11

Technology-based Industries and the Management of Innovation

Whereas a calculator on the ENIAC is equipped with 18,000 vacuum tubes and weighs 30 tons, computers in the future may have only 1,000 vacuum tubes and perhaps weigh only 1.5 tons.

—POPULAR MECHANICS, *MARCH 1949*

I can think of no conceivable reason why an individual should wish to have a computer in his own home.

—KENNETH OLSEN, CHAIRMAN, DIGITAL EQUIPMENT CORPORATION, 1977

OUTLINE

Introduction and Objectives

Industries where competition centers on innovation and the application of technology provide some of the most fascinating and complex competitive environments in which to apply the concepts of strategy analysis. Consider the upheaval that wireless communication and internet protocols have caused in the telecom sector:

- In 1996, the world's three most valuable telecom companies were AT&T, Nippon Telephone and Telegraph (NTT), and British Telecom (BT), the top three (in terms of market value) were China Mobile Vodafone, and AT&T – although the new AT&T was a renamed SBC Communication, not the direct descendant of the old AT&T. By the end of 2006.
- A similar upheaval occurred on the manufacturing side of the telecom industry. In 1996, the world's leading producers of telecom equipment were AT&T, Alcatel, NEC, Siemens, and GTE. By the end of 2003, three companies – Cisco Systems, Nokia, and Qualcomm – accounted for 78% of the stock market value of the world's top 10 telecom equipment producers.
- During 2006–7, the fixed-line telecom business was being rocked by new waves of competition from cable operators and internet telecom providers.

There are few industries that have seen as much technological upheaval as has the telecom industry over the past ten years. At the same time, technological change has been a feature of almost every sector of the economy, not least because of the pervasive influence of microelectronics, digitization, new materials, and new forms of communication. In this chapter, we concentrate on the strategic management of innovation and technological change. Our focus is on technology-intensive industries, which include both emerging industries (those in the introductory and growth phases of their life cycle) and well-established industries (such as pharmaceuticals, chemicals, telecommunications, and electronics) where technology continues to be the major driver of competition. The issues we examine, however, are also relevant to a much broader range of industries. Although industries such as food processing, fashion goods, domestic appliances, and financial services are not technology based to the same extent as consumer electronics or pharmaceuticals, innovation and the application of new technologies are important sources of competitive advantage.

In the last chapter, we saw how innovation is responsible for the creation of new industries, how innovation changes over the course of the industry life cycle, and the implications of this industry structure and competitive advantage. In this chapter we shall be looking at innovation and technology as weapons of competitive strategy. Our focus is the firm: how does the firm use technology and innovation to establish competitive advantage, to survive the brutal competition that characterizes so many technology-based industries and, ultimately, to earn superior profits over the long term?

By the time you have completed this chapter, you will be able to:

- Analyze how technology affects industry structure and competition.
- Identify the factors that determine the returns to innovation, and evaluate the potential for an innovation to establish competitive advantage.
- Formulate strategies for exploiting innovation and managing technology, focusing in particular on:
  - the relative advantages of being a leader or a follower in innovation;
  - identifying and evaluating strategic options for exploiting innovation;
  - how to win standards battles;
  - how to manage risk.
- Design the organizational conditions needed to implement such strategies successfully.

This chapter is organized as follows. First, we examine the links between technology and competition in technology-intensive industries. Second, we explore the potential for innovation to establish sustainable competitive advantage. Third, we deal with key issues in designing technology strategies, including timing (to lead or to follow), alternative strategies for exploiting an innovation, setting industry standards, and managing risk. Finally, we examine the organizational conditions for the successful implementation of technology-based strategies.

Competitive Advantage in Technology-intensive Industries

Our focus is innovation. Innovation is responsible for industries coming into being, and innovation – if successful – creates competitive advantage. Let us begin by exploring the linkage between innovation and profitability.

The Innovation Process

Invention is the creation of new products and processes through the development of new knowledge or from new combinations of existing knowledge. Most inventions are the result of novel applications of existing knowledge. Samuel Morse's telegraph, patented in 1840, was based on several decades of research into electromagnetism from Ben Franklin to Orsted, Ampere, and Sturgion. The compact disc embodies knowledge about lasers developed several decades previously.

Innovation is the initial commercialization of invention by producing and marketing a new good or service or by using a new method of production. Once introduced, innovation diffuses: on the demand side, through customers purchasing the good or service; on the supply side, through imitation by competitors. An innovation may be the result of a single invention (most product innovations in chemicals and pharmaceuticals involve discoveries of new chemical compounds) or it may combine many inventions. The first automobile, introduced by Benz in 1885, embodied a multitude of inventions, from the wheel, invented some 5,000 years previously, to the internal combustion engine, invented nine years earlier. Not all invention progresses into innovation: among the patent portfolios of most technology-intensive firms are numerous inventions that have yet to find a viable commercial application. Many innovations may involve little or no new technology: the personal computer brought together existing components and technologies, but no fundamental scientific breakthroughs; most new types of packaging – including the vast array of anti-tamper packages – involve clever design but little in the way of new technology. Most business method patents are process innovations with little technological content.

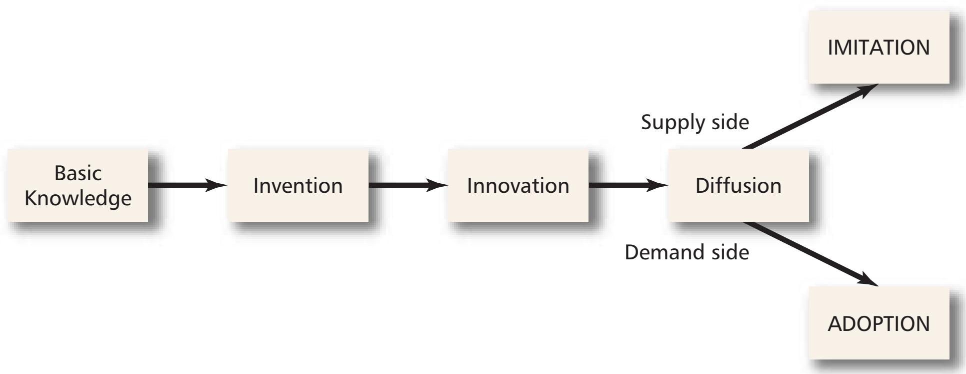
Figure 11.1 shows the pattern of development from knowledge creation to invention and innovation. Historically, the lags between knowledge creation and innovation have been long:

- Chester F. Carlson invented xerography in 1938 by combining established knowledge about electrostatics and printing. The first patents were awarded in 1940. Xerox purchased the patent rights and launched its first office copier in 1958. By 1974, the first competitive machines were introduced by IBM, Kodak, Ricoh, and Canon.
- The jet engine, employing Newtonian principles of forces, was patented by Frank Whittle in 1930. The first commercial jet airliner, the Comet, flew in 1957. Two years later, the Boeing 707 was introduced.

Recently, the innovation cycle has speeded up:

- The mathematics of *fuzzy logic* were developed by Lofti Zadeh at Berkeley during the 1960s. By the early 1980s, Dr. Takeshi Yamakawa of the Kyushu

FIGURE 11.1 The development of technology: from knowledge creation to diffusion



Institute of Technology had registered patents for integrated circuits embodying fuzzy logic, and in 1987 a series of fuzzy logic controllers for industrial machines was launched by Omron of Kyoto. By 1991, the world market for fuzzy logic controllers was estimated at $2 billion.[1]

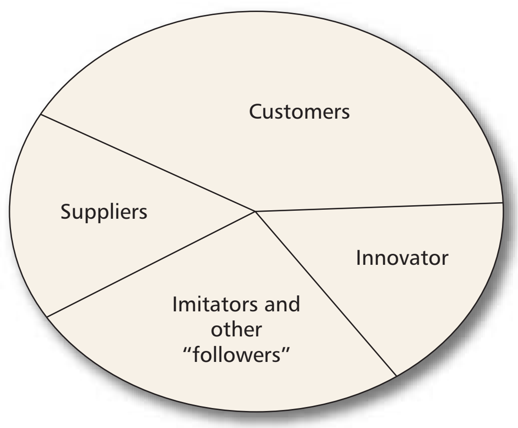
- MP3, the audio file compression software, was developed at the Fraunhofer Institute in Germany in 1987; by the mid-1990s, the swapping of MP3 music files had taken off in US college campuses and in 1998 the first MP3 player, Diamond Multimedia's *Rio*, was launched.

The Profitability of Innovation

"If a man . . . make a better mousetrap than his neighbor, though he build his house in the woods, the world will make a beaten path to his door," claimed Emerson. Yet, the inventors of new mousetraps, and other gadgets too, are more likely to be found at the bankruptcy courts than in the millionaires' playgrounds of the Caribbean. Certainly, innovation is no guarantor of fame and fortune, either for individuals or for companies. The empirical evidence on technological intensity, innovation, and profitability confirms this mixed picture. Across companies, R&D intensity and frequency of new product introductions tend to be negatively associated with profitability.[2]

The profitability of an innovation to the innovator depends on the value created by the innovation and the share of that value that the innovator is able to appropriate. The value created by an innovation is distributed among a number of different parties (see Figure 11.2). In the case of the personal computer, the innovators – MITS, Tandy, Apple, and Xerox – earned modest profits from their innovation. The imitators – IBM, Dell, Compaq, Acer, Toshiba and a host of other followers into the PC industry earned rather more in total profits. Nevertheless, their returns were overshadowed by the huge profits earned by the suppliers to the industry: Intel in microprocessors, Seagate Technology and Quantum Corp. in disk drives, Sharp in flat-panel displays, and Microsoft in operating systems. However, because of strong competition

FIGURE 11.2 Appropriation of value: who gets the benefits from innovation?



in the industry, the greatest part of the value created by the personal computer was appropriated by customers, who typically paid prices for their PCs that were far below the value that they derived.[3]

The term *regime of appropriability* is used to describe the conditions that influence the distribution of returns to innovation. In a strong regime of appropriability, the innovator is able to capture a substantial share of the value created: Nutrasweet artificial sweetener (developed by Searle, subsequently acquired by Monsanto), Pfizer's Viagra, and Pilkington's float glass process generated huge profits for their owners. In a weak regime of appropriability, other parties derive most of the value. In internet Telephony (VoIP), ownership of technologies is diffused and standards are public, with the result that no players are likely to earn massive profits. Four factors are critical in determining the extent to which innovators are able to appropriate the value of their innovation: property rights, the tacitness and complexity of the technology, lead-time and, complementary resources.

Property Rights in Innovation Appropriating the returns to innovation depends, to a great extent, on the ability to establish property rights in the innovation. It was the desire to protect the returns to inventors that prompted the English Parliament to pass the 1623 Statute of Monopolies, which established the basis of patent law. Since then, the law has been extended to several areas of *intellectual property*, including:

- *Patents* – exclusive rights to a new and useful product, process, substance, or design. Obtaining a patent requires that the invention is novel, useful, and not excessively obvious. Patent law varies from country to country. In the United States, a patent is valid for 17 years (14 for a design).
- *Copyrights* – exclusive production, publication, or sales rights to the creators of artistic, literary, dramatic, or musical works. Examples include articles, books, drawings, maps, photographs, and musical compositions.
- *Trademarks* – words, symbols, or other marks used to distinguish the goods or services supplied by a firm. In the US and UK, they are registered with the Patent Office. Trademarks provide the basis for brand identification.
- *Trade secrets* – which offer less well-defined legal protection. Their protection relates chiefly to chemical formulae, recipes, and industrial processes.

The effectiveness of these legal instruments of protection depends on the type of innovation being protected. For some new chemical products and basic mechanical inventions, patents can provide effective protection. For products that involve new configurations of existing components or new manufacturing processes, patents may be less effective due to opportunities to innovate around the patent. Patents granted on dubious grounds may later be revoked or challenged in the courts. The US courts and Patent Office have continually broadened the scope of the patent laws. In 1980 patent law was extended to new plants created by biotechnology, in 1981 to software, and in 1998 to business methods. Thus, Netflix has a patent covering the method by which customers choose titles and the process by which Netflix distributes movies, while Amazon holds a patent on its "one-click-to-buy" internet purchasing.[4] While patents and copyright establish property rights, their disadvantage (from the inventor's viewpoint) is that they make information public. Hence, companies may prefer secrecy to patenting as a means of protecting innovations.

Whatever the imperfections of patents and copyrights, companies have become increasingly attentive to the economic value of their intellectual property and, in the process, more careful about protecting and exploiting these knowledge assets. During the 1950s and 1960s, the leading companies in electronics research – RCA, IBM, and AT&T – pursued liberal patent licensing policies, almost to the point of giving away access to their technologies.

When Texas Instruments began exploiting its patent portfolio as a revenue source during the 1980s, the technology sector as a whole woke up to the value of its knowledge assets. During the 1990s, TI's royalty income exceeded its operating income from other sources. An average of 180,000 patents were granted by the US Patent Office in each year between 2000 and 2006 – well over double the annual rate during the 1980s.

Tacitness and Complexity of the Technology In the absence of effective legal protection through patents and copyrights, the extent to which an innovation can be imitated by a competitor depends on the ease with which the technology can be comprehended and communicated. Two characteristics are especially important. The first is the extent to which the technical knowledge is tacit or codifiable. *Codifiable knowledge*, by definition, is that which can be written down. Hence, if it is not effectively protected by patents or copyright, diffusion is likely to be rapid and the competitive advantage not sustainable. Financial innovations such as mortgage-backed securities, zero-interest bonds, and new types of index options embody readily codifiable knowledge that can be copied very quickly. Similarly, Coca-Cola's recipe is codifiable and, in the absence of trade secret protection, is easily copied. Intel's designs for advanced microprocessors are codified and copyable; however, the processes for manufacturing these integrated circuits are based on deeply tacit knowledge. Sharp was able to sustain its leadership in flat screen manufacture primarily because of the experiential knowledge required to make these difficult products.

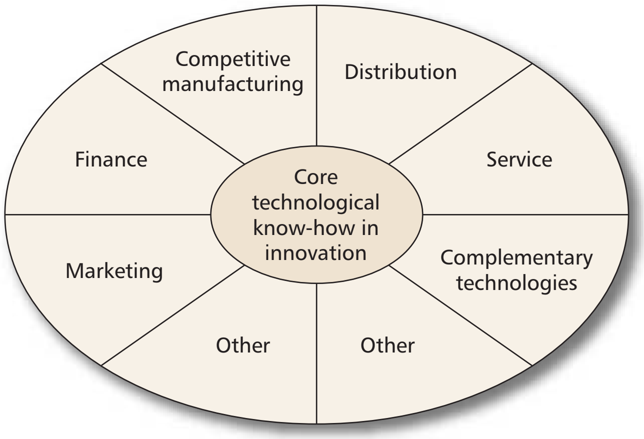
The second characteristic is *complexity*. Most new toys, from the hula-hoop of 1958 to Powerizer jumping shoes, and every new fashion, from the Mary Quant miniskirt of 1962 to Alexander McQueen's frilly dresses of 2007, involve simple, easy-to-copy ideas. Airbus's A380 and Intel's Xeon microprocessor represent entirely different challenges for the would-be imitator.

Lead-Time Tacitness and complexity do not provide lasting barriers to imitation, but they do offer the innovator *time*. Innovation creates a *temporary* competitive advantage that offers a window of opportunity for the innovator to build on the initial advantage.

The innovator's *lead-time* is the time it will take followers to catch up. The challenge for the innovator is to use initial lead-time advantages to build the capabilities and market position to entrench industry leadership. Microsoft, Intel, and Cisco Systems were brilliant at exploiting lead-time to build advantages in efficient manufacture, quality, and market presence. By contrast, a number of innovative British companies have squandered their initial lead-time advantage: DeHavilland with the Comet (the world's first jet airliner), EMI with its CT scanner, Clive Sinclair and the home computer, all failed to capitalize on their lead-time with large-scale investments in production, marketing, and continued product development.

A key advantage of lead-time is the ability to move down the learning curve ahead of followers. In new generations of microprocessors, Intel has traditionally been first

FIGURE 11.3 Complementary resources



to market, allowing it to move quickly down its experience curve, cut prices, and so pressure the profit margins of AMD. The ability to turn lead-time into cost advantage is thus a key aspect of the innovator's advantage.[5]

Complementary Resources[6] Innovation brings new products and processes to market. This requires more than invention, it requires the diverse resources and capabilities needed to finance, produce, and market the innovation. These are referred to as *complementary resources* (see Figure 11.3). Chester Carlson invented xerography, but was unable for many years to bring his product to market because he lacked the complementary resources needed to develop, manufacture, market, distribute, and service his invention. Conversely, Searle (and its later parent, Monsanto) was able to provide almost all the development, manufacturing, marketing, and distribution resources needed to exploit its Nutrasweet innovation. As a result, Carlson was able to appropriate only a tiny part of the value created by his invention of the plain-paper Xerox copier, while Searle/Monsanto was successful in appropriating a major part of the value created by its new artificial sweetener.

When an innovation and the complementary resources that support it are supplied by different firms, the division of value between them depends on their relative power. A key determinant of this is whether the complementary resources are *specialized* or *unspecialized*. Fuel cells may eventually displace internal combustion engines in many of the world's automobiles. However, the problem for the developers of fuel cells is that their success depends on automobile manufacturers making specialized investments in designing a whole new range of cars, oil companies providing specialized refueling facilities, and service and repair firms investing in training and new equipment. For fuel cells to be widely adopted will require that the benefits of the innovation are shared widely with the different providers of these complementary resources. Where complementary resources are generic, the innovator is in a much stronger position to capture value. Because Adobe Systems' Acrobat Portable Document Format (pdf) works with files created in almost any software application, Adobe is well positioned to capture most of the value created by its innovatory software product. However, one advantage of co-specialized complementary resources is that they raise

SOURCE: W. M. COHEN, R. R. NELSON, AND J. P. WALSH, "PROTECTING THEIR

barriers to imitation. Consider the threat that Linux presents to Microsoft Window's dominance of PC operating systems. Because Intel has adapted its microprocessors to the needs of Windows and most applications software is written to run on Windows, the challenge for the Linux community is not just to develop a workable operating system, but also to encourage the development of applications software and hardware that are compatible with the Linux operating system.

Which Mechanisms are Effective at Protecting Innovation?

How effective are these different mechanisms in protecting innovations? The evidence in Table 11.1 shows that, despite considerable variation across industries, patent protection is of limited effectiveness as compared with lead-time, secrecy, and complementary manufacturing and sales/service resources. Indeed, since the late 1980s, the effectiveness of patents appeared to have declined despite the strengthening of patent law. Although patents are effective in increasing the lead-time before competitors are able to bring imitative products to market, the lead-time gains tend to be small. The great majority of patented products and processes are duplicated within three years.[7]

Given the limited effectiveness of patents, why do firms continue to engage in patenting? As shown in Table 11.2, although protection from imitation is the principal motive, several others are also very important. In particular, much patenting activity appears to be strategic – it is directed towards blocking the innovation efforts of other companies and establishing property rights in technologies that can then be used in bargaining with other companies for access to their proprietary technologies. In semiconductors and electronics, cross-licensing arrangements – where one company gives access to its patents across a field of technology in exchange for access

TABLE 11.1 The Effectiveness of Mechanisms for Protecting Innovation: Percentage of Innovations for which Different Mechanisms were Considered Effective

	Product innovations					Process innovations				
	Secrecy (%)	Patents (%)	Lead-time (%)	Sales/service (%)	Manufacturing (%)	Secrecy (%)	Patents (%)	Lead-time (%)	Sales/service[1] (%)	Manufacturing[1] (%)
Food	59	18	53	40	51	56	16	42	30	47
Chemicals	53	37	49	45	41	54	20	27	28	42
Drugs	54	50	50	33	49	68	36	36	25	44
Computers	44	41	61	35	42	43	30	40	24	36
Electronic components	34	21	46	50	51	47	15	43	42	56
Telecom equipment	47	26	66	42	41	35	15	43	34	41
Medical equipment	51	55	58	52	49	49	34	45	32	50
All industries	51	35	53	43	46	51	23	38	31	43

1 Shows the percentage of companies that reported that complementary capabilities in sales and service, and in manufacturing, were effective in protecting their innovations.

SOURCE: W. M. COHEN, R. R. NELSON, AND J. P. WALSH, "PROTECTING THEIR INTELLECTUAL ASSETS: APPROPRIABILITY CONDITIONS AND WHY US MANUFACTURING FIRMS PATENT (OR NOT)," NBER WORKING PAPER NO. W7552 (FEBRUARY 2000).

TABLE 11.2 Why do companies patent? (Responses by 674 US manufacturers)

	Product Innovations (%)	Process Innovations (%)
To prevent copying	95	77
For licensing revenue	28	23
To prevent law suits	59	47
To block others	82	64
For use in negotiations	47	43
To enhance reputation	48	34
To measure performance	6	5

SOURCE: W. M. COHEN, R. R. NELSON, AND J. P. WALSH, "PROTECTING THEIR INTELLECTUAL ASSETS: APPROPRIABILITY CONDITIONS AND WHY US MANUFACTURING FIRMS PATENT (OR NOT)," NBER WORKING PAPER NO. W7552 (FEBRUARY 2000).

to another company's patents – are critical in permitting "freedom to design": the ability to design products that draw on technologies owned by different companies.[8]

Strategies to Exploit Innovation: How and When to Enter

Having established some of the key factors that determine the returns to innovation, let us consider some of the main questions concerning the formulation of strategies to manage technology and exploit innovation.

Alternative Strategies to Exploit Innovation

How should a firm maximize the returns to its innovation? A number of alternative strategies are available. Figure 11.4 orders them according to the size of the commitment of resources and capabilities that each requires. Thus, licensing requires little involvement by the innovator in subsequent commercialization; hence a limited investment. Internal commercialization – possibly through creating a new enterprise or business unit – involves a much greater investment of resources and capabilities. In between, there are various opportunities for collaboration with other companies. Joint ventures and strategic alliances typically involve substantial resource sharing between companies. On a more limited scale, specific activities may be outsourced to other companies.

The choice of strategy mode depends on two main sets of factors: the characteristics of the innovation, and the resources and capabilities of the firm.

Characteristics of the Innovation The extent to which a firm can establish clear property rights in an innovation critically determines the choice of strategy options. Licensing is only viable where ownership in an innovation is clearly defined by patent or copyrights. Thus, in pharmaceuticals, licensing is widespread because patents are clear and defensible. Many biotech companies engage only in R&D and license their drug discoveries to large pharmaceutical companies that possess the necessary complementary resources. Royalties from licensing its sound-reduction technologies accounted for 76% of Dolby Laboratories' 2006 revenues. Conversely, Steve Jobs and Steve Wozniak, developers of the Apple I and Apple II computers, had little

FIGURE 11.4 Alternative strategies for exploiting innovation

	Licensing	Outsourcing certain functions	Strategic alliance	Joint venture	Internal commercialization
Risk and return	Very small investment risk, but small returns also limited (unless patent position very strong). Some legal risks	Limits capital investment, but may create dependence on suppliers/partners	Benefits of flexibility. Risks of informal structure	Shares investment and risk. Risk of partner disagreement and culture clash	Biggest investment requirement and corresponding risks. Benefits of control
Resource requirements	Few	Permits external resources and capabilities to be accessed	Permits pooling of the resources and capabilities of more than one firm		Substantial requirements in terms of finance, production capability, marketing capability, distribution, etc.
Examples	Ericsson licenses its Bluetooth wireless technology to National Semiconductor and ST Microelectronics	Microsoft's XBox was largely designed by other companies and Flextronics does the manufacturing	Ballard's strategic alliance with DaimlerChrysler to develop fuel cells	Psion created Symbian as a joint venture with Ericsson, Nokia, and Motorola to develop the Symbian mobile phone operating system	Larry Page and Sergey Brin established Google Inc. to develop and market their internet search technology

option other than to go into business themselves – the absence of proprietary technology ruled out licensing as an option.

The advantages of licensing are, first, that it relieves the company of the need to develop the full range of complementary resources and capabilities needed for commercialization, and second, that it can allow the innovation to be commercialized quickly. If the lead-time offered by the innovation is short, multiple licensing can allow for a fast global rollout. The problem, however, is that the success of the innovation in the market is totally dependent on the commitment and effectiveness of the licensees. Strategy Capsule 11.1 outlines two examples of companies that met difficulties in licensing their inventions.

STRATEGY CAPSULE 11.1

To License or Commercialize Internally? Dyson Vacuum Cleaners and Benecol Margerine

The Dyson Vacuum Cleaner

In 1981, British inventor James Dyson patented his "dual cyclone" bagless vacuum cleaner. For four years, Dyson tried unsuccessfully to interest US and European appliance manufacturers in his prototype before finally licensing to a Japanese appliance maker where it was successfully launched as the "G-Force." Meanwhile, in the US, Amway, with whom Dyson had negotiated over a license, introduced its own bagless vacuum cleaner – the "Amagram." In 1990, after incurring $4 million in legal costs, Dyson won his case against Amway for patent infringement. In Europe, Dyson decided to go it alone. Using his licensing royalties from Japan, Dyson opened a plant in Wiltshire, England in June 1993. Within two years, Dyson had established UK market leadership. By 1999, Dyson was back in court claiming that Hoover with its "Vortex" vacuum cleaner had infringed his patents. Dyson won his case forcing Hoover to withdraw its offending product. In 2002, Dyson entered the US market. By the beginning of 2005, Dyson had gained market share leadership – mainly at the expense of Hoover which was now incurring substantial losses for its owner, Maytag.

Raisio and Benecol

At the end of 1995, Raisio, a 57-year-old grain milling and vegetable oils company based in Finland, launched "Benecol" – a patented, cholesterol-reducing margarine that contained plant stanol. The phenomenal success of Benecol encouraged Raisio to sell international licensing rights to Johnson & Johnson. In 1999, Benecol was launched in the US and Europe after several years of delay caused by regulatory hurdles in the US and J&J's indecision as to whether to launch Benecol as a food, a food supplement, or a pharmaceutical. In the meantime, Raisio's lead-time had been lost. Unilever launched its own cholesterol reducing margarine ("Take Control" in the US; "Flora ProActif" in Europe) at about the same time as Benecol and quickly established a strong market share lead.

Sources: James Dyson, *Against the Odds*, 2nd edn (Texere, 2003); "Dyson's Magic Carpet Ride," *Business Week* (April 1, 2005); "Raisio and the Benecol Launch," in R. M. Grant, *Cases for Contemporary Strategy Analysis*, 6th edn (Blackwell, 2008).

Resources and Capabilities of the Firm As Figure 11.4 shows, the different strategic options require very different resources and capabilities. Business startups and other small firms possess few of the complementary resources and capabilities needed to commercialize their innovations. Inevitably they will be attracted to licensing or to accessing the resources of larger firms through outsourcing, alliances, or joint ventures. Yet, for all their advantages in commercializing innovation, evidence suggests that most invention is the result of individual creativity – often by mavericks and eccentrics who do not fit easily into large corporations. Most of the major innovations of the 20 century, were contributed by individual inventors – frequently working in their garage or garden shed.[9] Among 27 key inventions of the post-WWII period, only seven emerged from the R&D departments of established corporations.[10] Hence, in many sectors it seems that different stages of the innovation process are best conducted by different types of firm. In biotechnology and electronics, a two-stage model for innovation is common: the technology is developed initially by a small, technology-intensive startup, which then licenses to, or is acquired by, a larger concern.

Conversely, large, established corporations, which can draw on their wealth of resources and capabilities, are better placed for internal commercialization. Companies such as Sony, GE, Siemens, Hitachi, and IBM have traditionally developed innovations internally – yet, as technologies evolve, converge, and splinter, even these companies have increasingly resorted to joint ventures, strategic alliances, and outsourcing arrangements in order to access technical capabilities outside their corporate boundaries.

In the video games software industry, an industry structure has emerged that allows different types of firm to specialize in different stages of the innovation process according to their different resources and capabilities. Large video games publishers such as Electronic Arts and Sega undertake marketing, financing and distribution. New game concepts and software development is undertaken by small game development firms.

Timing Innovation: To Lead or to Follow?

To gain competitive advantage in emerging and technologically intensive industries, is it best to be a leader or a follower in innovation? As Table 11.3 shows, the evidence is mixed: in some products the leader has been the first to grab the prize, in others the leader has succumbed to the risks and costs of pioneering. Optimal timing of entry into an emerging industry and the introduction of new technology are complex issues. The extent of first-mover advantages (or disadvantages) associated with pioneering depends on the following factors:

1. *The extent to which innovation can be protected by property rights or lead-time advantages*. If an innovation is appropriable through a patent, copyright, or lead-time advantage, there is advantage in being an early mover. This is especially the case where patent protection is important, as in pharmaceuticals. Here, competition can take the form of a patent race.
2. *The importance of complementary resources*. The more important are complementary resources in exploiting an innovation, the greater the costs and risks of pioneering. Several firms – from Clive Sinclair with a battery-driven car to General Motors with a fuel-cell car – have already failed in their

TABLE 11.3 Leaders, Followers, and Success in Emerging Industries

Product	Innovator	Follower	The winner
Helicopter	Sikorsky	Augusta Westland	Leader
Jet airliner	De Haviland (Comet)	Boeing (707)	Follower
Float glass	Pilkington	Corning	Leader
X-ray scanner	EMI	General Electric	Follower
Office PC	Xerox	IBM	Follower
VCRs	Ampex/Sony	Matsushita	Follower
Instant camera	Polaroid	Kodak	Leader
Pocket calculator	Bowmar	Texas Instruments	Follower
Microwave oven	Raytheon	Samsung	Follower
Fiber-optic cable	Corning	Many companies	Leader
Video games player	Atari	Nintendo/Sony	Followers
Disposable diaper	Procter & Gamble	Kimberley-Clark	Leader
Ink jet printer	IBM and Siemens	Hewlett Packard	Follower
Web browser	Netscape	Microsoft	Follower
MP3 music players	Diamond Multimedia	Apple (iPod)	Follower
Operating systems for mobile phones	Symbian	Microsoft	Leader
Flash memory	Toshiba	Samsung, Intel	Followers

SOURCE: BASED IN PART ON DAVID TEECE, *THE COMPETITIVE CHALLENGE: STRATEGIES FOR INDUSTRIAL INNOVATION AND RENEWAL* (CAMBRIDGE: BALLINGER, 1987): 186–8.

attempts to develop and market an electric automobile. The problem for the pioneer is that the development costs are huge because of the need to orchestrate multiple technologies and establish facilities for service and recharging. Followers are also favored by the fact that, as an industry develops, specialist firms emerge as suppliers of complementary resources. Thus, in pioneering the development of the British frozen foods industry, Unilever's Bird's Eye subsidiary had to set up an entire chain of cold stress and frozen distribution facilities. Later entrants were able to rely on the services of public cold stores and refrigerated trucking companies.

3 *The potential to establish a standard.* As we shall see later in this chapter, some markets converge toward a technical standard. The greater the importance of technical standards, the greater the advantages of being an early mover in order to influence those standards and gain the market momentum needed to establish leadership. Once a standard has been set, displacing it becomes exceptionally difficult. IBM had little success with its PS2 operating system against the entrenched position of Microsoft Windows. However, there is also a risk of entering too early, before the direction of technological development is clear.

Optimal timing depends also on the resources and capabilities that the individual firm has at its disposal. Different companies have different *strategic windows* – periods in time when their resources and capabilities are aligned with the opportunities available in the market. A small, technology-based firm may have no choice but to pioneer the introduction of an innovation. Given its lack of complementary resources, its only chance of building sustainable competitive advantage is to grab first-mover advantage and use this to develop the necessary complementary resources before more powerful rivals appear. For the large, established firm with financial resources and strong production, marketing, and distribution capabilities, the strategic window is likely to be both longer and later. The risks of pioneering are greater for an established firm with a reputation and brands to protect, and to exploit its complementary resources effectively typically requires a more developed market. Consider the following examples:

- In personal computers, Apple was a pioneer, IBM a follower. The timing of entry was probably optimal for each. Apple's resources were its imagination and its technology. Its strategic window occurred at the very beginning of the industry when these strengths could make the biggest impact. IBM had enormous strengths in manufacturing, distribution, and reputation. It could use these resources to establish competitive advantage even without a clear technological advantage. What was important for IBM was to delay its entry to the point when market and technological risks had been reduced and the industry had reached a stage of development where strengths in large-scale manufacturing, marketing, and distribution could be brought to bear.
- In the browser war between Netscape and Microsoft, Microsoft had the luxury of being able to follow the pioneer, Netscape. Microsoft's huge product development, marketing, and distribution capabilities, and – most important – its vast installed base of the Windows operating system allowed it to overhaul Netscape's initial lead.
- Although General Electric entered the market for CT scanners some four years after EMI, GE was able to overtake EMI within the space of three years because of its ability to apply vast technological, manufacturing, sales, and customer service capabilities within the field of medical electronics.

To exploit strategic windows effectively, Don Sull argues that companies need to engage in a process of *active waiting*:

> *During periods of active waiting, leaders must probe the future and remain alert to anomalies that signal potential threats or opportunities; exercise the restraint to preserve their war chests; and maintain the discipline to keep the troops battle ready. When a golden opportunity or sudden-death threat emerges, they must have the courage to declare the main effort and concentrate resources to seize the moment.*

Managing Risks

Emerging industries are risky. There are two main sources of uncertainty:

- *Technological uncertainty* arises from the unpredictability of technological evolution and the complex dynamics through which technical standards and dominant designs are selected. Hindsight is always 20/20, but ex ante it is difficult to predict how technologies and the industries that deploy them will evolve.
- *Market uncertainty* relates to the size and growth rates of the markets for new products. When Xerox introduced its first plain-paper copier in 1959, Apple its first personal computer in 1977, or Sony its Walkman in 1979, none had

any idea of the size of the potential market. Forecasting demand for new products is hazardous since all forecasting is based on some form of extrapolation or modeling based on past data. One approach is to use analogies.[11] Another is to draw on the combined insight and experience of experts through the *Delphi technique*.[12]

If reliable forecasting is impossible, the keys to managing risk are alertness and responsiveness to emerging trends together with limiting vulnerability to mistakes through avoiding large-scale commitments. Useful strategies for limiting risk include:

- *Cooperating with lead users*. During the early phases of industry development, careful monitoring of and response to market trends and customer requirements is essential to avoid major errors in technology and design. Von Hippel argues that lead users provide a source of leading market indicators, they can assist in developing new products and processes, and offer an early cash flow to fund development expenditures.[13] In computer software, "beta versions" are released to computer enthusiasts for testing; in footwear, Nike test markets new product ideas with inner-city gangs; in communications and aerospace, government defense contracts play a crucial role in developing new technologies.[14]
- *Limiting risk exposure*. The high level of risk in emerging industries requires that firms adopt financial practices that minimize their exposure to adversity. Uncertainties over development costs and the timing and amount of future cash flows require a strong balance sheet with limited debt financing. Restricting risk exposure also requires economizing on capital expenditure commitments and other sources of fixed cost. Smaller players in high-tech, high-risk industries from biotechnology to computer games typically concentrate on research and development and rely on larger companies for manufacture, marketing and distribution. Even large companies are resorting increasingly to strategic alliances and joint ventures in developing major new initiatives.
- *Flexibility*. The high level of uncertainty in emerging industries makes flexibility critical to long-term survival and success. Because technological and market changes are difficult to forecast, it is essential that top management closely monitors the environment and responds quickly to market signals. For Sichiro Honda, the founder of Honda Motor Company, a key aspect of flexibility was learning from failure: "Many people dream of success. To me success can only be achieved through repeated failure and introspection. In fact, success represents the 1% of your work that only comes from the 99% that is called failure."[15] Flexibility also means keeping options open and delaying commitment to a specific technology until its potential becomes clear. Microsoft is well known for its strategy of investing in alternative technologies (see Strategy Capsule 11.2).

Competing for Standards

In the previous chapter, I noted that the establishment of standards is a key event in industry evolution. The emergence of the digital, networked economy has made

STRATEGY CAPSULE 11.2

Keeping Your Options Open: Microsoft in Operating Systems

In 1988, as I wandered about the floor of Comdex, the computer industry's vast annual trade show, I could feel the anxiety among the participants. Since the birth of the IBM PC, six years earlier, Microsoft's Disk Operating System (DOS) had been the de facto standard for PCs. But DOS was now starting to age. Everyone wanted to know what would replace it.

Apple Computer, at the peak of its powers, had one of the largest booths showcasing the brilliantly graphical Macintosh operating system . . . Two different alliances of major companies, including AT&T, HP, and Sun Microsystems, offered graphical versions of Unix . . . And IBM was touting its new OS/2.

Amid the uncertainty, there was something very curious about the Microsoft booth . . . [which] resembled a Middle Eastern bazaar. In one corner, the company was previewing the second version of its highly criticized Windows system . . . In another, Microsoft touted its latest release of DOS. Elsewhere it was displaying OS/2, which it had developed with IBM. In addition, Microsoft was demonstrating new releases of Word and Excel that ran on Apple's Mac. Finally, in a distant corner, Microsoft displayed SCO Unix . . .

"What am I supposed to make of this?" grumbled a corporate buyer standing next to me. Columnists wrote that Microsoft was adrift, that its chairman and chief operating officer, Bill Gates, had no strategy.

Although the outcome of this story is now well known, to anyone standing on the Comdex floor in 1988 it wasn't obvious which operating system would win. In the face of this uncertainty, Microsoft followed the only robust strategy: betting on every horse.

Source: E. D. Beinhocker, "Robust Adaptive Strategies," *Sloan Management Review* (Spring 1999): 95–106.

standards increasingly important and companies that own and influence industry standards are capable of earning returns that are unmatched by any other type of competitive advantage. The shareholder value generated by Microsoft and Intel from the "Wintel" PC standard, by Qualcomm from its CDMA digital wireless communications technology, and Cisco from its leadership role in setting internet protocol standards are examples of this potential. Table 11.4 lists several companies whose success is closely associated with their control of standards within a particular product category.

Types of Standard

A standard is a format, an interface, or a system that allows interoperability. It is adherence to standards that allow us to browse millions of different web pages, that ensure the light bulbs made by any manufacture will fit any manufacturer's lamps, and that keep the traffic moving in Los Angeles (most of the time). Standards can be *public* or *private*.

TABLE 11.4 Examples of Companies that Own De Facto Industry Standards

Company	Product category	Standard
Microsoft	PC operating systems	Windows
Intel	PC microprocessors	x86 series
Matsushita	Videocassette recorders	VHS system
Sony/Philips	Compact disks	CD-ROM format
Sun Microsystems	Programming language for websites	Java
Rockwell and 3Com	56K modems	V90
Qualcomm	Digital cellular wireless communication	CDMA
Adobe Systems	Common file format for creating and viewing documents	Acrobat Portable Document Format
Bosch	Antilock braking systems	ABS and TCS (Traction Control System)
Symbian	Operating systems for mobile phones	Symbian OS

- Public (or *open*) standards are those that are available to all either free or for a nominal charge. Typically they do not involve any privately owned intellectual property or the IP owners make access free (e.g. Linux). Public standards are set by public bodies and industry associations. Thus, the GSM mobile phone standard was set by the European Telecom Standards Institute. Internet protocols are standards governing internet addressing and routing. These are governed by several international bodies, including the Internet Engineering Task Force.
- Private (*proprietary*) standards are those where the technologies and designs are owned by companies or individuals. If I own the technology that becomes a standard, I can embody the technology in a product that others buy (Microsoft Windows) or license the technology to others who wish to use it (Qualcomm's CDMA).

Standards can also be classified according to who sets them. *Mandatory standards* are set by government and have the force of law behind them. They include standards relating to automobile safety and construction specifications and to TV broadcasting. *De facto standards* emerge through voluntary adoption by producers and users. Table 11.4 gives examples.

A problem with de facto standards is that they may take a long time to emerge, resulting in duplication of investments and delayed development of the market. It was 40 years before a standard railroad gauge was agreed in the US.[16] One reason for the slow transition of wireless telecoms in the US from analog to digital technology was continuing competition between TDMA and CDMA standards. By contrast, Europe officially adopted GSM (a close relative of TDMA) in 1992.[17] Delayed emergence of a standard may kill the technology altogether. The failure of quadraphonic sound to displace stereophonic sound during the 1970s resulted from incompatible technical standards among manufacturers of audio equipment. The absence of a dominant standard discouraged record companies and consumers from investing in quadraphonic systems.[18]

Why Standards Appear: Network Externalities

Why do standards emerge in some product markets and not in others? Basically, standards emerge because suppliers and buyers want them. They want standards for those goods and services subject to *network externalities*.

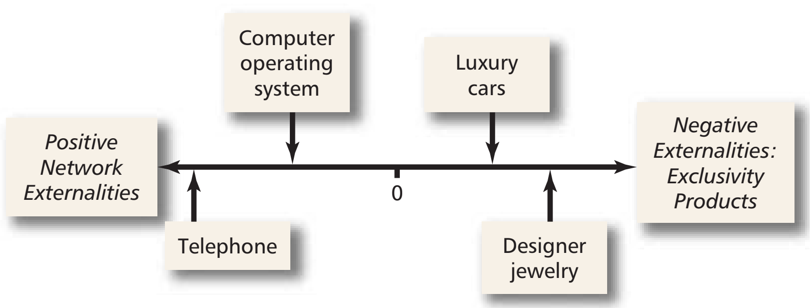
A network externality exists whenever the value of a product to an individual customer depends on the number of other users of that product. The classic example of network externality is the telephone. Since there is little satisfaction to be gained from talking to oneself on the telephone, the value of a telephone to each user depends on the number of other users connected to the same telephone system. This is different from most products. When I pour myself a glass of Glenlivet after a couple of exhausting MBA classes, my enjoyment is independent of how many other people in the world are also drinking Glenlivet. Indeed, some products may have *negative* network externalities – the value of the product is less if many other people purchase the same product. If I spend $3,000 on an Armani silver lamé tuxedo and find that half my colleagues at the faculty Christmas party are wearing the same jacket, my satisfaction is lessened. Figure 11.5 compares such "exclusivity" products with "network externality" products.

Network externalities do not require everyone to use the same product or even the same technology, but rather that the different products are *compatible* with one another through some form of common interface. In the case of wireless telephone service, it doesn't matter (as far as network externalities are concerned) whether we purchase service from AT&T, Nextel, or Sprint – the key issue is that each supplier's system is compatible to allow connectivity. Similarly with railroads, if I am transporting coal from Wyoming to New Orleans, my choice of railroad company is not critical since I know that, unlike during the 1870s, every railroad company now uses a standard gauge and is required to give "common carrier" access to other companies' rolling stock.

Network externalities arise from several sources:

- *Products where users are linked to a network*. Telephones, railroad systems, and e-mail instant messaging groups are networks where users are linked together. Applications software, whether spreadsheet programs or video games, also link users – they can share files and play games interactively. User-level externalities may also arise through social identification. I watch *Big Brother* and the Hollywood Oscar presentations on TV not because I

FIGURE 11.5 Positive and negative network externalities



enjoy them, but in order to engage in conversation with my colleagues on these subjects.[19]

- *Availability of complementary products and services*. Where products are consumed as systems, the availability of complementary products and services depends on the number of customers for that system. The key problem for Apple Computer is that, because the Macintosh accounts for only 9% of the installed base of personal computers, fewer and fewer producers of applications software are writing Mac-based applications. I choose to drive a Ford Focus rather than a Ferrari Testarossa because I know that, should I break down 200 miles from Bismarck, North Dakota, spare parts and a repair service will be more readily available.
- *Economizing on switching costs*. By purchasing the product or system that is most widely used, there is less chance that I shall have to bear the costs of switching. By using Microsoft Office rather than Lotus SmartSuite, it is more likely that I will avoid the costs of retraining and file conversion when I become a visiting professor at another university.

The implication of network externalities is that they create *positive feedback*. The technology or system that has the largest installed base attracts the greatest proportion of new buyers because of the benefits of going with the market leader. Conversely, the more a technology is perceived to have a minority of the market, the more new and existing users will defect to the market leader. This process is called *tipping*: once a market leader begins to emerge, the leader will progressively gain market share at the expense of rivals.[20] The result is a tendency toward a *winner-takes-all* market. The markets subject to significant network externalities tend to be dominated by a single supplier (Microsoft in the case of PC operating systems and office applications software, eBay in the case of internet auctions). Rival technologies may coexist for a time, but after one company appears to be gaining the upper hand, the market may then "tip" very quickly.

Once established, technical and design standards tend to be highly resilient. Standards are difficult to displace due to learning effects and collective lock-in. Learning effects cause the dominant technology and design to be continually improved and refined. A new technology, even though it may have the potential to overtake the existing standard, will initially be inferior. Even where the existing standard is inherently inferior, switching to a superior technology may not occur because of collective lock-in. The classic case is the QWERTY typewriter layout. Its 1873 design was based on the need to *slow* the speed of typing to prevent typewriter keys from jamming. Although the jamming problem was soon solved, the QWERTY layout has persisted, despite the patenting in 1932 of the more ergonomic Dvorak Simplified Keyboard (DSK).[21]

Winning Standards Wars

In markets subject to network externalities, control over standards is the basis of competitive advantage, and may be essential for survival. Apple Computer lost the standards war with IBM/Microsoft by the mid-1980s, since when it has been a marginal player in the computer industry. Other companies that lost standards wars with Microsoft – Lotus in spreadsheet software, Netscape in browers, WordPerfect in word processing software – no longer exist as independent companies. What can we learn from these and other standards wars about designing a winning strategy in markets subject to network externalities?

The first key issue is to determine whether we are competing in a market that will converge around a single technical standard. This requires a careful analysis of the presence and sources of network externalities.

The second most important strategic issue in standards setting is recognition of the role of positive feedback: the technology that can establish early leadership will tend to attract new adopters. Building a "bigger bandwagon," according to Shapiro and Varian,[22] requires the following:

- *Before you go to war, assemble allies*. You'll need the support of consumers, suppliers of complements, even your competitors. Not even the strongest companies can afford to go it alone in a standards war.
- *Preempt the market* – enter early, achieve fast-cycle product development, make early deals with key customers, and adopt penetration pricing.
- *Manage expectations*. The key to managing positive feedback is to convince customers, suppliers, and the producers of complementary goods that you will emerge as the victor. These expectations become a self-fulfilling prophecy. The massive pre-launch promotion and publicity built up by Sony prior to the American and European launch of Playstation 2 in October 2000 was an effort to convince consumers, retailers, and game developers that the product would be the blockbuster consumer electronics product of the new decade, thereby stymieing Sega and Nintendo's efforts to establish their rival systems.

The lesson that has emerged from the classic standards battles of the past is that in order to create initial leadership and maximize positive feedback effects, a company must share the value created by the technology with other parties (customers, competitors, complementors, and suppliers). If a company attempts to appropriate too great a share of the value created, it may well fail to build a big enough bandwagon to gain market leadership (see Strategy Capsule 11.3). Thus, most of the standards battles being waged currently involve broad alliances, where the owner makes the standard open and offers attractive licensing terms to complementors and would-be competitors. The current battle being fought between Sony and Toshiba for leadership in high-definition DVDs involves broad alliances: Toshiba has recruited Microsoft and Intel to its HD-DVD camp; Sony has enlisted Philips, Dell, and most Hollywood studios to back its Blu-ray format.[23]

Achieving compatibility with existing products is a critical issue in standards battles. Advantage typically goes to the competitor that adopts an *evolutionary strategy* (i.e., offers backward compatibility) rather than one that adopts a *revolutionary strategy*.[24] Microsoft Windows won the PC war against the Apple Macintosh for many reasons. Both companies offered an operating system with a graphical user interface. However, while Windows was designed for compatibility with the DOS operating system, the Apple Mac was incompatible both with DOS and the Apple II. Similarly, a key advantage of the Sony PlayStation 2 over the Sega Dreamcast and Nintendo Cube was its compatibility with the Playstation 1.

What are the key resources needed to win a standards war? Shapiro and Varian emphasize the following:

- Control over an installed base of customers.
- Owning intellectual property rights in the new technology.

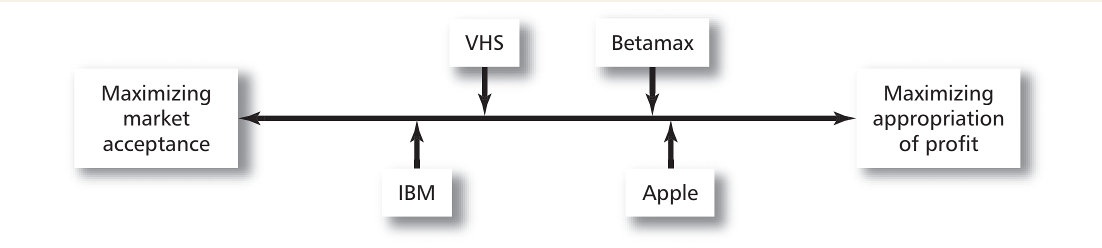
STRATEGY CAPSULE 11.3

Building a Bandwagon by Sharing Value: Lessons from VCRs and PCs

Profiting from standards requires two elements: first, setting the standard; second, retaining some proprietary interest in the standard in order to appropriate part of its value. There is a tradeoff between the two – the more value a company tries to appropriate, the greater the difficulty in building early support for its technology. Consider the standards wars in VCRs and PCs:

- In VCRs, Matsushita's VHS format won against Sony's Betamax format not because of the technical superiority of VHS, but because Matsushita did not insist on such tight ownership of its technology and was more effective in gaining acceptability in the market. The key here was Matsushita's encouragement of adoption through licensing of the VHS system to Sharp, Philips, GE, RCA, and other competitors.
- In personal computers, IBM was highly successful in setting the standard, partly because it did not restrict access to its technology. Its product specifications were openly available to "clone makers," and its suppliers (including Microsoft and Intel) were free to supply them with microprocessors and the MS-DOS operating system. IBM was remarkably successful at setting the standard, but failed to appropriate much value because it retained no significant proprietary interest in the standard – it was Intel and Microsoft that owned the key intellectual property. For Apple, the situation was the reverse. It kept tight control over its Macintosh operating system and product architecture, it earned high margins during the 1980s, but it forfeited the opportunity of setting the industry standard.

The tradeoff between market acceptance of a technology and appropriating the returns to a technology is shown below:



The innovator who enforces no ownership rights and gives away the innovation to anyone who wants it will probably maximize market penetration. On the other hand, the innovator who is most restrictive in enforcing ownership rights will maximize margins in the short run, but will probably have difficulty building a bandwagon big enough to establish market leadership. In recent battles over technical standards, the desire to gain market leadership has encouraged firms to be less and less restrictive over ownership in the interests of building their market bandwagon. Thus, in the battle for dominance of internet browser software, both Microsoft (Internet Explorer) and Netscape (Navigator) offered their products for free in the interests of wresting market leadership. When attacking an existing standard, there may be no alternative to giving the technology away: the only chance for Unix and Sun Microsystems' Java to establish themselves against Microsoft's Windows was by committing to an open standard.

Increasingly, companies are trying to reconcile market acceptance with value appropriation: Adobe gives away its Acrobat Reader to broaden the user base, but charges for the software needed to create pdf documents in Acrobat.

Where competition is weak, a company may be able to set the dominant standard while also appropriating most of the value: Nintendo in video games during the late 1980s and early 1990s is the classic example. However, once Nintendo met competition from Sega and Sony, its strategy backfired, as games developers and retailers welcomed competitors that offered a better deal.

Sources: *The World VCR Industry*, Case No. 9-387-098 (Boston: Harvard Business School, 1990); *Apple Computer – 1992*, Case No. 9-792-081 (Boston: Harvard Business School, 1994); *The Browser Wars, 1994–1998*, Case No. 9-798-094 (Boston: Harvard Business School, 1998); "Rivalry in Video Game Consoles," in R. M. Grant, *Cases to Accompany Contemporary Strategy Analysis*, 6th edn (Oxford: Blackwell Publishing, 2008).

- The ability to innovate in order to extend and adapt the initial technological advance.
- First-mover advantage.
- Strength in complements (e.g., Intel has preserved its standard in microprocessors by promoting standards in buses, chipsets, graphics controllers, and interfaces between motherboards and CPUs).
- Reputation and brand name.[25]

However, even with such advantages, standards wars are costly and risky. A prolonged standards war can rack up huge losses for all contenders, and may result in giving away so much value to partners and customers that the returns to the winner are meager. Microsoft won the browser war against Netscape, but only by offering its Internet Explorer for free. The key is to give away enough to ensure rapid market acceptance, while keeping hold of sufficient sources of value to make ownership of the winning standard valuable. Thus, Adobe achieved rapid customer acceptance for its Acrobat pdf software by making the Acrobat Reader freely available, while charging a remunerative price for the full version of the software.

Implementing Technology Strategies: Creating the Conditions for Innovation

As we have noted previously, strategy formulation cannot be separated from its implementation. Nowhere is this more evident than in technology-intensive businesses.

Our analysis so far has taught us about the potential for generating competitive advantage from innovation and about the design of technology-based strategies, but has said little about the conditions under which innovation is achieved. The danger is that strategic analysis can tell us a great deal about making money out of innovation, but this isn't much use if we cannot generate innovation in the first place. If the essence of innovation is creativity and one of the key features of creativity is its resistance to planning, it is evident that strategy formulation must pay careful attention to the organizational processes through which innovations emerge and are commercialized. Because the features of new products and processes are unknown when resources are committed to R&D and there is no predetermined relationship between R&D expenditure and the output of innovations, the productivity of R&D depends heavily on the organizational conditions that foster innovation. Hence, the most crucial challenge facing firms in emerging and technology-based industries is: how does the firm create conditions that are conducive to innovation?

To answer this question, we must return to the critical distinction between invention and innovation. Invention is dependent on creativity. Creativity is not simply a matter of individual brilliance; it depends on the organizational conditions that foster ideas and imagination at the individual and group levels. Similarly, innovation is not just a matter of acquiring the resources necessary for commercialization; innovation is a cooperative activity that requires interaction and collaboration between technology development, manufacturing, marketing, and various other functional departments within the firm.

Managing Creativity

The Conditions for Creativity Invention is an act of creativity requiring knowledge and imagination. The creativity that drives invention is typically an individual act that establishes a meaningful relationship between concepts or objects that had not previously been related. This reconceptualizing can be triggered by accidents: an apple falling on Isaac Newton's head or James Watt observing a kettle boiling. Creativity is associated with particular personality traits. Creative people tend to be curious, imaginative, adventurous, assertive, playful, self-confident, risk taking, reflective, and uninhibited.

Individual creativity also depends on the organizational environment in which they work – this is as true for the researchers and engineers at Amgen and Microsoft as it was for the painters and sculptors of the Florentine and Venetian schools. Few great works of art or outstanding inventions are the products of solitary geniuses. Creativity is stimulated by human interaction: the productivity of R&D laboratories depends critically on the communication networks that the engineers and scientists establish.[26] An important catalyst of interaction is *play*, which creates an environment of inquiry, liberates thought from conventional constraints, and provides the opportunity to establish new relationships by rearranging ideas and structures at a safe distance from reality. The essence of play is that it permits unconstrained forms of experimentation. Stefan Thomke argues that experimentation is the basis for innovation and that experimentation needs to be managed in order to maximize learning, speed discovery, and avoid costly mistakes. In almost all fields, the costs of experimentation have fallen substantially with developments in computer modeling and simulation that permit prototyping and market research to be undertaken speedily and virtually.[27]

The development of innovative ideas can be accelerated through conflict, criticism, and debate. Dorothy Leonard points to the merits of *creative abrasion* within innovative teams – fostering innovation through the interaction of different personalities and perspectives. Managers must resist the temptation to clone in favor of embracing diversity of cognitive and behavioral characteristics within work groups – creating what Leonard refers to as "*whole brain teams*." Managing creative groups – whether in research, product development, marketing, or quality management – requires that conflict is constructive rather than destructive. The role of the manager is to clarify goals, make operating guidelines explicit, and depersonalize conflict.[28]

Balancing Creativity and Commercial Direction A central challenge is balancing the creative freedom of individuals with the need for direction, discipline and integration. Within media companies, the *Economist* notes: "The two cultures – of the ponytail and the suit – are a world apart, and combustible together."[29] Anita Roddick of Body Shop cultivated a culture of "benevolent anarchy – encouraging questioning of established ways and going in the opposite direction to everyone else." Yet this whirlwind of creativity can lead a company over the edge of chaos.[30] However, for most companies the dangers are in the opposite direction – reluctance to allow creative freedom for those in research, development, design and new business ventures. At Walt Disney, constant interference in creative processes by CEO Michael Eisner seems to be a key factor in Disney's wilting creative performance during 1998–2006. Conversely, the success of HBO in producing TV shows (such as *The Sopranos*, *The Wire*, and *Six Feet Under*) owes much to its ability to offer creative freedom to its content producers.

The most important discipline for ensuring that creativity is productive is to maintain linkage between creative processes and market need. Few important inventions have been the result of spontaneous creative activity by technologists; almost all have resulted from grappling with practical problems. James Watt's redesign of the steam engine was conceived while repairing an early Newcomen steam engine owned by Glasgow University. The basic inventions behind the Xerox copying process were the work of Chester Carlson, a patent attorney who became frustrated by the problems of accurately copying technical drawings. These observations reaffirm the notion that "necessity is the mother of invention," which explains why customers are such fertile sources of innovation – they are most acutely involved with matching existing products and services to their needs.[31] Involving customers in the innovation process is the first stage in the move towards *open innovation* – innovation processes that involve users, suppliers, and even competitors. The relocation of R&D from corporate research departments to operating businesses is motivated by the desire to link technology development more closely with the needs of the business. Innovating organizations not only have less defined internal structures, they are also likely to require the flow of knowledge and ideas between those in the organization and those outside. Open innovation is fostered by *creation nets* – networks of collaboration.

Organizing for Creativity Creativity requires management systems that are quite different from those appropriate to pursuing cost efficiency. In particular, creatively oriented people tend to be responsive to distinctive types of incentive. They desire to work in an egalitarian culture with enough space and resources to provide the opportunity to be spontaneous, experience freedom, and have fun in the performance of a task that, they feel, makes a difference to the strategic performance of the firm. Praise, recognition, and opportunities for education and professional growth are also more important than assuming managerial responsibilities.[32] Table 11.5 contrasts

TABLE 11.5 The Characteristics of "Operating" and "Innovating" Organizations

	Operating organization	Innovating organization
Structure	Bureaucratic. Specialization and division of labor. Hierarchical control. Defined organizational boundaries	Flat organization without hierarchical control. Task-oriented project teams. Fuzzy organizational boundaries.
Processes	Emphasis on eliminating variation (e.g. six-sigma). Top–down control. Tight financial controls.	Emphasis on enhancing variation. Loose controls to foster idea generation. Flexible strategic planning and financial control.
Reward systems	Financial compensation, promotion up the hierarchy, power, and status symbols.	Autonomy, recognition, equity participation in new ventures.
People	Recruitment and selection based on the needs of the organization structure for specific skills: functional and staff specialists, general managers, and operatives.	Key need is for idea generators that combine required technical knowledge with creative personality traits. Managers must act as sponsors and orchestrators.

SOURCE: BASED ON JAY R. GALBRAITH AND ROBERT K. KAZANJIAN, *STRATEGY IMPLEMENTATION: STRUCTURE, SYSTEMS AND PROCESSES*, 2ND EDN (ST. PAUL, MN: WEST, 1986).

some characteristics of innovative organizations compared with those designed for operational efficiency.

From Invention to Innovation: The Challenge of Cross-functional Integration

The commercialization of new technology – in terms of developing and introducing new products and implementing new processes – requires linking creativity and technological expertise with capabilities in production, marketing, finance, distribution, and customer support. As we noted in Chapter 5, the challenge of new product development is that it draws upon every area of functional and technical expertise within the company. If the organizational requirement for innovation and "operation" are very different, the organizational challenge is to reconcile these two. If operating functions such as production and sales must be organized differently from technology and product development functions, there needs to be *differentiation* and *integration*.[33]

Achieving such integration is difficult. Tension between the operating and the innovating parts of organizations is inevitable. Innovation upsets established routines and threatens the status quo. The more stable the operating and administrative side of the organization, the greater the resistance to innovation. A classic example was the opposition by the US naval establishment to continuous-aim firing, a process that offered huge improvements in gunnery accuracy.[34]

In recent years, established corporations have striven to emulate the flexibility, creativity, and entrepreneurial spirit of technology-based startups and reconcile these traits with the quest for operational efficiency. Among the organizational innovations being introduced by large corporations to improve new product development and the exploitation of new technologies are the following:

- *Cross-functional product development teams*. Cross-functional product development teams have proven to be highly effective mechanisms for integrating the different functional capabilities required to develop a new product, and for developing communication and cooperation across functional divisions. Japanese companies in automobiles, electronics, and construction equipment have been the most prominent pioneers of product development teams. Autonomous product development teams allow specialists from different functional and technical departments the flexibility to share knowledge, learn, and develop innovative new products.[35] Clark and Fujimoto's study of new automobile development in Japan, the United States, and Europe provides fascinating insight into the organization of product development teams and the advantages derived from "overlapping" the different stages of product development rather than simply sequencing them, and from providing strong leadership through "heavyweight" product managers.[36]
- *Product champions* provide a means by which individual creativity and the desire to make a difference can be reconciled within organizational processes. The key is to permit the same individuals who are the creative forces behind an innovation or business idea also to be the leaders in commercializing those innovations. Companies that are consistently successful in innovation have the ability to capture and direct individuals' drive for achievement and success within their organizational processes; creating product champion roles is the most common means for achieving this. Given resistance to change within organizations and the need to forge cross-functional integration, leadership by committed individuals can help overcome vested interests in stability and functional separation. Schön's study of 15 major innovations concluded that: "the new idea either finds a champion or dies."[37] A British study of 43 matched pairs of successful and unsuccessful innovations similarly concluded that a key factor distinguishing successful innovation was the presence of a "business innovator" to exert entrepreneurial leadership.[38] 3M Corporation is exemplary in its use of product champions to develop new product ideas and grow them into new business units (see Strategy Capsule 11.4).
- *Buying innovation*. Ultimately, large corporations must recognize that small, technology-intensive startups have advantages in the early stages of the innovation process. Microsoft and Cisco Systems have become highly experienced in commercializing new areas of technology through acquiring small pioneers of innovation.
- *Incubators*. Large corporations also use technology-intensive startups as a means of developing their own innovations. During the 1990s, many large corporations established *corporate incubators* – business development units designed to provide infrastructure and venture capital funding for new business ideas, both from within and outside the corporation. Ford's Consumer Connect was created to identify and develop new ways to leverage the company's capabilities, consumer base, and purchasing power in the new economy. British Telecom set up Brightstar in 2001 to create new businesses that would exploit BT's portfolio of over 14,000 patents.[39]

STRATEGY CAPSULE 11.4

Innovation at 3M: The Role of the Product Champion

Start Little and Build

We don't look to the president, or the vice-president for R&D to say, all right, on Monday morning 3M is going to get into such-and-such a business. Rather, we prefer to see someone in one of our laboratories, or marketing or manufacturing units bring forward a new idea that he's been thinking about. Then, when he can convince people around him, including his supervisor, that he's got something interesting, we'll make him what we call a "project manager" with a small budget of money and talent, and let him run with it.

In short, we'd rather have the idea for a new business come from the bottom up than from the top down. Throughout all our 60 years of history here, that has been the mark of success. Did you develop a new business? The incentive? Money, of course. But that's not the key. The key . . . is becoming the general manager of a new business . . . having such a hot project that management just has to become involved whether it wants to or not. (Bob Adams, vice-president for R&D, 3M Corporation)

Scotchlite

Someone asked the question, "Why didn't 3M make glass beads, because glass beads were going to find increasing use on the highways?" . . . I had done a little working in the mineral department on trying to color glass beads we'd imported from Czechoslovakia and had learned a little about their reflecting properties. And, as a little extra-curricular activity, I'd been trying to make luminous house numbers – and maybe luminous signs as well – by developing luminous pigments.

Well, this question and my free-time lab project combined to stimulate me to search out where glass beads were being used on the highway. We found a place where beads had been sprinkled on the highway and we saw that they did provide a more visible line at night . . . From there, it was only natural for us to conclude that, since we were a coating company, and probably knew more than anyone else about putting particles onto a web, we ought to be able to coat glass beads very accurately on a piece of paper.

So, that's what we did. The first reflective tape we made was simply a double-coated tape – glass beads sprinkled on one side and an adhesive on the other. We took some out here in St. Paul and, with the cooperation of the highway department, put some down. After the first frost came, and then a thaw, we found we didn't know as much about adhesives under all weather conditions as we thought . . .

We looked around inside the company for skills in related areas. We tapped knowledge that existed in our sandpaper business on how to make waterproof sandpaper. We drew on the expertise of our roofing people who knew something about exposure. We reached into our adhesive and tape division to see how we could make the tape stick to the highway better.

The resulting product became known as "Scotchlite." Its principal application was in reflective signs; only later did 3M develop the market for highway marking. The originator of the product, Harry Heltzer, interested the head of the New Products Division in the product, and he encouraged Heltzer to go out and sell it. Scotchlite was a success and Heltzer became the general manager of the division set up to produce and market it. Heltzer later went on to become 3M's president.

Source: "The Technical Strategy of 3M: Start More Little Businesses and More Little Businesses," *Innovation* no. 5 (1969).

Summary

In emerging industries and other industries where technology is the primary medium of competition, nurturing and exploiting innovation is the fundamental source of competitive advantage and the focus of strategy formulation. Does this mean that the principles of strategic management are fundamentally different in technology-based industries from other types of business environments? Many of the strategy issues we have discussed in this chapter are the same as those we covered in the previous chapters of the book. For example, the analysis of the determinants of the returns to innovation covered almost the same factors as our analysis of the returns to resources and capabilities: relevance to customer needs, barriers to imitation, and appropriability through well-established property rights.

At the same time, some aspects of strategic management in technology-based industries are distinctive. A common problem in technology-based industries is the speed of change and the difficulty of forecasting change. Conditions of Schumpeterian "creative destruction" (or, in Rich D'Aveni's terminology, *hypercompetition*) mean that traditional approaches to strategy formulation based on forecasting must be abandoned in favor of strategic management approaches that combine a clear sense of direction based on vision and mission, with the flexibility to respond to and take advantage of the unexpected.

Despite this turbulence and uncertainty, the principles of strategic analysis are critical in guiding the quest for competitive advantage in technology-intensive industries. Our analysis has been able to guide us on key issues such as:

- whether an innovation has the potential to confer sustainable competitive advantage;
- the relative merits of licensing, alliances, joint ventures, and internal development as alternative strategies for exploiting an innovation;
- the factors that determine the comparative advantages of being a leader or a follower in innovation.

This chapter also pointed to the central importance of strategy implementation in determining success. The key to successful innovation is not resource allocation decisions, but creating the structure, integration mechanisms, and organizational climate conducive to innovation. No other type of industry environment reveals so clearly the inseparability of strategy formulation and strategy implementation. Strategies aimed at the exploitation of innovation, choices of whether to be a leader or a follower, and the management of risk must take careful account of organizational characteristics.

Technology-based industries also reveal some of the dilemmas that are a critical feature of strategic management in complex organizations and complex business environments. For example, technology-based industries are unpredictable, yet some investments in technology have time horizons of a decade or more. Successful strategies must be responsive to changing market conditions, but successful strategies also require long-term commitment. The fundamental dilemma is that innovation is an unpredictable process that requires creating a nurturing organizational context, whereas strategy is about resource-allocation decisions. How can a company create the conditions for nurturing innovation while planning the course of its development? As John Scully of Apple has observed:

> *Management and creativity might even be considered antithetical states. While management demands consensus, control, certainty, and the status quo, creativity thrives on the opposite: instinct, uncertainty, freedom, and iconoclasm.*[40]

Fortunately, the experiences of companies such as 3M, Sony, Merck, Cisco Systems, and Canon point to solutions to these dilemmas. The need for innovation to reconcile individual creativity with coordination points toward the advantages of cross-functional team-based approaches over the isolation of R&D in a separate "creative" environment. Moreover, the need to reconcile innovation with efficiency points toward the advantage of parallel organizational structures where, in addition to the "formal" structure geared to the needs of existing businesses and products, an informal structure exists, which is the source of new products and businesses. The role of top management in balancing creativity with order and innovation with efficiency becomes critical. The success of companies in both Japan and Silicon Valley in managing technology (especially compared with the poor innovation performance of many large, diversified US and British corporations) points to the importance of technological knowledge among senior managers.

The increasing pace of technological change and intensifying international competition suggests that the advanced, industrialized countries will be forced to rely increasingly on their technological capabilities as the basis for international competitiveness. Strategies for promoting innovation and managing technology will become more important in the future.

Self-Study Questions

1 Trevor Baylis, a British inventor, submitted a patent application in November 1992 for a wind-up radio for use in Africa in areas where there was no electricity supply and people were too poor to afford batteries. He was excited by the prospects for radio broadcasts as a means of disseminating health education in areas of Africa devastated by AIDS. After appearances on British ad South African TV, Baylis attracted a number of entrepreneurs and companies interested in manufacturing and marketing his clockwork radio. However, Baylis was concerned by the fact that his patent provided only limited protection for his invention: most of the main components – a clockwork generator and transistor radio – were long-established technologies. What advice would you offer Baylis as to how he can best protect and exploit his invention?

2 Table 11.1 shows that:

a) Patents have been more effective in protecting product innovations in drugs and medical equipment than in food or electronic components;
b) Patents are more effective in protecting product innovations than process innovations.

Can you suggest reasons why?

3 What lessons would you draw from the experiences of Dyson and Raisio (Strategy Capsule 11.1) as to the merits and pitfalls of licensing as a means by which individuals and small companies can exploit their inventions?

4 From the evidence presented in Table 11.3, what conclusions can you draw regarding the factors that determine whether leaders or followers win out in the markets for new products?

5 In the battle for dominance of the US satellite radio market, XM's lead was being rapidly eroded by Sirius following its signing of "shock jock" Howard Stern and new CEO Mel Kamazin. XM has deals with GM, VW, and Honda; Sirius with Ford, DaimlerChrysler, and BMW. XM carries Major League Baseball; Sirius with the National Football League. XM has support from equipment manufacturers Delphi and Pioneer; Sirius with Kenwood. After holding a 3:1 advantage in subscribers during 2004, by the end of 2006, XM had about 8 million subscribers and Sirius 6.4 million. To what extent will satellite radio be a winner-take-all market? What recommendations would you offer XM for how it might gain market dominance?

Notes

1 "The Logic that Dares Not Speak its Name," *Economist* (April 16, 1994): 89–91.
2 R. D. Buzzell and B. T. Gale, *The PIMS Principles* (New York: Free Press, 1987): 274.
3 The excess of the benefit received by the consumer over the price they paid is called *consumer surplus* in the economics literature. See: D. Besanko, D. Dranove, and M. Shanley, *Economics of Strategy* (New York: Wiley, 1996): 442–3.
4 "Knowledge Monopolies: Patent Wars," *Economist* (April 8, 2000): 95–9.
5 The unit costs (and prices) of new products tend to decline rapidly. The ballpoint pen, invented by Ladislao Biro, is a classic example. At Christmas 1945, Biro pens sold at Gimbel's New York store for $12.50; by 1950, ballpoint pens were being sold for 15 cents. "Bic and the Heirs of Ball-Point Builder Are No Pen Pals," *Wall Street Journal* (May 27, 1988): 1, 27.
6 This section draws on: D. J. Teece, "Profiting from Technological Innovation: Implications for Integration, Collaboration, Licensing and Public Policy," in *The Competitive Challenge: Strategies for Industrial Innovation and Renewal* (Cambridge, MA: Ballinger, 1987): 190.
7 R. C. Levin, A. K. Klevorick, R. R. Nelson, and S. G. Winter, "Appropriating the Returns from Industrial Research and Development," *Brookings Papers on Economic Activity* 3 (1987).
8 P. Grindley and D. J. Teece, "Managing Intellectual Capital: Licensing and Cross-Licensing in Semiconductors and Electronics," *California Management Review* 39 (Winter 1997).
9 J. Jewkes, D. Sawyers, and R. Stillerman, *The Sources of Invention*, 2nd edn (London: Macmillan, 1969).
10 D. Hamberg, *Essays in the Economics of Research and Development* (New York: John Wiley, 1966).
11 For example, data on penetration rates for electric toothbrushes and CD players were used to forecast the market demand for HD TVs in the United States (B. L. Bayus, "High-Definition Television: Assessing Demand Forecasts for the Next Generation Consumer Durable," *Management Science* 39 (1993): 1319–33).
12 See B. C. Twiss, *Managing Technological Innovation*, 2nd edn (New York: Longman, 1980).
13 E. von Hippel, "Lead Users: A Source of Novel Product Concepts," *Management Science* 32 (July 1986).
14 In electronic instruments, customers' ideas initiated most of the successful new products introduced by manufacturers. See E. Von Hippel, "Users as Innovators," *Technology Review* 5 (1976): 212–39.
15 Tom Peters, *Thriving on Chaos* (New York: Knopf, 1987): 259–66.
16 A. Friedlander, *The Growth of Railroads* (Arlington, VA: CNRI, 1995).
17 C. Shapiro and H. R. Varian, *Information Rules: A Strategic Guide to the Network Economy* (Boston: Harvard Business School Press, 1999): 264–7.
18 S. Postrel, "Competing Networks and Proprietary Standards: The Case of Quadraphonic Sound," *Journal of Industrial Economics* 24 (December 1990): 169–86.
19 S. J. Liebowitz and S. E. Margolis ("Network Externality: An Uncommon Tragedy," *Journal of Economic Perspectives* 8, Spring 1994: 133–50) refer to these user-to-user externalities as *direct externalities*.
20 M. Gladwell, *The Tipping Point* (Boston: Little Brown, 2000).
21 P. David, "Clio and the Economics of QWERTY," *American Economic Review* 75 (May 1985): 332–7; S. J. Gould, "The Panda's Thumb of Technology," *Natural History* 96 no. 1 (1986). For an alternative view see S. J. Leibowitz and S. Margolis, "The Fable of the Keys," *Journal of Law and Economics* 33 (1990): 1–26.
22 C. Shapiro and H. R. Varian, "The Art of Standards Wars," *California Management Review* 41 (Winter 1999): 8–32.
23 "Format Wars: Everyone Could End Up Losing," *Financial Times* (April 3, 2006).
24 Shapiro and Varian, "The Art of Standards Wars," ibid.: 15–16.
25 Ibid.: 16–18.

26 M. L. Tushman, "Managing Communication Networks in R&D Laboratories," *Sloan Management Review* (Winter 1979): 37–49.
27 S. Thomke, "Enlightened Experimentation: The New Imperative for Innovation," *Harvard Business Review* (February 2001): 66–75.
28 D. Leonard and S. Straus, "Putting Your Company's Whole Brain to Work," *Harvard Business Review* (July–August 1997): 111–21; D. Leonard and P. Swap, *When Sparks Fly: Igniting Creativity in Groups* (Boston: Harvard Business School Press, 1999).
29 "How to Manage a Dream Factory," *Economist* (January 16, 2003).
30 L. Grundy, J. Kickel, and C. Prather, "Building the Creative Organization," *Organizational Dynamics* (Spring 1994): 22–37.
31 E. Von Hippel, *The Sources of Innovation* (New York: Oxford University Press, 1988), provides strong evidence of the dominant role of users in the innovation process.
32 R. Florida and J. Goodnight, "Managing for Creativity," *Harvard Business Review* (July–August 2005).
33 P. Lawrence and S. Lorsch, *Organization and Environment: Managing Differentiation and Integration* (Cambridge, MA: Harvard University Press, 1967).
34 E. Morrison, "Gunfire at Sea: A Case Study of Innovation," in M. Tushman and W. L. Moore (eds), *Readings in the Management of Innovation* (Cambridge, MA: Ballinger, 1988): 165–78.
35 K. Imai, I. Nonaka, and H. Takeuchi, "Managing the New Product Development Process: How Japanese Companies Learn and Unlearn," in K. Clark, R. Hayes, and C. Lorenz (eds), *The Uneasy Alliance* (Boston: Harvard Business School Press, 1985).
36 K. Clark and T. Fujimoto, *Product Development Performance: Strategy, Organization, and Management in the World Auto Industry* (Boston: Harvard Business School Press, 1991).
37 D. A. Schön, "Champions for Radical New Inventions," *Harvard Business Review* (March–April, 1963): 84.
38 R. Rothwell et al., "SAPPHO Updated – Project SAPPHO Phase II," *Research Policy* 3 (1974): 258–91.
39 M. T. Hansen, H. W. Chesborough, N. Nohria, and D. N. Sull, "Networked Incubators: Hothouse of the New Economy," *Harvard Business Review* (September–October, 2000): 74–88; "How to Make the Most of a Brilliant Idea," *Financial Times* (December 6, 2000): 21.
40 J. Scully, *Odyssey* (Toronto: Fitzhenry and Whiteside, 1987): 184.