CHAPTER

# 1 Introduction

*[M]ost of the fundamental errors currently committed in economic analysis are due to a lack of historical experience more often than to any other shortcoming of the economist's equipment[.]*

—JOSEPH A. SCHUMPETER (1954) in *A History of Economic Analysis* (Schumpeter and Schumpeter, 1986 edition, p. 13)

*[The master economist] must reach a high standard in several different directions and must combine talents not often found together. He must be mathematician, historian, statesman, philosopher – in some degree.*

—JOHN MAYNARD KEYNES (1933) in *Essays in Biography* (1971 edition, p. 173)

*I concluded in my most recent research that detailed longitudinal case studies, covering long periods of time, were necessary to study [competitive success] . . . This style of research nudges strategy research, and indeed industrial economics, into the world of the historian.*

—MICHAEL PORTER in *Strategic Management Journal* (1991, p. 116)

*The Mecca of the economist lies in economic biology . . . But biological concepts are more complex than those of mechanics.*

—ALFRED MARSHALL (1890) in *Principles of Economics* (1997 edition, p. xx)

*[E]xplaining many things about the coevolution of populations in a community requires narrative history as a complement to statistical analysis.*

—PAUL DIMAGGIO in *Evolutionary Dynamics of Organizations* (1994, p. 446)

There are few things – perhaps only one – that can arouse the passions of human beings as much as wealth. Humans need material objects to survive. But as social creatures, human beings desire wealth often not in an absolute sense of possessing more than before but in the relative sense of possessing more than one's neighbor. Thorstein Veblen (1899, p. 290) called this passion "the emulative predatory impulse," which he regarded as an evolved cultural modification of the basic instinct of workmanship that gave human beings a predilection for worthwhile achievement. It is not a coincidence that Adam Smith's classic text *The Wealth of Nations* (1776) was preceded by his *Theory of Moral Sentiments* (1761), in which he inquired into the passions that were necessary for creating a society capable of generating wealth. A close reading of Smith reveals that understanding economic inequality – a topic that became a key issue a century later in the development of sociology – was for him quite essential in identifying wealth-generating processes (see, for example, *The Wealth of Nations*, Book V, Chapter 1). Despite this longstanding human passion for wealth and the almost equally long-standing fear of destabilizing inequalities in modern societies (Hirschman, 1977), economics and sociology have not yet provided a complete understanding of how nations generate wealth and how they can distribute it relatively evenly. Even when we narrow the question considerably and inquire why nations differ dramatically in the performance of a particular branch of industry, existing theories do not provide us with an adequate explanation (Porter, 1990; Mowery and Nelson, 1999). Consider the following intriguing puzzle.

**The Puzzle**

London, 1856: William Henry Perkin serendipitously invents the first synthetic dye while trying to synthesize quinine, a medicine for malaria. Against the advice of his professor, August Wilhelm Hofmann, the nineteen-year-old Perkin leaves the Royal College of Chemistry and quickly commercializes his aniline purple dye, thereby launching the synthetic dye industry. From this time on, the industry continued to dazzle the eye with ever-new and appealing dye colors. Perkin, along with entrepreneurs from Britain and France, dominated the synthetic dye industry for the next eight years. During this period, British and French firms introduced most other innovative synthetic dyes onto the market and held the largest global market share.

Contrary to contemporary predictions, however, these firms were not able to sustain their leadership position in the new industry. German firms such as Bayer, BASF, and Hoechst[1] (some of the largest firms in the global chemical industry at the turn of twenty-first century) started to gain in market share. By 1870, Germany had about 50 percent of the global synthetic dye market. Britain fell to second place. By 1900, Germany's worldwide share climbed as high as 85 percent,[2] where it stayed with relatively minor fluctuations until World War I. From the 1860s on, American firms also tried to be successful participants in the U.S. market but could not compete with

[1] Hoechst merged on December 15, 1999, with the French firm Rhône-Poulenc. The combined company was renamed Aventis.

[2] This is Reader's (1970, p. 258) estimate. Thissen (1922) provides a lower estimate of 75 percent for Germany's global market share. If one includes German plants in foreign countries, the share may have been as much as 90 percent. Even though there is no agreement on the exact figure, everyone concurs that German firms collectively dominated the world market on the eve of World War I by a wide margin.

German and Swiss firms before World War I; they remained relatively small players or went out of business.

Any explanation of the shift in industrial leadership from Britain and France to Germany quickly becomes mired in an intriguing puzzle where the obvious suspects have surprising alibis. Possessing cheaper raw materials or a larger home market cannot account for why German firms left British and U.S. firms in the dust, because both latter countries had more raw materials and a larger home market. Why, then, did Britain lose its leadership position? Why did the American dye industry remain so small before 1914? This book takes a new tack to resolve the puzzle by engaging in a detailed historical analysis of what caused this transition in industrial leadership.

The purpose of trying to solve this particular puzzle of why industrial leadership shifted during the first fifty-seven years of the synthetic dye industry is to make a contribution to two important intellectual agendas pursued by scholars in a number of different fields. Adam Smith (1776) and David Ricardo (1817) and, more recently, Michael Porter (1990) and David Mowery and Richard Nelson (1999) are prominent examples of a wide array of social scientists who have tried to identify the factors that lead nations and firms to prosper. For economists and management researchers, the question of how economic success is generated remains a key intellectual challenge (Kogut and Zander, 1996; Landes, 1998; O'Sullivan, 2000). In tracing the development of one industry within the context of three countries, I hope to make a significant contribution toward formulating a much-needed dynamic theory of industrial leadership. At the heart of the theory lies the concept of coevolution, which has been employed with much success by researchers of biological (Kauffman, 1993, Chapter 6; Thompson, 1994) and cultural (Lumsden and Wilson, 1981; Durham, 1991) change. Recently, ideas of coevolution have been introduced in the discourse on industrial leadership (Nelson, 1995a), technological change and economic growth (Mokyr, 2002), and development of firms (Lewin, Long, and Carroll, 1999). What we need now is a theory that does more than explain industrial leadership at a particular time. I believe a coevolutionary theory that models firms as interacting with their social environment takes a significant step toward explaining how industrial leadership is gained and lost and how small initial differences in performance can translate into large differences over time.

In placing national institutions and technology into the center of my analytical framework, I continue an unduly neglected tradition that flourished around the turn of the twentieth century. Prominent social scientists such as Thorstein Veblen (1915) saw national institutions and their effects on technological development as a key to understanding why Germany, for instance, achieved higher rates of economic growth than Britain in those years. More recently, scholars from various disciplines have relied on institutional accounts to explain both Japan's rise to economic leadership after World War II (Fruin, 1992; Gerlach, 1992) and its recent economic troubles (Thomas, 2001). Nobel laureate Douglass North (1990) has argued in a recent book for an important role of institutions in shaping economic performance. However, institutional arguments have long been given scant attention in economic analysis (Hodgson, 1998; Hall and Soskice, 2001).[3] The goal is to help move these arguments

[3] To be sure, in some areas of sociology, institutional arguments have been more prominent in the last couple of decades (Hollingsworth and Boyer, 1997). Scholars who compare the development of

once again onto center stage and to focus our attention on a critical missing piece in institutional analysis, namely, how institutions are created in the first place.

The book also tries to make a contribution to a second important line of work that concerns itself with the rise and development of the large managerial firm as a new economic institution. The business historian Alfred Chandler (1962, 1977, 1990), who pioneered the study of this corporate entitity that appeared on the scene in the second half of the nineteenth century, identified this new organizational form as a key source of economic growth over the past century. On the Chandlerian model, large firms – those run by professional managers rather than owners – came to dominate industrial activity in modern industrialized economies because they could operate more efficiently by exploiting the scale and scope economies made possible by cheap transportation (railroads) and communication (telegraph). Sociologists Neil Fligstein (1990) and William Roy (1997) have argued that Chandler's analysis is incomplete because it leaves out the political context in which large managerial firms originate. I attempt to integrate the writings on the rise of the large managerial firm in business history and sociology by focusing on how collective action on the part of firms molded the social and institutional environment in which firms operate. I marshal considerable evidence to show how the rise of the large managerial firm required the construction of an institutional regime that would favor such firms over other forms of organization. As we shall see, German firms in the synthetic dye industry were much more successful in molding their institutional environment than were their British and American counterparts. In Chandler's analysis of the rise of large firms in Germany, Bayer figures prominently (Chandler, 1990, pp. 474–81) as an example of how a sophisticated managerial hierarchy was created that could organize more efficient production than smaller firms could. I will argue that Bayer could only realize its economic advantage precisely because it became a key player in lobbying efforts to create a favorable institutional environment. Bayer's leaders sought prominent roles in the chemical industry trade association and participated in collective action to improve the German education system in chemistry as well as change German patent laws to give large firms an advantage over foreign competitors and smaller domestic rivals.

One of the key propositions of this book is that the creation of German dominance in the synthetic dye industry before World War I cannot be understood without coming to terms with successful and unsuccessful patent law, science funding, and tariff lobbying efforts in the three countries. My analysis of the synthetic dye industry shows that we need to rediscover scholarship that recognized the importance of lobbying in industrial development, such as Galambos's (1966) *Competition & Cooperation: The Emergence of a National Trade Association* and Hirsch's (1975) *Organizational Effectiveness and the Institutional Environment*. Comparing the fates of firms in the three countries, this study shows that firms depended on their social environment for resources to prevail against foreign competitors. In the case of Germany, firms were able

professions across different countries (Gispen, 1989; Cocks and Jarausch, 1990; Jarausch, 1990; Lundgreen, 1990; Guillén, 1991) cannot but notice the importance of institutional differences. Similarly, scholars of comparative management such as Mauro Guillén (1994) frequently appeal in their explanations to institutional arguments. Comparative political scientists have also frequently resorted to institutional arguments in explaining differences in behavior across countries. See Thelen (1999) for a recent review of this literature.

to obtain more resources from their social environment than were their British and American counterparts. My analysis of why German firms overtook their foreign rivals and then cemented their leadership is consistent with Pfeffer and Salancik's (1978) theory of resource dependence, which highlights the political nature of creating successful organizations. One of the critical resources that firms in the synthetic dye industry needed to obtain was access to organic chemical knowledge and dye innovations. Because this knowledge, as well as dye innovations, was heavily concentrated at universities in the early period of the synthetic dye industry, firms needed to develop ties to university professors and their students. Examining the dependencies of a dye firm through Burt's (1992) more formal, network version of resource dependence theory makes apparent that firms were competing for access to the leading organic chemists in the world.[4] Those firms that were able to maintain ties to the best chemical talent of the day outperformed rivals that were not as well connected. After working in a professor's university laboratory, chemists often moved from academia to industry, from one firm to the next, and sometimes back to a university position. This created an informal network of ties that connected players in industry and academia. Mapping the network on a worldwide scale for the period before World War I reveals not only that this informal network was overwhelmingly constituted of Germans but also that the central positions were occupied by players from Germany. Explaining the shift in industrial leadership in the synthetic dye industry is intimately bound up with being able to account for the strong and weak ties in what I will call the academic–industrial knowledge network.

The informal network assumed a second function beyond simply transferring knowledge about chemical synthetic dyes. It served as a mechanism for organizing collective action. A key reason why German firms engaged in significantly more successful collective action to shape domestic patent laws and university policies is that they could rely on a much stronger network of actors spanning industry, academe, and government.[5] To be effective in orchestrating lobbying efforts, the informal academic–industrial network was enriched by ties to high-level government officials. Where this industrial–academic–government network was large and close-knit (Germany), collective action on behalf of the dye industry tended to succeed; where the network was small and distant (Britain and the United States), collective action was more likely to fail.

**Is This Book for You?**

Having made a careful investigation of the synthetic dye industry, I attempt to articulate a theory of coevolution of firms, technology, and national institutions so that other scholars can join the effort to formulate a rigorous theory of coevolution and to collect empirical support for it. My goal is to stimulate debate and new research rather than to provide the definitive word on the subject. I have not studied in detail all industries that ever existed from the industrial revolution until current times and hence it is an open question whether the theory I develop in this book is universal in scope. But my reading of other industry studies (e.g., Mowery and Nelson, 1999)

[4] My empirical analysis does not present a full-fledged test of Pfeffer and Salancik's (1978) or Burt's (1992) theories. Rather it draws on these theories to illuminate the historical dynamics in the synthetic dye industry.

[5] For an overview of the literature on organizational networks and alliances, see Gulati (1998).

gives me confidence that the theory provides a powerful analytical lens for industrial development in general.

Two communities – analysts of industrial leadership and scholars working on the rise of large managerial firms – are likely to find the study of the synthetic dye industry rewarding. If one surveys the literature in business strategy and organization theory, it becomes clear that both fields would benefit from devoting more attention to business history (Chandler, 1990; Galambos and Sewell, 1995; McCraw, 1997b; Jones, 2000; Lazonick, 2002).[6] Management scholars in business schools have become very competent over the past 25 years in conducting rigorous cross-sectional studies that relate differences in the structure of firms at a particular time to differences in their outcomes. But apart from organizational ecologists (Hannan and Freeman, 1989; Carroll and Hannan, 1995b; Rao and Singh, 1999) and several other scholars (e.g., Tushman and Anderson, 1986), not enough research on business strategy and organization theory is longitudinal in nature (Lewin and Volberda, 1999). Business historians, in contrast, take it as a given that understanding the actions of a particular firm requires the analyst to examine the development of the firm over time. Through a detailed study of the evolution of the dye industry, I hope to persuade management scholars that the field would be able to build more robust models of organizational development if it could draw on more historical studies.

This book also brings the sampling methods of organizational ecologists to business history. In doing so, I examine the entire population of dye firms that existed from 1857 to 1914 – large firms and small firms, short-lived and long-lived, failures and successes. Conclusions derived from the study of an entire industry become much more convincing if they are supported by detailed evidence from specific firms. Hence I also conduct matched comparisons of three pairs of firms – a winner and a loser from Britain, from Germany, and from the United States. These case analyses will demonstrate the benefit of examining causal processes with a higher resolution lens at the level of specific firms.

The resource-based theory of the firm (Wernerfeld, 1984; Dierickx and Cool, 1989; Barney, 1991; Teece, Pisano, and Shuen, 1997; Kraatz and Zajac, 2001) has received wide attention in the field of business strategy during the past decade and, given the current trend of viewing knowledge management as the key to success in a globalizing economy, the theory is likely to remain at the forefront of the research agenda. (See Kogut and Zander [1992] and Zander and Kogut [1995] for pioneering statements about the importance of knowledge in firm success, and Loasby's [1998; 2001] contributions on the cognitive foundations of organizational capabilities.) This literature identifies firm resources and capabilities that are hard to trade and hard to replicate as the key source of competitive advantage. Because empirical support for the theory has been collected generally within the context of one country, the resource-based theory of the firm has never dealt with the question of how the larger social environment rather than a particular firm itself may be an important source of

[6] Although many strategy scholars cite Chandler's (1962) book *Strategy and Structure: Concepts in the History of American Industrial Enterprise* as the pioneering study in the field of strategy, the share of historical analyses is much smaller than one would expect for a field that refers to *Strategy and Structure* as a foundational study.

competitive advantage. I show that bringing the resource-based theory together with ideas from institutional theory can refine the resource-based theory of the firm.

The new institutionalists in sociology and organization theory (Meyer and Rowan, 1977; Powell and DiMaggio, 1991; Dobbin, 1994; Scott, 1995) have argued against taking an atomistic view of organizations in which causal processes originate and end within the boundaries of the firm. Understanding why organizations fail and succeed, why they take on a particular form and not another, must be analyzed at the level of the field or, to use Marshall's (1923) term, the industrial district. The field comprises not only buyers, sellers, and suppliers but also regulatory organizations and a host of other supporting institutions. In bringing together the literatures around the resource-based theory of the firm and the new institutionalism, I develop the concept of "raw capabilities," which are created by the social environment and not within the boundaries of the firm. Comparing firms in the different national settings reveals that what firms do, to a significant extent, is to combine these raw capabilities into firm-specific capabilities that may be competitive in the global marketplace. The institutional environments in which firms are embedded frequently confer competitive advantage precisely because the institutional environments are hard to replicate and hard to imitate: They typically develop incrementally over long periods, their causal structures tend to be imperfectly understood, and changes in their makeup typically require agreement among a large number of actors, whose interests often do not coincide.

Institutional theorists in sociology have marshaled considerable evidence that institutions assert control over organizations (Dobbin and Dowd, 2000); with the notable exception of Holm (1995) and Ingram and Inman (1996), however, few studies have examined how institutions come about. My detailed account of how universities and patent laws were shaped through collective action should, therefore, prove valuable reading for the institutional scholar who wants to develop a deeper understanding of how institutions come about.

Evolutionary economists (e.g., Dosi, 1984; Metcalfe and Gibbons, 1989; Klepper and Graddy, 1990; Winter, 1990; Saviotti and Metcalfe, 1991; Witt, 1992; Nelson, 1995a) can profit from this study in at least two ways. Ernst Homburg and I argued in an earlier paper (Murmann and Homburg, 2001) that empirical studies of industry evolution have typically focused on one particular country. As a result, we have very little understanding of how patterns of industry evolution may differ from one social setting to the next. Are firms founded and dissolved at the same rates? Why are some national industries much more successful than others? Do industry shakeouts occur in every setting? Do industries run through the same stages of development in each country? Because the synthetic dye industry started at the same time in different national settings, a study of this industry can provide some answers to these questions. Although the specialist in evolutionary economics will read this book primarily for its empirical evidence, my formulation of a coevolutionary theory may provide the impetus for a vigorous debate about how to model coevolutionary processes of economic phenomena.

Economic historians have debated for some time why Victorian Britain lost its economic leadership position to the United States and, in some industries, to Germany. The study of the synthetic dye industry before World War I can be read as

another chapter in trying to come to terms with the relative decline of Great Britain. The theme that the economic historian may find most intriguing concerns the less powerful social network and the resulting collective action problems that the British dye industry faced in mounting successful lobbying campaigns against established industries. The British dye industry and the other new science-based industries were at an inherent disadvantage against powerful existing industries such as textiles. Germany industrializing later would, of course, encounter the same problems, but to a significantly smaller degree than Britain because the textile industry in Germany was not nearly as large in relative terms as in Britain. As Gerschenkron (1962) highlighted some time ago, it is crucial to pay attention to both when a new industry arises and how existing institutions may help or hinder the development of a new branch of industry.

Finally, a few words about what this book is not: It is not new history of the synthetic dye industry. The specialist historian of the synthetic dye industry will thus not find a revisionist interpretation of the synthetic dye industry before World War I. I have not uncovered new data that would call into question all existing accounts. Because a comprehensive database on all synthetic dye firms before 1914 has never been assembled, my data collection efforts with Ernst Homburg allow me to offer a systematic investigation of the organization of dye industry, shedding new light on how Germany was able to become and remain the dominant player in dye-making for so long. While I have made all efforts to get the history of the industry right, the purpose of the study is not to record all facts that are available on the synthetic dye industry or to provide the reader with a comprehensive handbook on the synthetic dye industry up to 1914. The reader who requires econometric analyses to be persuaded by an empirical argument will also be disappointed. I do not attempt to estimate an econometric model. The purpose of this book is to articulate a coevolutionary argument about the dynamics of industrial leadership and provide empirical data that give such arguments face validity. I hope the book can stimulate other scholars to test the arguments in a more systematic fashion.

**Key Ideas in Evolutionary Theory**

Let me preview the theoretical argument that I develop throughout the book. I have formulated the precise mechanisms of my coevolutionary theory after constructing a comparative narrative about the development of the synthetic dye industry in Britain, Germany, and the United States. All good theory development in the empirical sciences is a mixture of deductive and inductive reasoning that involves shuttling back and forth between the two modes of thought (Glaser and Strauss, 1967; Stinchcombe, 1968; Skocpol, 1984; Ragin, 1987; Eisenhardt, 1989a). By first studying in detail the evolution of the industry, I have placed more emphasis on the inductive aspect. I will now present a sketch of my coevolutionary theory, but a full articulation of the mechanisms that allow us to construe firms, technology, and institutions as coevolving will wait until I have given readers an opportunity to learn about the development of the synthetic dye industry. This will permit readers to develop their own notions about the causes of industrial leadership before they see the details of my model. Furthermore, those who are not predisposed to accept coevolutionary arguments can learn about the developments in the synthetic dye industry without having to see it through the lens of coevolution.

Evolutionary theory in the social sciences is sometimes misunderstood and seen as advocating social Darwinism, a view in which "successful" individuals in society have the right to trample and exploit its weakest members because nature works to let the strong prosper and the weak die out. Quite rightly, this so-called social Darwinism has been rejected as pseudoscience, and many people now greet the unreflective application of biological concepts to the social world with strong skepticism. Unfortunately, many people who for good reasons reject social Darwinist doctrines throw the baby out with the bath water by rejecting evolutionary arguments altogether. Moreover, many do not realize that the logical structure of an evolutionary theory is much broader than its biological versions (Campbell, 1969; Dawkins, 1976; Dennett, 1995; Hull, Langman, and Glenn, 2001). Evolutionary explanations have been applied to a diverse set of phenomena such as the development of the earth's geological features, economic change, and the development of languages.[7] Given that evolutionary theories of language existed long before Darwin, an evolutionary theory should not be interpreted as "biologizing" social theory before one has studied the specific arguments set forth.

The development of languages is perhaps the best example of evolutionary arguments that carry a much-needed neutral connotation and do not come with the heavy ideological baggage of biological concepts. The proposition that all languages spoken across the world today have evolved from one or a few common ancestor languages that branched out into families and subfamilies as people migrated to new places over the course of human history is widely accepted (Samuels, 1972; Ruhlen, 1994).[8] Similarly, the idea that today's vocabulary is evolving through a process of creating words for new phenomena – the World Wide Web, the Web, the Internet, electronic mail, e-mail, and so forth – (variation on existing words) and winnowing out a few of them that become most commonly used over the long run (selection) is not controversial (Müller, 1870).[9] In fact, in 1859, Darwin in *On the Origin of Species* (1964 facsimile, p. 422) appealed to the work of linguists to illustrate his ideas of a biological genealogy, underscoring the fact that evolutionary ideas existed before Darwin's application to the biological world. Hull (1995) recently examined the formal structures that characterize the evolution of language and biological life and concluded that they are essentially the same. Clearly, language is a better entry point to rigorous evolutionary theories in the social sciences than biology is.[10] One must

[7] Lewontin (1974, p. 6) has argued that an evolutionary perspective is equivalent to being interested in the change of the state of some universe in time, whether that universe consists of societies, languages, species, geological features, or stars. This definition is a bit too broad because it turns almost any development into an evolutionary account. As I will discuss later, the criteria for a rigorous evolutionary explanation are more narrow. But Lewontin also underlines the key point that evolutionary explanations are much broader than their biological versions.

[8] For an overview of the early connections between evolutionary thought in linguistics and biology, see Schleicher (1850) for the state of linguistics before Darwin. The essays by Schleicher, Bleek, and Haeckel presented in Schleicher (1850) give an early reaction in linguistics to the ideas of Darwin. For a comparison of intellectual developments in linguistics and geology in the nineteenth century, see the edited volume by Naumann, Plank, and Hofbauer (1992).

[9] For a contemporary evolutionary theory of language change, see Croft (2000).

[10] The best model for the evolution of firms, technology, and institutions is evolutionary epistemology, developed by Campbell (1974), Hull (1988), and others. As Hull (1995) points out, the evolution of languages has the property that evolutionary lines do not cross. Linguists report that two distinct languages

realize, however, that evolution does not necessarily imply progress or improvement, but rather cumulative and transmissible change. No society ever creates a new language from scratch without borrowing heavily from previous languages. Similarly, no society ever creates new industrial practices without drawing heavily on existing practices. As a general principle, novel things come about by changing and recombining existing things. The excellent summary description "descent with modification" crystallizes the key point of evolutionary theory into three words.

Identifying the formal structure that any evolutionary argument must possess to constitute a complete explanation[11] will make it easier to judge whether the theory I am proposing meets the formal requirements of an evolutionary explanation. More general than Nelson and Winter's (1982) articulation of evolutionary economics, evolutionary epistemology as articulated by Campbell (1974) and Hull (1988) provides, in my view, the most useful starting point for an evolutionary theory of industrial, institutional, and technological development. Expanding on Campbell's (1969) variation, selection, and retention model of evolutionary change, Durham (1991, p. 22) identifies five system requirements for an evolutionary theory of change:

R1. Units of transmission
R2. Sources of variation
R3. Mechanisms of transmission
R4. Processes of transformation
R5. Sources of isolation

An evolutionary explanation needs to identify clearly a unit of transmission – for example, genes, ideas, values, words, or even entire languages (R1).[12] It has to specify how these units are transmitted through time and space – for example, sexual intercourse in biology or social intercourse in culture (R3). It needs to say where variations come from – for example, gene mutation in biology or invention in culture (R2). And it has to articulate clearly the process that transforms the system through selection – for example, changes in the frequency of a trait in a population based on

have apparently never merged into one common language. Languages borrow words from one another, but linguists have not been able to find a true merger of two distinct languages. Industrial and conceptual evolution, by contrast, are replete with mergers of distinct lines of development. Industrial firms often merge and so do schools of thought. Because industrial evolution and evolutionary epistemology share key properties, evolutionary epistemology is, in my view, the best model for studying industrial phenomena.

[11] I draw here mostly on the excellent work of the philosopher David Hull (1988, 1989a) and the anthropologist William Durham (1991).

[12] Units of transmission come in different scales. Both individual words and entire languages can function as a unit of transmission. Later I will say more about how to deal with the different sizes of units of transmission and the relationship between them. The term "meme" is becoming increasingly popular to refer to nongenetic units of transmission. Susan Blackmore's *The Meme Machine* (1999) provides a useful introduction to memetics. I disagree with her insistence that memes are the only units of selection in cultural evolution. Sober and Wilson (1998) provide the most comprehensive argument for "group selection" as opposed to the "individual selection" that Blackmore, following Dawkins and other neo-Darwinians, is committed to. For a recent critical evaluation of meme literature, see the useful collection of essays for and against meme theory edited by Aunger (2000). Aunger (2002) lays out in more detail a neurological, brain-based model of memes.