk decided to found SpaceX to develop reusable rockets, and also became part of the founding team of Tesla Motors, an electric vehicle company. Tesla subsequently acquired Solar City (a solar panel company that Elon Musk had helped his cousins create) and diversified into energy storage and more. Musk crosses boundaries because he enjoys tackling new, difficult problems. He has been able to be successful in a wide range of industries in part because he challenges the traditional models in those industries.[10] For example, SpaceX was able to dramatically decrease the price of rocket components by building them in-house, and Solar City was able to dramatically increase solar panel adoption by offering a business model based on leasing that gave customers the option of putting no money down and paying for the panels with part of their energy savings.

Another great example is provided by Gavriel Iddan, a guided missile designer for the Israeli military who invented a revolutionary way to allow doctors to see inside a patient's gastrointestinal system. The traditional approach for obtaining images inside the gut is a camera on the end of a long flexible rod. This method is quite uncomfortable, and cannot reach large portions of the small intestine, but it was the industry standard for many decades. Most gastroenterologists have invested in significant training to use endoscopic tools, and many have also purchased endoscopic equipment for their clinics. Not surprisingly then, most innovation in this domain has focused on incremental improvements in the rod, cameras, and imaging software. Iddan, however, approached the problem of viewing the inside of the gut like a guided missile designer—not a gastroenterologist. He did not have the same assumptions about the need to control the camera with a rod, nor to transmit images with a wire. Instead, he invented a capsule (called the PillCam) with a power source, a light source, and two tiny cameras that the patient can swallow. The patient then goes about her day while the camera pill broadcasts images to a video pack worn by the patient. Roughly eight hours later, the patient returns to the doctor's office to have the images read by a software algorithm that can identify any locations of bleeding (the camera pill exits naturally). The PillCam has proven to be safer and less expensive than traditional endoscopy (the PillCam costs less than $500), and it is dramatically more comfortable. For patients, the camera pill was a no brainer; getting doctors to adopt it has been slower because of their existing investment and familiarity with endoscopy. The PillCam is now sold in more than 60 countries, and several companies now offer competing products. The camera pill is a remarkable solution to a difficult problem, and it is easy to see why it came from an outsider, rather than an endoscope producer.[11]

Outsiders often face resistance and skepticism. People tend to discount generalists and are suspicious of people who engage in activities that seem inconsistent with their identity. Outsiders like Musk, however, bring an advantage that insiders and industry veterans often lack. They aren't trapped by the paradigms and assumptions that have long become calcified in industry veterans, nor do they have the existing investments in tools, expertise, or supplier and customer relationships that make change difficult and unappealing.

The *personality* trait most often associated with creativity is "openness to experience."[12] Openness to experience reflects an individual's use of active imagination, aesthetic sensitivity (e.g., the appreciation for art and literature), attentiveness to emotion, a preference for variety, and intellectual curiosity. It is assessed by asking individuals to rate their degree of agreement or disagreement with statements such as "I have a vivid imagination," "I enjoy hearing new ideas," "I have a rich vocabulary," "I rarely look for deeper meaning in things" (reversed), "I enjoy going to art museums," "I avoid philosophical discussions" (reversed), "I enjoy wild flights of fantasy," and more. Individuals who score high on the openness to experience dimension tend to have great intellectual curiosity, are interested in unusual ideas, and are willing to try new things.

Intrinsic *motivation* has also been shown to be very important for creativity.[13] That is, individuals are more likely to be creative if they work on things they are genuinely interested in and enjoy. In fact, several studies have shown that creativity can be undermined by providing extrinsic motivation such as money or awards.[14] This raises serious questions about the role played by idea collection systems in organizations that offer monetary rewards for ideas. On the one hand, such extrinsic rewards could derail intrinsic motivation. On the other hand, if the monetary rewards are small, such systems may be primarily serving to invite people to offer ideas, which is a valuable signal about the culture of the firm. More research is needed in this area to know exactly what kind of solicitation for ideas, if any, is most effective.

Finally, to fully unleash an individual's creative potential usually requires a supportive *environment* with time for the individual to explore their ideas independently, tolerance for unorthodox ideas, a structure that is not overly rigid or hierarchical, and decision norms that do not require consensus.[15]

Organizational Creativity

The creativity of the organization is a function of creativity of the individuals within the organization and a variety of social processes and contextual factors that shape the way those individuals interact and behave.[16] An organization's overall creativity level is thus not a simple aggregate of the creativity of the individuals it employs. The organization's structure, routines, and incentives could thwart individual creativity or amplify it.

The most familiar method of a company tapping the creativity of its individual employees is the suggestion box. In 1895, John Patterson, founder of National Cash Register (NCR), created the first sanctioned suggestion box program to tap the ideas of the hourly worker.[17] The program was considered revolutionary in its time. The originators of adopted ideas were awarded $1. In 1904, employees submitted 7000 ideas, of which one-third were adopted. Other firms have created more elaborate systems that not only capture employee ideas, but incorporate mechanisms for selecting and implementing those ideas. Google, for example, utilizes an idea management system whereby employees e-mail their ideas for new products and processes to a company-wide database where every employee can view the idea, comment on it, and rate it (for more on how Google encourages innovation, see the Theory in Action on Inspiring Innovation at Google). Honda of America utilizes an employee-driven idea system (EDIS) whereby employees submit their ideas, and if approved, the employee who submits the idea is responsible for following through on the suggestion, overseeing its progress from concept to implementation. Honda of America reports that more than 75 percent of all ideas are implemented.[18] Bank One, one of the largest holding banks in the United States, has created an employee idea program called "One Great Idea." Employees access the company's idea repository through the company's **intranet**. There they can submit their ideas and actively interact and collaborate on the ideas of others.[19] Through active exchange, the employees can evaluate and refine the ideas, improving their fit with the diverse needs of the organization's stakeholders.

intranet
A private network, accessible only to authorized individuals. It is like the Internet but operates only within ("intra") the organization.

At Bank of New York Mellon they go a step further—the company holds enterprise-wide innovation competitions where employees form their own teams and compete in coming up with innovative ideas. These ideas are first screened by judges at both the regional and business-line level. Then, the best ideas are pitched to senior management in a "Shark Tank" style competition that is webcast around the world. If a senior executive sees an idea they like, they step forward and say they will fund it and run with it. The competition both helps the company come up with great ideas and sends a strong signal to employees about the importance of innovation.[20]

Idea collection systems (such as suggestion boxes) are relatively easy and inexpensive to implement, but are only a first step in unleashing employee creativity. Today companies such as Intel, Motorola, 3M, and Hewlett-Packard go to much greater lengths to tap the creative potential embedded in employees, including investing in

Theory in Action Inspiring Innovation at Google

Google is always working on a surprising array of projects, ranging from the completely unexpected (such as autonomous self-driving cars and solar energy) to the more mundane (such as e-mail and cloud services).[a] In pursuit of continuous innovation at every level of the company, Google uses a range of formal and informal mechanisms to encourage its employees to innovate:[b]

20 Percent Time: All Google engineers are encouraged to spend 20 percent of their time working on their own projects. This was the source of some of Google's most famous products (e.g., Google Mail, Google News).

Recognition Awards: Managers were given discretion to award employees with "recognition awards" to celebrate their innovative ideas.

Google Founders' Awards: Teams doing outstanding work could be awarded substantial stock grants. Some employees had become millionaires from these awards alone.

Adsense Ideas Contest: Each quarter, the Adsense online sales and operations teams reviewed 100 to 200 submissions from employees around the world, and selected finalists to present their ideas at the quarterly contest.

Innovation Reviews: Formal meetings where managers present ideas originated in their divisions directly to founders Larry Page and Sergey Brin, as well as to CEO Eric Schmidt.[c]

[a] D. Bradbury, "Google's rise and rise," *Backbone,* (October 2011): 24–7.

[b] Boris Groysberg, David A. Thomas, and Alison Berkley Wagonfeld, Keeping Google "Googley." *Harvard Business School Case* 9 (2011): 409–39.

[c] J. Kirby, "How Google really does it," *Canadian Business* 82, no. 18 (2009): 54–8.

creativity training programs. Such programs encourage managers to develop verbal and nonverbal cues that signal employees that their thinking and autonomy are respected. These cues shape the culture of the firm and are often more effective than monetary rewards—in fact, as noted previously, sometimes monetary rewards undermine creativity by encouraging employees to focus on extrinsic rather than intrinsic motivation.[21] The programs also often incorporate exercises that encourage employees to use creative mechanisms such as developing alternative scenarios, using analogies to compare the problem with another problem that shares similar features or structure, and restating the problem in a new way. One product design firm, IDEO, even encourages employees to develop mock prototypes of potential new products out of inexpensive materials such as cardboard or styrofoam and pretend to use the product, exploring potential design features in a tangible and playful manner.

TRANSLATING CREATIVITY INTO INNOVATION

Innovation is more than the generation of creative ideas; it is the implementation of those ideas into some new device or process. Innovation requires combining a creative idea with resources and expertise that make it possible to embody the creative idea in a useful form. We will first consider the role of individuals as innovators, including innovation by inventors who specialize in creating new products and processes, and innovation by end users. We then will look at innovation activity that is organized by firms, universities, and government institutions.

Theory in Action What Breakthrough Innovators Have in Common

The book *Quirky: The Remarkable Story of the Traits, Foibles, and Genius of Breakthrough Innovators Who Changed the World*[a] reports the results of a six-year research study on serial breakthrough innovators, that is, innovators identified in on multiple "most famous innovators" lists and noted for multiple breakthrough innovations. It turns out there are some strong commonalities among serial breakthrough innovators, and some of them are quite surprising. Here are some of the key commonalities noted in the book:

1. **They felt a sense of "separateness" and tended to challenge rules.** Nearly all of the innovators studied exhibited a social detachment, or a sense of not belonging to the social world. This had the surprising benefit of enabling them to challenge assumptions and pursue unconventional paths. As Albert Einstein put it in an autobiographical essay, The World as I See It, "*I have never lost an obstinate sense of detachment. . . Such a person no doubt loses something in the way of geniality and light-heartedness; on the other hand, he is largely independent of the opinions, habits, and judgments of his fellow and avoids the temptation to take his stand on such insecure foundations.*" His ability to reject norms and disregard accepted wisdom is precisely the reason he was able to revolutionize physics. Grace Hopper, a woman who invented one of the first computer programming languages, noted that during her lifetime women were not really supposed to be in business or science. However, because she attained the rank of Admiral in the Navy, companies like IBM and Hewlett Packard were willing to break with tradition to seek her expertise—being an Admiral essentially made her genderless.
2. **They had intense faith in their ability to achieve their objectives.** All of the innovators had extreme levels of something psychologists call "self-efficacy"—a type of confidence specific to overcoming obstacles and achieving goals. Elon Musk's quest to bring humanity to Mars, Nikola Tesla's work on free energy, and Dean Kamen's efforts to create affordable water purification illustrate the power of self-efficacy in its extreme. When people told Kamen that his water purification idea was impossible, he said, "*Don't tell me it's impossible. Tell me you can't do it.*" Things that other people think are impossible may not seem impossible to someone who believes they can overcome any obstacle, and this faith increases their likelihood of tackling a big challenge and sticking with it even in the face of failure or criticism.
3. **They were keenly idealistic.** Another characteristic that fueled the innovators' drive to pursue huge problems with fierce tenacity was their belief that they were pursuing something intrinsically noble and important. This drove them to work extremely long hours, often neglecting family, friends, and health. They poured their money, time, and energy into projects even if they had a high probability of failure. For example, in a 2014 interview on *60 Minutes,* Elon Musk noted that when he started Tesla Motors he had thought it would probably fail. When the interviewer asked him, "But you say you didn't expect the company to be successful? Then why try?" Musk responded, "If something is important enough you should try—even if you think the probable outcome is failure."
4. **They began with modest means and worked very hard for their success.** None of the innovators studied began their careers with significant financial resources. Nikola Tesla, for example, landed in the United States with four cents and a poem, and Benjamin Franklin arrived in New York with enough money for two rolls of bread. Dean Kamen, Thomas Edison, and Steve Jobs started their innovation careers as teenagers in working class families, and Elon Musk started his career by moving to Canada at seventeen, against his father's wishes, and supported himself with odd jobs such as shoveling grain and cleaning the boiler room of a lumber mill. All of the innovators were also happiest when working hard. Marie Curie worked so hard she often fainted at her laboratory bench, having forgotten to eat or rest, and Thomas Edison and Nikola Tesla often worked through the night. But as Edison noted, "Work made the Earth a paradise for me. I never intend to retire."

continued

concluded

5. **They were often self-taught.** Many of the innovators had significantly less formal education than would be expected for the fields in which they worked and made substantial contributions to areas outside of the fields in which they were trained. They were avid self-educators who were described as voracious readers, and several attained exceptional mastery of subjects without earning credentials. For example, Dean Kamen invented the world's first portable drug infusion pump, the world's first portable kidney dialysis machine, and many other extremely important medical inventions (such as the Segway Personal Transporter) without ever earning a college degree. Benjamin Franklin provides an even more extreme example. Having only attended a few years of grammar school, Benjamin Franklin went on to discover many fundamental principles of electricity, invent an improved urinary catheter, and was the first person to chart the Gulf Stream current.

ARE THESE CHARACTERISTICS IMITABLE?

Many of the breakthrough innovators had some personal traits that are difficult to imitate, like exceptional intelligence and memory, or mild manic tendencies. However, understanding *how* these factors helped them to become breakthrough innovators also reveals how anyone can nurture the breakthrough innovation potential in themselves and others. For example, anyone can cultivate a grand ambition that helps them to think bigger and stay motivated. There are a range of ways people can increase self-efficacy in themselves and others. It is also possible to modify cultural norms at schools, work, and home to help people become more comfortable challenging assumptions and mastering new subjects independently.

[a] Melissa A. *Quirky: The Remarkable Story of the Traits, Foibles, and Genius of Breakthrough Innovators Who Changed the World* (New York: Public Affairs, 2018).

The Inventor

The familiar image of the inventor as an eccentric and doggedly persistent scientist may have some basis in cognitive psychology. Analysis of personality traits of inventors suggests these individuals are likely to be interested in theoretical and abstract thinking, and have an unusual enthusiasm for problem solving. One 10-year study of inventors concludes that the most successful inventors possess the following characteristics:

1. They have mastered the basic tools and operations of the field in which they invent, but they have not specialized solely in that field; instead they have pursued two or three fields simultaneously, permitting them to bring different perspectives to each.
2. They are curious and more interested in problems than solutions.
3. They question the assumptions made in previous work in the field.
4. They often have the sense that all knowledge is unified. They seek global solutions rather than local solutions, and are generalists by nature.[22]

These traits are amply demonstrated by people like Albert Einstein (who overthrew several paradigms in physics), Marie Curie (who used her techniques of measuring radioactivity to show that Lord Kelvin was wrong in his calculations of the age of the Earth), and Elon Musk (who refused to listen to people who said that building reusable rockets was impossible). They are also illustrated in the following quotes by Nobel laureates. Sir MacFarlane Burnet, Nobel Prize–winning immunologist, noted, "I think there are dangers for a research man being too well trained in the field he is going to study,"[23] and Peter Debye, Nobel Prize–winning chemist, noted, "At the beginning of the Second World War, R. R. Williams of Bell Labs came to Cornell to try to interest me in the polymer field. I said to him, 'I don't know anything about polymers. I never thought about them.' And his answer was, 'That is why we want you.'"[24] The global search for global solutions is aptly illustrated by Thomas Edison, who did not set out to invent just a lightbulb: "The problem then that I undertook to solve was . . . the production of the multifarious apparatus, methods, and devices, each adapted for use with every other, and all forming a comprehensive system."[25]

Such individuals may spend a lifetime developing numerous creative new devices or processes, though they may patent or commercialize few. The qualities that make people inventive do not necessarily make them entrepreneurial; many inventors do not actively seek to patent or commercialize their work. Many of the most well-known inventors (e.g., Alexander Graham Bell, Thomas Alva Edison, Albert Einstein, and Benjamin Franklin), however, had both inventive and entrepreneurial traits.[26]

Innovation by Users

Innovation often originates with those who create solutions for their own needs. Users often have both a deep understanding of their unmet needs and the incentive to find ways to fulfill them.[27] While manufacturers typically create new product innovations in order to profit from the sale of the innovation to customers, user innovators often have no initial intention to profit from the sale of their innovation—they create the innovation for their own use.[28] Users may alter the features of existing products, approach existing manufacturers with product design suggestions, or develop new products themselves. For example, the extremely popular small sailboat, the Laser, was designed without any formal market research or concept testing. Instead it was the creative inspiration of three former Olympic sailors, Ian Bruce, Bruce Kirby, and Hans Vogt. They based the boat design on their own preferences: simplicity, maximum performance, transportability, durability, and low cost. The resulting sailboat became hugely successful; during the 1970s and '80s, 24 Laser sailboats were produced daily.[29]

Another dramatic example is the development of Indermil, a tissue adhesive based on Super Glue. Super Glue is a powerful instant adhesive, and while its strength and speed of action were a great asset in most product applications, these features also caused a key product concern—its tendency to bond skin. Managers at Loctite, the company that developed Super Glue, wondered if this tendency could be exploited to develop an alternative to sutures for surgical applications. In the 1970s, the company experimented with developing a version of the adhesive that could be packaged and sterilized, but the project failed and funding for it was canceled. In 1980, the project was resurrected when Loctite was approached by a pharmaceutical company that wanted to collaborate on developing a wound closure product. The two companies spent three years attempting to develop special Super Glues that would degrade quickly in the body, but ultimately shelved the project again. By this point most managers in the company no longer wanted to be involved in developing an alternative to sutures—it was considered far too risky. However, in 1988, Bernie Bolger of Loctite was contacted by Professor Alan Roberts, a worldwide figure in reconstructive surgery. Roberts proceeded to give the managers at Loctite a stunning presentation about doctors who had responded to the Bradford football stadium fire of 1983. Roberts and many other doctors had been called in to carry out surgery and skin grafting in makeshift tents around the stadium. Because stitching was too slow and skin damage was such that sutures would be ineffective, the doctors had used standard tubes of Super Glue to repair the skin and stick skin grafts in place! Roberts showed pictures of doctors in green garb standing around with Super Glue tubes stuck to their aprons, and pictures of people with large areas of skin missing and then those same people years later, with almost perfect skin repairs. Roberts begged the Loctite managers to continue their work on developing a version of Super Glue for tissue adhesion. Roberts's presentation was so compelling that the company again took up the project, this time with support from the CEO and serious funding. Approval from the U.S. Food and Drug Administration was won in 2002, and by 2003 the product was selling well in over 40 countries.[30]

basic research
Research targeted at increasing scientific knowledge for its own sake. It may or may not have any long-term commercial application.

Research and Development by Firms

Across all nations, one of the most obvious sources of firm innovation is the firm's own research and development efforts. In most developed countries, firms account for the majority of R&D performed (see Figure 2.2).

applied research
Research targeted at increasing knowledge for a specific application or need.

development
Activities that apply knowledge to produce useful devices, materials, or processes.

Though the terms *research* and *development* are often lumped together, they actually represent different kinds of investment in innovation-related activities. *Research* can refer to both basic research and applied research. **Basic research** is effort directed at increasing understanding of a topic or field without a specific immediate commercial application in mind. This research advances scientific knowledge, which may (or may not) turn out to have long-run commercial implications. **Applied research** is directed at increasing understanding of a topic to meet a specific need. In industry, this research typically has specific commercial objectives. **Development** refers to activities that apply knowledge to produce useful devices, materials, or processes. Thus, the term *research and development* refers to a range of activities that extend from early exploration of a domain to specific commercial implementations. A firm's R&D intensity (its R&D expenditures as a percentage of its revenues) has a strong positive correlation with its sales growth rate, sales from new products, and profitability.[31]

FIGURE 2.2
R&D for Selected Countries by Type, 2017 or most recent year

Sources: National Center for Science and Engineering Statistics, National Science Foundation, National Patterns of R&D Resources (annual series); Organisation for Economic Co-operation and Development, *Main Science and Technology Indicators* (2019/1); United Nations Educational, Scientific and Cultural Organization Institute for Statistics Data Centre.

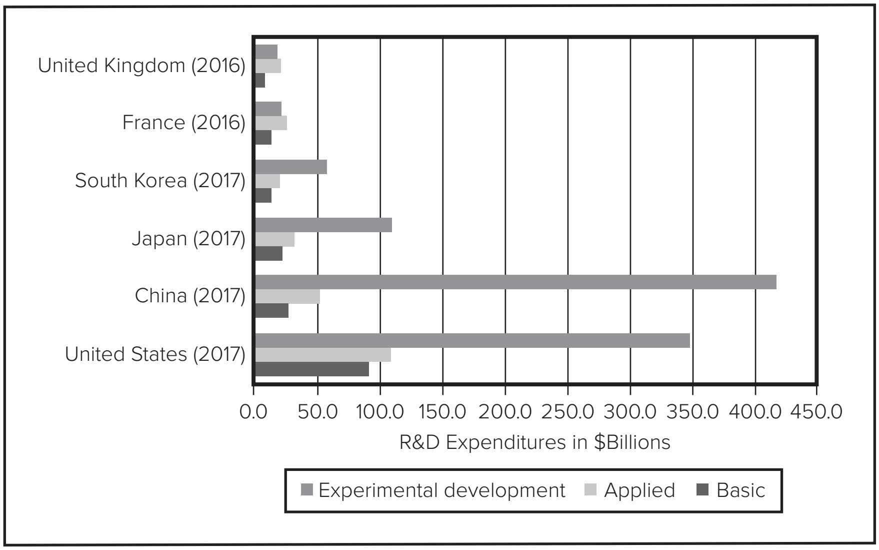


Figure 2.2 shows the percent of R&D that was basic, applied, or experimental for a selected number of countries in 2017. As shown, most countries spend proportionately more on applied research and experimental development than basic research.

During the 1950s and 1960s, scholars of innovation emphasized a *science-push* approach to research and development.[32] This approach assumed that innovation proceeded linearly from scientific discovery, to invention, to engineering, then manufacturing activities, and finally marketing. According to this approach, the primary sources of innovation were discoveries in basic science that were translated into commercial applications by the parent firm. This linear process was soon shown to have little applicability to real-world products. In the mid-1960s, another model of innovation gained prominence: the *demand-pull* model of research and development. This approach argued that innovation was driven by the perceived demand of potential users. Research staff would develop new products in efforts to respond to customer problems or suggestions. This view, however, was also criticized as being too simplistic. Rothwell, for example, points out that different phases of innovation are likely to be characterized by varying levels of science push and demand pull.[33]

Most current research suggests that firms that are successful innovators utilize multiple sources of information and ideas, including:

- In-house research and development, including basic research.
- Linkages to customers or other potential users of innovations.
- Linkages to an external network of firms that may include competitors, complementors, and suppliers.
- Linkages to other external sources of scientific and technical information, such as universities and government laboratories.[34]

Firm Linkages with Customers, Suppliers, Competitors, and Complementors

Firms often form alliances with customers, suppliers, complementors, and even competitors to jointly work on an innovation project or to exchange information and other resources in pursuit of innovation. Collaboration might occur in the form of alliances, participation in research consortia, licensing arrangements, contract research and development, joint ventures, and other arrangements. The advantages and disadvantages of different forms of collaboration are discussed in Chapter Eight. Collaborators can pool resources such as knowledge and capital, and they can share the risk of a new product development project.

The most frequent collaborations are between firms and their customers, suppliers, and local universities (see Figure 2.3).[35] Several studies indicate that firms consider users their most valuable source of new product ideas. The use of such collaborations is consistent across North America, Europe, and Japan, though Japanese firms may be somewhat more likely to collaborate extensively with their customers (see Figure 2.3).

complementors
Producers of complementary goods or services (e.g., for video game console producers such as Sony or Nintendo, game developers) are complementors.

Firms may also collaborate with competitors and complementors. **Complementors** are organizations (or individuals) that produce complementary goods, such as lightbulbs for lamps, chargers for electric vehicles, or applications for smartphones. In some industries, firms produce a range of goods and the line between competitor and complementor can blur.

FIGURE 2.3
Percentage of Companies That Report Extensive Collaboration with Customers, Suppliers, and Universities

Source: E. Roberts, "Benchmarking Global Strategic Management of Technology," *Research Technology Management*, March–April 2001: 25–36.

	North America (%)	Europe (%)	Japan (%)
Collaborates with:			
Customers	44	38	52
Suppliers	45	45	41
Universities	34	32	34

In some circumstances, firms might be bitter rivals in a particular product category and yet engage in collaborative development in that product category or complementary product categories. For instance, Microsoft competes against Rockstar Games in many video game categories, yet also licenses many Rockstar Games to play on its Xbox models. Rockstar is thus both a competitor and complementor to Microsoft. This can make the relationships between firms very complex—firms may have to manage a delicate balance between their roles of competitor versus complementor, or complementors might refuse to cooperate. For example, when Google bought Motorola Mobility in 2011, makers of mobile phone handsets that used Google's Android operating system such as Samsung and HTC were watching closely to see if Google would give Motorola handsets preferential access to Google software. Many analysts speculated that Samsung and HTC would begin developing more phones based on Microsoft's mobile operating system. To avoid the ire and defection of its complementors, Google announced that Motorola would be run as a separate entity and be given no advantages over makers of other Android-powered handsets. Android was to remain an equal-opportunity platform where any handset maker had a shot at making the next great Android phone.[36]

External versus Internal Sourcing of Innovation

Critics have often charged that firms are using external sources of technological innovation rather than investing in original research. But empirical evidence suggests that external sources of information are more likely to be complements to rather than substitutes for in-house research and development. Research by the Federation of British Industries indicated firms that had their own research and development were also the heaviest users of external collaboration networks. Presumably doing in-house R&D helps to build the firm's **absorptive capacity**, enabling it to better assimilate and utilize information obtained externally.[37] Absorptive capacity refers to the firm's ability to understand and use new information (absorptive capacity is discussed in more detail in Chapter Four).

absorptive capacity
The ability of an organization to recognize, assimilate, and utilize new knowledge.

Universities and Government-Funded Research

Another important source of innovation comes from public research institutions such as universities, government laboratories, and incubators. A significant share of companies report that research from public and nonprofit institutions enabled them to develop innovations that they would not have otherwise developed.[38]

Universities

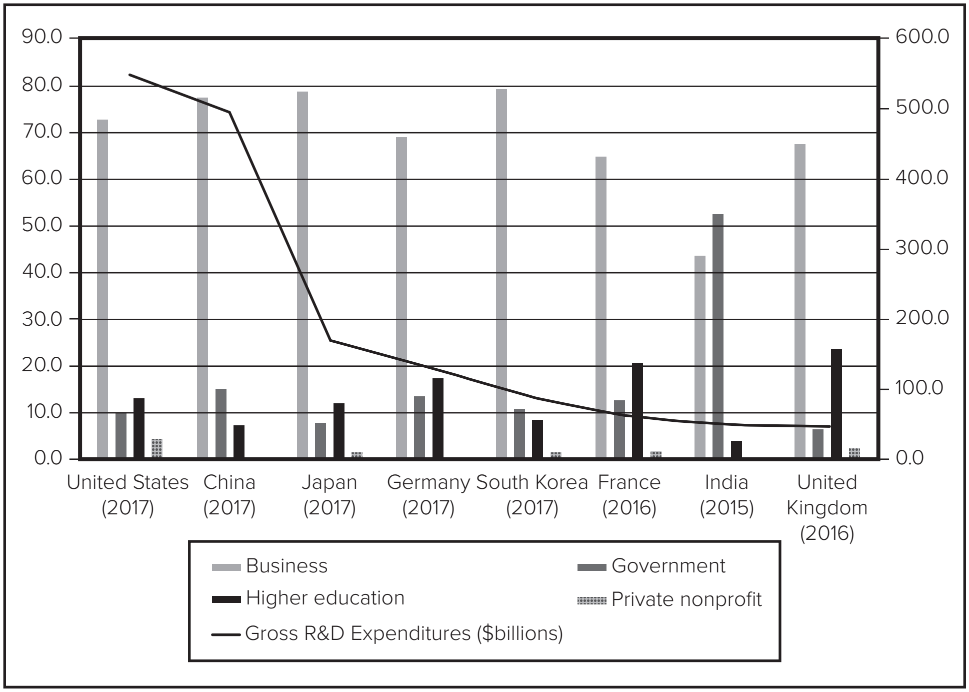
Universities in the United States performed $71.4 billion worth of R&D in 2017, making them the second largest performer of R&D in the United States after industry, and making the United States the place where universities spend the most money on R&D, on an absolute basis, in the world (see Figure 2.4). Of that, over $40 billion was for *basic research* (versus *applied research*), making universities the number one performer of basic research in the United States. The nation where universities perform the highest share of R&D, on the other hand, is the France where universities spend $16.8 billion, accounting for 20.7% of total R&D performance in the country. Many universities encourage their faculty to engage in research that may lead to useful innovations. Typically the intellectual property policies of a university embrace both patentable and unpatentable innovations, and the university retains sole discretion over the rights to commercialize the innovation. If an invention is successfully commercialized, the university typically shares the income with the individual inventor(s).[39] To increase the degree to which university research leads to commercial innovation, many universities have established **technology transfer offices**.

technology transfer offices
Offices designed to facilitate the transfer of technology developed in a research environment to an environment where it can be commercially applied.

In the United States, the creation of university technology transfer offices accelerated rapidly after the Bayh–Dole Act was passed in 1980. This act allowed universities to collect royalties on inventions funded with taxpayer dollars. Before this, the federal government was entitled to all rights from federally funded inventions.[40] Several European and Asian countries subsequently followed the U.S. lead and established legislation similar to Bayh–Dole, including Denmark, Austria, Finland, Norway,

FIGURE 2.4
R&D Expenditures for Top 8 R&D-Performing Countries by Performance Sector, 2017 or most recent year

Sources: National Center for Science and Engineering Statistics, National Science Foundation, National Patterns of R&D Resources (annual series); Organisation for Economic Co-operation and Development, *Main Science and Technology Indicators* (2019/1); United Nations Educational, Scientific and Cultural Organization Institute for Statistics Data Centre.



Germany, France, United Kingdom, Japan, China, and India. Sweden and Italy, on the other hand, still have a policy of "professor's privilege" where university faculty retain sole ownership rights over their inventions. While the revenues from the university technology transfer activities are still quite small in comparison to university research budgets, their importance is growing. Initially, many anticipated that businesses would flock to license the intellectual property created by universities, leading to a substantial flow in licensing revenues. This "if you build it they will come" mindset turned out to be wrong, and licensing revenues were far less than expected. Now universities are taking a much more active role in helping to create start-ups based on their intellectual property, and in proactively forging relationships with the commercial sector.[41] Universities also contribute significantly to innovation through the publication of research results that are incorporated into the development efforts of other organizations and individuals.

Government-Funded Research

Governments of many countries actively invest in research through their own laboratories, the formation of **science parks** and **incubators**, and grants for other public or private research entities. For example, the U.S. Small Business Administration manages two programs that enable innovative small businesses to receive funding from federal agencies such as the Department of Defense, the Department of Energy, the Department of Health and Human Services, and others. The first is the Small Business Innovation Research (SBIR) program. Under the SBIR program, agencies award grants of up to $1,730,000 to small businesses to help them develop and commercialize a new innovation. The second is the Small Business Technology Transfer (STTR) program, which awards grants of up to $1,730,000 to facilitate a partnership between a small business and a nonprofit research institution—its objective is to more fully leverage the innovation that takes place in research laboratories by connecting research scientists with entrepreneurs.

science parks
Regional districts, typically set up by government, to foster R&D collaboration between government, universities, and private firms.

incubators
Institutions designed to nurture the development of new businesses that might otherwise lack access to adequate funding or advice.

Notable examples of science parks with incubators include:

- Stanford Research Park, established near Stanford University in 1951.
- Research Triangle Park, established in North Carolina in 1959.
- Sophia Antipolis Park, established in Southern France in 1969.
- Cambridge Science Park, established in Cambridge, England, in 1972.

These parks create fertile hotbeds for new start-ups and a focal point for the collaboration activities of established firms. Their proximity to university laboratories and other research centers ensures ready access to scientific expertise. Such centers also help university researchers implement their scientific discoveries in commercial applications.[42] Such parks often give rise to technology clusters that have long-lasting and self-reinforcing advantages (discussed later in the chapter).

Private Nonprofit Organizations

Private nonprofit organizations, such as private research institutes, nonprofit hospitals, private foundations, professional or technical societies, academic and industrial consortia, and trade associations, also contribute to innovation activity in a variety of complex ways. Many nonprofit organizations perform their own research and development activities, some fund the research and development activities of other organizations but do not do it themselves, and some nonprofit organizations do both in-house research and development and fund the development efforts of others.

INNOVATION IN COLLABORATIVE NETWORKS

As the previous sections indicate, there is a growing recognition of the importance of collaborative research and development networks for successful innovation.[43] Such collaborations include (but are not limited to) joint ventures, licensing and second-sourcing agreements, research associations, government-sponsored joint research programs, value-added networks for technical and scientific interchange, and informal networks.[44] Collaborative research is especially important in high-technology sectors, where it is unlikely that a single individual or organization will possess all of the resources and capabilities necessary to develop and implement a significant innovation.[45]

As firms forge collaborative relationships, they weave a network of paths between them that can act as conduits for information and other resources. By providing member firms access to a wider range of information (and other resources) than individual firms possess, interfirm networks can enable firms to achieve much more than they could achieve individually.[46] Thus, interfirm networks are an important engine of innovation. Furthermore, the structure of the network is likely to influence the flow of information and other resources through the network. For example, in a dense network where there are many potential paths for information to travel between any pair of firms, information diffusion should be fairly rapid and widespread.[47]

Figure 2.5 provides pictures of the worldwide technology alliance network in 1995 and in 2000.[48] The mid-1990s saw record peaks in alliance activity as firms scrambled to respond to rapid change in information technologies. This resulted in a very large and dense web of connected firms. The network shown here connects 3856 organizations, predominantly from North America, Japan, and Europe. However, there was a subsequent decline in alliance activity toward the end of the decade that caused the web to diminish in size and splinter apart into two large components and many small components. The large component on the left is primarily made up of organizations in the chemical and medical industries. The large component on the right is primarily made up of organizations in electronics-based industries. If the size and density of the collaboration network influences the amount of information available to organizations that are connected via the network, then the difference between the network shown for 1995 and the network shown for 2000 could have resulted in a substantial change in the amount of information that was transmitted between firms. (The strategic implications for a firm's position within the network are discussed in Chapter Eight.)

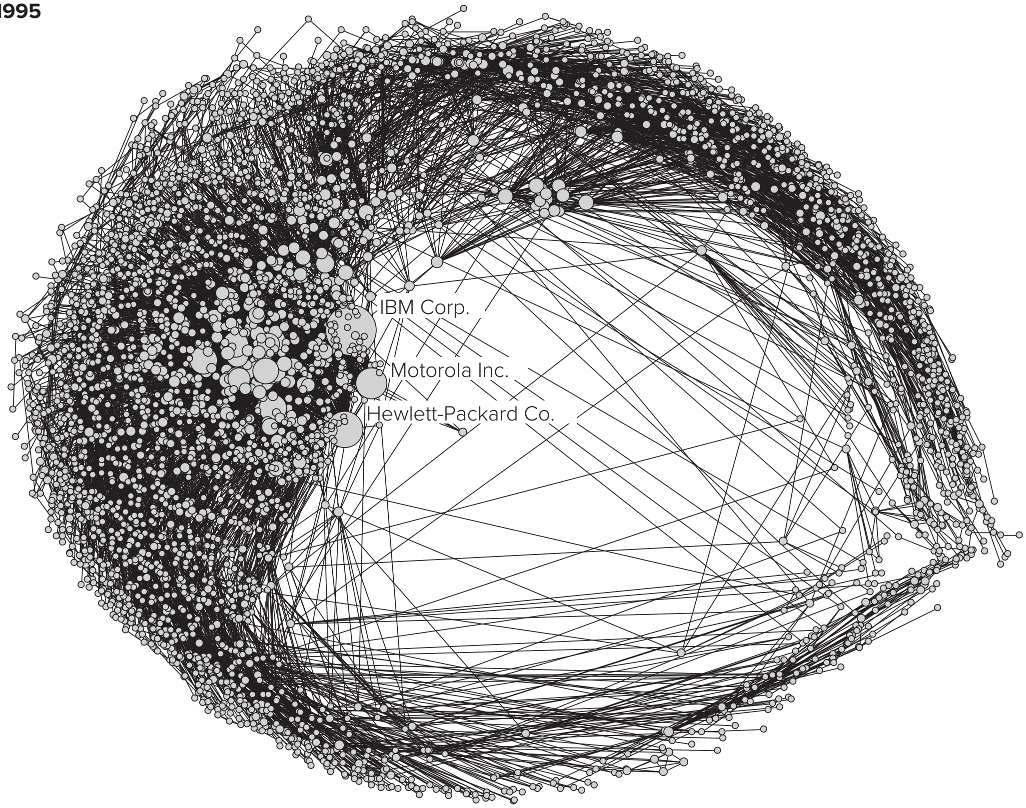
Technology Clusters

Sometimes geographical proximity appears to play a role in the formation and innovative activity of collaborative networks. Well-known regional clusters such as Silicon Valley's semiconductor firms, lower Manhattan's multimedia cluster, and the

FIGURE 2.5

The Global Technology Collaboration Network, 1995 and 2000[49]

1995



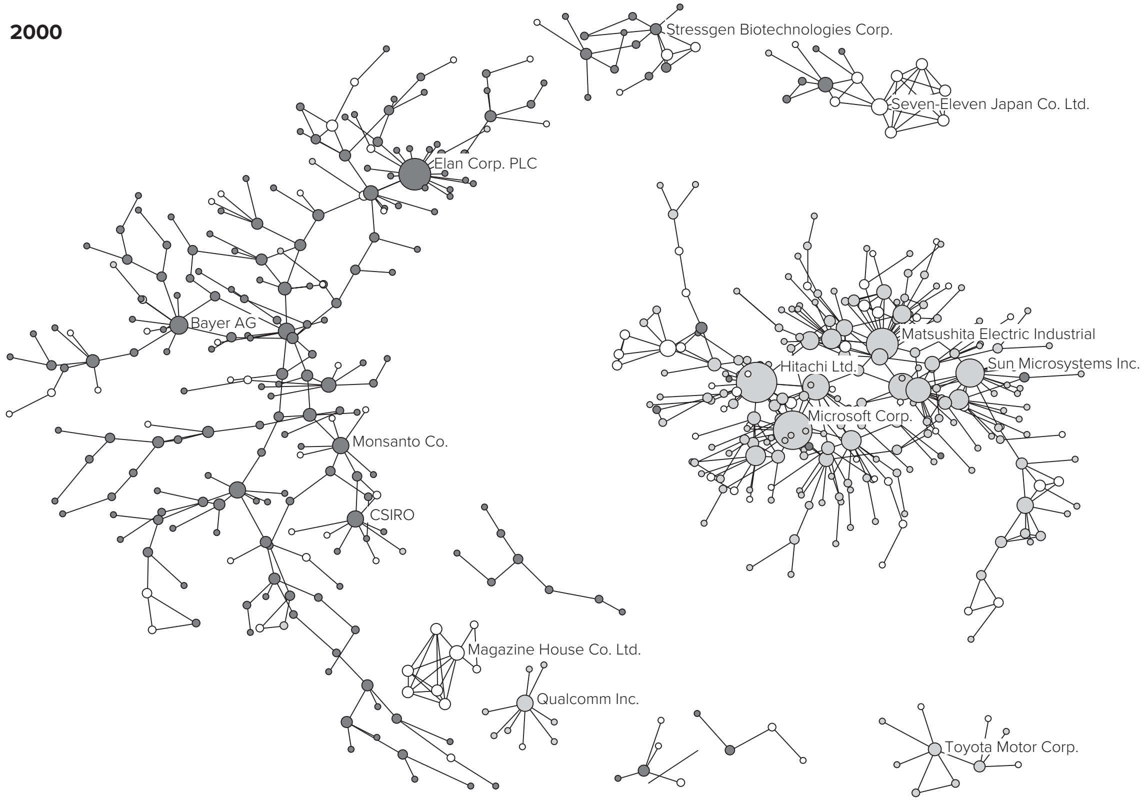
technology clusters
Regional clusters of firms that have a connection to a common technology, and may engage in buyer, supplier, and complementor relationships, as well as research collaboration.

Modena, Italy, knitwear district aptly illustrate this point. This has spurred considerable interest in the factors that lead to the emergence of a cluster. City and state governments, for example, might like to know how to foster the creation of a technology cluster in their region in order to increase employment, tax revenues, and other economic benefits. For firms, understanding the drivers and benefits of clustering is useful for developing a strategy that ensures the firm is well-positioned to benefit from clustering.

Technology clusters may span a region as narrow as a city or as wide as a group of neighboring countries.[50] Clusters often encompass an array of industries that are linked through relationships between suppliers, buyers, and producers of complements. One primary reason for the emergence of regional clusters is the benefit of proximity in knowledge exchange. Though advances in information technology have made it easier, faster, and cheaper to transmit information great distances, several studies indicate that knowledge does not always transfer readily via such mechanisms.

FIGURE 2.5 *Continued*

2000



complex knowledge
Knowledge that has many underlying components, or many interdependencies between those components, or both.

tacit knowledge
Knowledge that cannot be readily codified (documented in written form).

Proximity and interaction can directly influence firms' ability and willingness to exchange knowledge. First, knowledge that is **complex** or **tacit** may require frequent and close interaction to be meaningfully exchanged.[51] Firms may need to interact frequently to develop common ways of understanding and articulating the knowledge before they are able to transfer it.[52] Second, closeness and frequency of interaction can influence a firm's *willingness* to exchange knowledge. When firms interact frequently, they can develop trust and reciprocity norms. Firms that interact over time develop greater knowledge of each other, and their repeated interactions give them information as to the likelihood of their partner's behaving opportunistically. A shared understanding of the rules of engagement emerges, wherein each partner understands its obligations with respect to how much knowledge is exchanged, how that knowledge can be used, and how the firms are expected to reciprocate.[53]

Firms that are proximate thus have an advantage in sharing information that can lead to greater innovation productivity. This can, in turn, lead to other self-reinforcing geographical advantages. A cluster of firms with high innovation productivity can lead to more new firms starting up in the immediate vicinity and can attract other firms to the area.[54] As firms grow, divisions may be spun off into new firms, entrepreneurial employees may start their own enterprises, and supplier and distributor markets emerge to service the cluster. Successful firms also attract new labor to the area and help to make the existing labor pool more valuable by enabling individuals to gain experience working with the innovative firms. The increase in employment and tax revenues in the region can lead to improvements in infrastructure (such as roads and utilities), schools, and other markets that service the population (shopping malls, grocery stores, health-care providers, etc.). The benefits firms reap by locating in close geographical proximity to each other are known collectively as **agglomeration economies**.[55]

agglomeration economies
The benefits firms reap by locating in close geographical proximity to each other.

There are also some downsides to geographical clustering. First, the proximity of many competitors serving a local market can lead to competition that reduces their pricing power in their relationships with both buyers and suppliers. Second, close proximity of firms may increase the likelihood of a firm's competitors gaining access to the firm's proprietary knowledge (this is one of the mechanisms of technology spillovers, discussed in the next section). Third, clustering can potentially lead to traffic congestion, inordinately high housing costs, and higher concentrations of pollution.[56]

A big part of the reason that technologies are often regionally localized is that technological knowledge is, to a large extent, held by people, and people are often only reluctantly mobile. In a well-known study, Annalee Saxenian found that engineers in Silicon Valley were more loyal to their craft than to any particular company, but they were also very likely to stay in the region even if they changed jobs.[57] This was due in part to the labor market for their skills in the region, and in part to the disruption in an individual's personal life if he or she were to move out of the region. Thus, if for some reason an innovative activity commences in a geographic locale, the knowledge and expertise that accumulates might not spread readily into other geographic locales, leading to a localized cluster of technological expertise.[58]

Studies have indicated that while many innovative activities appear to have some geographic component, the degree to which innovative activities are geographically clustered depends on things such as:

- The nature of the technology, such as its underlying knowledge base or the degree to which it can be protected by patents or copyright, and the degree to which its communication requires close and frequent interaction.
- Industry characteristics, such as the degree of market concentration or stage of the industry life cycle, transportation costs, and the availability of supplier and distributor markets.
- The cultural context of the technology, such as the population density of labor or customers, infrastructure development, or national differences in the way technology development is funded or protected.

For example, one study that examined the spatial distribution of technology sectors in different countries found that pharmaceutical development was highly clustered in the United Kingdom and France, but much more spatially diffused in Italy and Germany.[59] The same study found, however, that the manufacture of clothing demonstrated high clustering in Italy, but not in France, Germany, or the United Kingdom. While the clustering of pharmaceutical development may have been influenced by the national