1. Introduction

**Jens Laage-Hellman, Maureen McKelvey and
Annika Rickne**

1. INTRODUCTION TO ECONOMIC DYNAMICS

The Economic Dynamics of Modern Biotechnology is about the dynamics of knowledge – the economic processes that shape the exploration and exploitation of new knowledge in society. This book rests on the idea that innovations and the related development of new knowledge and information go hand in hand with economic transformation.¹ The economy is in flux, changing fundamentally over time, with new products, firms and activities starting up and with existing ones being significantly modified or disappearing. This constant transformation is based on learning and innovation, which are largely economic processes with economic objectives. This book explores such processes, using the empirical probe of modern biotechnology.

Analysing these types of processes requires a theoretical insight into a fundamental puzzle of the economics of the modern learning society. The puzzle concerns how and why the development of knowledge and ideas interact with market processes and with the formation of industries and firms. Using evidence from modern biotechnology, the book probes more general and abstract issues about how to conceptualize and analyse the modern economy. In doing so, the focus is on relationships between firms, markets, governments and the ongoing innovation processes.

Modern biotechnology is both a broad emerging technological area and a specific economic activity. It involves many industries, and as such the processes of innovation and economic change are interwoven in society. This has, in turn, led to a broader societal debate around modern biotechnology, a debate that raises at least four paradoxes. These four paradoxes help frame our understanding of why modern biotechnology is an interesting empirical probe, providing insight into more general and abstract theoretical issues.

First, controversies continue to abound over the negative versus positive societal impacts. On the one hand, modern biotechnology is often claimed to be crucially important to many industrial sectors, to large as well as to

small firms, and to address basic human needs and societal problems. On the other hand, modern biotechnology is also the centre of controversies about the modification of nature, food safety, animal welfare, environmental protection and impacts on global poverty. Given these different views, deep chasms divide those who focus on the potential benefits based on assumptions of individual creativity and social welfare returns, from those who debate the potential problems and therefore propose solutions such as government regulation and strong social control.

Second, despite such controversies about the economic and social potentials of modern biotechnology, little truly comparative statistics or empirical evidence exists. Many studies are narrowly based, with poor comparative scope, and the definitions, methods and empirical data on modern biotechnology differ greatly between studies. These differences frequently make it impossible to compare what is going on in one country or region with another. The reasons why such differences matter is that these types of empirical and methodological decisions greatly affect which aspects of the phenomena are picked up, compared and highlighted as the major strengths and weaknesses of a firm, region or country. One can speculate what implications follow if US data mainly report firms in the range of 100–500 employees, while data from Sweden or Germany mostly include firms with up to 100 employees. Of course, one plausible reason why few truly internationally comparative studies exist is the dearth of official data and accepted definitions, although the Organisation for Economic Co-operation and Development (OECD) has been engaged in important work to develop international statistics (OECD 2001).

Third, modern biotechnology is at once fundamentally global in terms of the knowledge flows resulting from movement of skilled persons, ideas, services and products – and yet, it is simultaneously extremely local in terms of co-located actors. Not only are actors located in specific geographical spots and networks, they also seem to agglomerate in those spots and maintain such linkages over long time periods. Some regions and nations seem to have a higher concentration and density of network relationships than others – and thereby gain competitive advantage. At the same time, global mobility is also visible among individual scientists, industrial researchers and firms. There is also a mobility of ideas through scientific competition, publications, reverse engineering, imitation of government policy and so on. Due to these simultaneously global and local aspects, this book is much more about the diversity of Europe as part of global trends, rather than Europe as a specific case.²

Fourth, modern biotechnology has seemed for several decades to be primarily a US phenomenon with the rest of the world lagging behind. Certainly, debates have raged about whether – and for what reasons – the

USA has competitive advantage, with explanations usually being based on empirical descriptions, and often resulting in advice for government policy. In relation to firms, the emergence of a dedicated biotechnology industry has been less successful in Europe. In 2001, there were 1453 biotech companies in the USA employing 141 000 people and with revenues exceeding \$25 billion. Europe had 1879 biotech companies, but they were on the average significantly smaller than their US counterparts, employing around 34 000 people and with sales totalling \$7.5 billion (Ernst & Young 2002).

The US competitive advantage is thought to be in the ability to generate and use a much higher quantity and quality of basic science as well as to commercialize diverse and rapidly adapting innovation opportunities. One explanation for this may lie in how and why the national institutional structure affects incentives for individuals and organizations. On the flip side, policy advice has also been abundant, particularly about how other countries and firms can get into or win the biotech race. This advice is often along the lines of 'imitate the leader'. More recently, Europe, Asia and the Pacific are claiming to be catching up quickly in terms of scientific achievements, university technology transfer offices, firm formation, venture capital investment and so on. This fourth paradox thus focuses on the existing distance between the 'leader' and the 'laggards' but competition should be understood as dynamic, not static.

An interesting aspect of the recent analysis and policy recommendations is the clear assumption of positive impacts of modern biotechnology, so those making policy recommendations seem to be in little doubt about the first of these paradoxes. A more nuanced analysis might be in order if the enduring reliability and validity of these claims is to be tested further. It is impossible to argue that the laggards are 'behind' or have 'caught up', if the relative positions of leaders and laggards has not been carefully and systematically compared in a historical perspective. Hence, it is not clear if this assertion of the supremacy of US science, commercialization, firms and so on, reflects true differences or whether it simply reflects early empirical evidence concentrated on the US experience. Probably, the answer is a bit of both and hence choices about definitions, indicators and data matter. Following on from the third paradox, one should ask whether an existing competitive advantage can be explained through national variables or as specialized actors within global processes. The question is thereby whether the USA as such generates this high potential internally or whether the research and business contexts have allowed a dynamic and self-reinforcing specialization to emerge thereby drawing the best individuals, within the global context. Social science plays an important role in this task of questioning paradoxes and 'accepted wisdom' with impacts on future allocation on societal and government resources.³

These four paradoxes indicate that modern biotechnology is an area rich in controversy. These broader contemporary debates illuminate the interwoven nature of societal and economic processes in emerging technological areas in many industries, as well as characteristics of the modern learning economy. This book is set within these broader debates, but the 14 chapters focus primarily on phenomena of relevance to the economic dynamics of knowledge. This book addresses a number of general and abstract issues concerning how and why to conceptualize the modern economy. This dynamic perspective is based on an understanding of how and why the development of knowledge and ideas interact with market processes and with the formation of industries and firms.⁴

The common starting-points for this book can be summarized as four ‘stylized facts’ (see Chapter 3). Each chapter implicitly uses at least one of these starting-points – and often several – even though each chapter also addresses a narrower research question and thereby makes a contribution in its own right. These stylized facts reflect more fundamental dimensions of the phenomena ‘economic dynamics of knowledge’, which is here applied to modern biotechnology.

1. *Innovations emerge from uncertain, complex processes involving knowledge and markets.* The development of new knowledge, technologies and markets involve ongoing, complex, dynamic processes within society and these affect, in turn, the development of innovation opportunities. Such processes affect both knowledge creation and knowledge exploitation. Science, technology and innovation are driven by an internal logic of knowledge accumulation as well as by market factors such as demand, customers’ preferences, profitability, investment as related to current and future returns and so on. The opening up of new innovation opportunities – and the exploitation of existing ones – affect broader economic phenomena like firm formation, industry structure and globalization. These processes are ongoing and thereby historically rooted. The institutional structure and incentives to be engaged in knowledge creation and knowledge exploitation change over time. As innovations and innovation opportunities emerge, this challenges the existing as well as forms the new.
2. *New scientific and technological areas create economic value in many different ways. The impacts of the economic value accrue within global actors as well as for geographically situated agglomerations.* Changes in knowledge bases relevant to science, technology and innovation create economic value in different ways. They can be used directly in goods and service products or can be incorporated as technological or organizational process improvements. Other ways of creating economic

value are also possible. The knowledge can be used as an intermediary good, an input into other industries and/or directly commercialized through selling licences and future options on the results of scientific research.⁵ These impacts accrue in various ways, such as property rights, firm profitability, employment, productivity increases, economic growth and so on. The positive and negative impacts may accrue to global actors as well as within geographically situated agglomerations.

3. *Societal linkages exist among diverse actors. Such networks as well as societal institutions affect innovation processes.* Actors are linked to society through market relationships as well as through other societal and economic relationships and social structures, such as innovation systems, networks and institutions. This implies that there is a diversity of relationships in society, and that these structures of relationships are likely to be unevenly distributed across the population of actors. One implication of this stylized fact is that public policy may contemplate a range of action, which is much wider than compensation for ‘market failure’.
4. *The firm as an organizational form plays a particularly important role in knowledge exploration and exploitation.* The firm as an organizational form plays a crucial role in exploration and exploitation of science, technology and innovation. This is so even though the firm and its future options are above argued to depend on broader processes as well as other actors, relationships and social structures. The argument is that it is significant how and why the firm (and a population of diverse firms) acts – and survives – in the face of the opportunities and challenges of innovations and markets. It matters because the firm – and population of diverse firms – will affect the rate, direction and outcome of knowledge creation and knowledge exploitation in the long run.

These four stylized facts are relevant to many types of innovation processes and to the general phenomena of economic dynamics of knowledge. In this book, these four stylized facts are common starting-points, as applied to the economic dynamics of modern biotechnology. Their relevance applies both to the empirical understanding of trends and in theoretical explanations of how and why such processes occur – and diverse actors are involved.

In approaching the dynamics of the modern learning economy, chapters in this book naturally address specific research questions, and the chapters use – and further develop – a variety of theories. As such, this book contributes to a novel and broader conceptualization, drawing on fields such as evolutionary and institutional economics, innovation studies, economic sociology, management and business economics. Theoretical explanations

are necessary to answer the questions and to capture the phenomena, and thereby a variety of more specific research questions and theories is relevant to this book. This variety may be necessary to understand the phenomena, given that the phenomena are seldom the result of a singular factor, such as an ideal market, social relationships or internal scientific institutions.

The theories used throughout this book may be seen as focusing primarily on (a) innovations and developments in science and technology as related to impacts on firms and regions; (b) markets, commercialization and industries as related to dynamics introduced by innovations, and new scientific and technological knowledge; (c) networks and innovation systems as enabling and constraining diverse actors; and finally (d) the firm as a particularly crucial actor, which is accessing resources and developing dynamic capabilities. Each chapter refers to theoretical literature appropriate to their specific research question. Still, the theoretical explanations found here are related to each other, in that the fundamental issues of the economic dynamics of modern biotechnology unite the contributions.

In summary, this book seeks to provide insight into one of the most important – and yet more controversial and paradoxical – knowledge fields for society, globally. The following chapters each address a specific theoretical and empirical issue, but the book as a whole also has a message. Unravelling modern biotechnology requires an understanding of the long-term interlinkages among government, markets and development of knowledge – as affecting decision-makers in firms, governments, universities and other organizations. Hence, the book argues for a more complex understanding of the economic dynamics of modern biotechnology, which is relevant for social science research as well as decision-making in governments, universities and firms.

2. MODERN BIOTECHNOLOGY

Modern biotechnology is a broad area of scientific and technological knowledge, which has been developing rapidly, in terms of the scope and rate of development of new ideas, techniques and tools. The development of knowledge – in combination with the economic uses – impacts on more aggregate economic variables, such as productivity, profitability and returns, firm performance and economic growth. This section gives a brief overview with regard to knowledge base and economic impacts – as an introduction to subsequent chapters (see Chapter 2).

The knowledge base continues to expand. The ‘modern’ in modern biotechnology refers to the post-genetic engineering era, that is after scientists

had developed the knowledge, techniques and tools to intervene directly at the gene level. This obviously gives more control than previous 'biotechnology', but the logic still follows upon more traditional ways of modifying cells and biological agents (see Katz and Sattelle 1991; McKelvey 1996: Ch. 4). Humans have used 'traditional' methods for thousands of years – to breed animals, improve plants, make beer and bread and so on.

Most definitions of modern biotechnology refer back to principles of living organisms. The influential OECD provided a working definition in 2001: 'Biotechnology is the application of scientific and engineering principles to the processing of materials by biological agents to provide goods and services'.⁶ Similar definitions may be found within national policy agencies, industry associations and so on – but putting these definitions into practice, for example applying them to categorize a particular piece of science, company, or product, is often more difficult.

Modern biotechnology is comprised of a broad range of knowledge fields. The OECD *ad hoc* meeting on biotechnology statistics held in Paris in 2001 further clarifies the above working definition to include the following five categories:

1. DNA (the coding): genomics, pharmaco-genetics, gene probes, DNA sequencing/synthesis/amplification, genetic engineering;
2. Proteins and molecules (the functional blocks): protein/peptide sequencing/synthesis, lipid/protein engineering, proteomics, hormones and growth factors, cell receptors/signalling/pheromones;
3. Cell and tissue culture and engineering: cell/tissue culture, tissue engineering, hybridization, cellular fusion, vaccine/immune stimulants, embryo manipulation;
4. Process biotechnology: bioreactors, fermentation, bioprocessing, bio-leaching, biopulping, biobleaching, biodesulphurization, bioremediation and biofiltration;
5. Sub-cellular organisms: gene therapy, viral vectors.

Hence, a broad range of scientific and technological knowledge fields are included within the definition of modern biotechnology – and this range keeps changing, as science and technology progress over time.

Modern biotechnology also has many economic impacts. Over time, many different ideas – including knowledge, techniques, tools, biological materials and so on – become useful economically. These ideas may come from various sources, and they may be sparked through scientific research, industrial research and development (R&D), insight into customer needs and so on. Some ideas are realized and turned into goods and service products for sale on markets. Other knowledge, techniques and tools are used

directly by the inventors and/or provide supplies and equipment to other firms and other industries. Not all succeed technically or economically – but some do.

This broad knowledge area has made it possible to develop new firms and industries – but also substantially affected existing firms and industries. The development of new ideas opens up innovation opportunities, in a dedicated ‘biotech industry’ as well as in many existing industries like pharmaceuticals, agriculture, forestry pulp and paper and so on.

The empirical evidence shows that both small dedicated biotech firms and larger firms in existing industries can turn such innovation opportunities into economic value. On the one hand, some of these innovative ideas are commercialized through the start-up of new biotech firms. For example, there may be individuals – such as scientists and professional entrepreneurs – who are using their broad contact networks to develop business ideas and build companies. Such firms, for historical reasons, typically have strong links to other actors such as universities, government agencies, venture capitalists and other firms.

On the other hand, for the incumbent firm, changes in the knowledge base and in innovation opportunities may be perceived as a peril to their organizational existence and to their routine ways of doing things. In other cases, existing firms may perceive these processes as the starting-point for reformulating their need to access new knowledge fields in order to develop strategies and access resources in order to make a profit and to survive. In such cases, the firm must thereby also realign its position within networks to access resources and relevant knowledge. These processes of adaptation occur globally as well as within specific regions and countries.

Hence, modern biotechnology involves moving phenomena, analysed in economic terms. This can be seen through a variety of indicators, such as in terms of affecting the type and number of products for sale, the processes being used, the start-up of new firms, the conditions for competing in different industries and so on. Within agriculture and the food industry, for example, heated debates over the advantages and disadvantages of genetically modified organisms (GMOs) in Europe have focused attention on the ability to modify plants and animals for very specific purposes. Differing regulations has led to differing firm strategy and sales by US and European companies in these product markets.

It is clear that major changes in knowledge, techniques and tools within a wide variety of medical, scientific and engineering disciplines result in an expanding definition. Initially in the mid- to late 1970s, modern biotechnology was mainly confined to genetic engineering techniques. In the decades since, the term has expanded to include many other things, which are as diverse as protein engineering, bioinformatics and life sciences for agro-

food. Some changes in definition are related to actors' preferences, and thereby negotiation over concepts to gain resources affects the definitions commonly used by analysts and researchers. Two examples are relevant here. As firms are started up and develop business plans for new goods and services not previously found on the market, they have to decide whether to market themselves as primarily 'core biotech' firms or as firms located in other industries. The firms may label themselves in different ways, but in either case, they are likely selling biotech-related knowledge, goods and services to consumers and/or firms in existing industries like pharmaceuticals, agriculture and medical technology. Moreover, as research funding becomes abundant within 'biotechnology', researchers within various disciplines have to decide whether to change their line of inquiry and relabel them to be awarded research grants. These two examples indicate that the boundaries between rapidly developing science and products are not clearly differentiated, but instead they are negotiated among actors at specific time periods. Hence, there are reasons to suspect that the definitions will continue to change over time and that a variety of definitions will be used at any one time.

This can be exemplified in relation to the large amount of studies done on biotechnology as related to human health care, particularly the pharmaceutical industry (Drew 1999). One explanation for this focus is that much biotech R&D has traditionally been related to the pharmaceutical industry and/or that much scientific research on biotechnology has emerged from medical fields. A second reason could be that more reliable indicators and data are assembled for the pharmaceutical industry and the large pharmaceutical firms can be identified and analysed.

A third reason for this focus is that modern biotechnology has truly had – and continues to have – a significant impact on existing economic activities in pharmaceuticals, and has also opened up opportunities for new activities to emerge. 'From the very beginning, the growth of biotechnology has been driven mainly – though not exclusively – by perceived application and commercialisation opportunities in the pharmaceuticals or health care field' (Granberg and Stankiewicz 2002, p. 6). Indeed, innovation opportunities coupled with customer demands has promised a high potential for profitability in pursuing the biotech track of development. Granberg and Stankiewicz rightly point out that such promises must be seen in the light of the industry's need to increase the efficiency and productivity of the drug development process, where modern biotechnology may provide a solution to technological hindrances. Modern biotechnology has greatly transformed the knowledge base within pharmaceuticals, both in terms of scope and cognitive differentiation. This can be seen in terms of knowledge needed for different parts of the value chain, including new

disciplines such as genomics, proteomics, combinatorial chemistry, bioinformatics and so on. The discovery phase involves new means and tools for target and lead identification, while in the development phase the ways to perform clinical trials change. Moreover, production may now entail, for example, cell culturing. As new commercial opportunities arise, new firms and other types of actors may emerge. The biotechnology-pharmaceutical sector is one example of the dynamic processes involving knowledge and markets.

Even so, global criticism has focused on the '10/90' gap, namely that only 10 per cent of resources go to research on diseases responsible for 90 per cent of the world's 'burden of diseases' (WHO 2001). Or, to put it the other way around, North America, Europe and Japan constitute the overwhelming majority of global demand for pharmaceuticals, given that they consume 90 per cent. This highlights the need to consider applications of modern biotechnology to human health care from a global perspective.

3. THE SCOPE OF THIS BOOK

This section provides a 'road-map' to individual chapters and the book as a whole. A brief recapitulation of the objectives of the book is useful. The 14 chapters in this book address a series of theoretical and empirical questions, but are also united by a common message. In doing so, they provide an insight into modern biotechnology in the European case – or more specifically, an insight into diverse national and sectoral cases found in Europe in relation to global trends. Modern biotechnology is seen both as specific empirical phenomena as well as an empirical probe to explore the general and abstract issues of economic dynamics of knowledge. There are two chapters of introduction in the first Part; 11 chapters grouped into the following three Parts; and a concluding chapter in the final Part.

In terms of this book, the ongoing development of knowledge bases and commercial opportunities matters because a diversity of definitions is applied to the empirical material (see Chapter 2). Subsequent chapters follow the broad definition of 'modern biotechnology', but may relate that to other concepts, like 'life sciences'. In other words, the chapters focus on a number of somewhat different, somewhat overlapping concepts. For example, one contribution delves into the convergence of modern biotechnology with information technology (IT), whereas another chapter examines the impacts of genetic information on insurance, which have not previously been studied in the biotech context. All of them fall, however, within the broader concept of 'modern biotechnology'.

Given the common agreement and interest in the broad concept of 'modern biotechnology', this diversity among chapters is a choice made in editing this collection of work into the book. It allows authors to capture the moving boundary of the intersection of modern biotechnology with other phenomena and other activities. This relates back to our objective to understand emerging technological areas, including impacts on industries. The concept must be stringent enough to define existing boundaries, but also plastic enough to capture changes in knowledge and products over time, where the boundaries are not clearly differentiated. The chapters are also united by their awareness of definitions, methodology and data, in that most chapters present novel empirical work.

'Introduction' constitutes Part I where Chapters 1 and 2 form the common introduction to the book. The current chapter 'Introduction' by Jens Laage-Hellman, Maureen McKelvey and Annika Rickne has introduced the idea of 'economic dynamics of knowledge' as well as the broader societal debate about modern biotechnology, thereafter introducing four stylized facts and a broad definition and the book chapters. Chapter 2, 'Conceptualizing and measuring modern biotechnology', by Johan Brink, Maureen McKelvey and Keith Smith focuses on how and why measurement and methodology matter. This chapter introduces key issues related to choosing definitions, indicators and empirical data as well as the implications of such choices for drawing conclusions and implications for decision-making.

The subsequent chapters are grouped into four parts: 'Setting the scene' (Chapters 3–5), 'Challenging the existing' (Chapters 6–9), 'Forming the new' (Chapters 10–13) and 'Conclusions' (Chapter 14). Each part contains chapters that share some common characteristics and that are of relevance to that topic.

'Setting the scene', (Chapters 3, 4 and 5) paints a broad view through historical accounts and broad overviews of trends, as linked to empirical details. These three chapters are thereby useful for orienting the reader and for setting the scene of the book as a whole. They help set the scene, in the sense of providing arguments about historical trajectories and possible future ones as well as detailing diversity across time, across geographic space and across industrial versus scientific institutions. Chapter 3 provides insight into innovation processes in modern biotechnology, as organized around four stylized facts. Chapter 4 provides one possible future in the development of international trends while Chapter 5 provides a detailed analysis of the current situation in eight European countries.

Chapter 3, 'Stylized facts about innovation processes in modern biotechnology', by Jens Laage-Hellman, Maureen McKelvey and Annika Rickne makes the argument that modern biotechnology has been – and continues

to be – developing at a rapid pace at the intersection of scientific and technological knowledge with innovation and business opportunities. This chapter is organized around the four stylized facts presented in Part I and draws on existing research as well as a case study of genomic companies and human biobanks.

Chapter 4, ‘The post-genome era: rupture in the organization of the life science industry?’, by Michel Quéré details one possible future trajectory. He argues how and why the current post-genome era (PGE) will be a structural shock in the organization of firms active in the life sciences industry. Quéré claims that under conditions where exploration as well as combination and adaptation of scientific opportunities are key, dedicated biotech firms (DBFs) will play an increasingly important role as drivers of knowledge dynamics. Further, the importance of the small firms will increase in the future, even though large firms have so far kept their advantages. So far, the large firms have had advantages in handling the complex character of knowledge as well as the necessity to coordinate complex capabilities in the pharmaceutical industry.⁷ In the future, environmental conditions will continue to change and should give advantages to the smaller firms.

Chapter 5, ‘An overview of biotechnology innovation in Europe: firms, demand, government policy and research’, by Jacqueline Senker demonstrates the diversity of western Europe, based on evidence within three sectors and eight countries. The integrated framework to analyse these countries includes factors such as industry structure, supply, demand, financial system, industrial development and social acceptability as well as knowledge and skill formation. The comparison is based on this common set of variables, which was used to organize a thorough industry survey and summarize secondary material. This chapter argues that three prevailing factors affect the firm’s propensity to innovate in different sectors and countries, namely, the existing structure of production, demand (including social acceptance) and a well-funded science base.

‘Challenging the existing’, (Chapters 6, 7, 8 and 9) gives an insight into the turbulence of modern biotechnology, including disruptive effects on existing businesses and economic phenomena.⁸ These contributions present arguments about how and why existing actors and broader social structures attempt to cope with the challenges of modern biotechnology. These four chapters address, respectively, the challenges of modern biotechnology to existing firms and industries; firm strategy and reallocation of risk; firm strategy to cope with new information and access new competences; and emergence of new actors within an existing structure. Moreover, they use evidence from firms and industries that are not included in more ‘traditional’ analysis of biotech industries, namely within agriculture, genetic testing, insurance and IT. In coping with these broader soci-

etal impacts, the ‘existing’ actors are of course changed as part of ongoing processes. Hence, these four chapters address issues about ‘Challenging the existing’ because they focus mainly on how and why the ‘existing’ becomes renewed and fundamentally changed over time.

Chapter 6, ‘Risk management and the commercialization of human genetic testing in the UK’, by Michael Hopkins and Paul Nightingale, analyses corporate strategic management, using genetic testing as an example within human health care. The authors conclude that effective risk handling and reallocation of risk to third parties is key when the firm is moving into new markets where uncertainty is high. Risk management is here seen as a combination of firm strategy and public concern. The chapter is based on case studies of four UK firms providing genetic testing services.

Chapter 7, ‘Networks and technology systems in science-driven fields’, by Finn Valentin and Rasmus L. Jensen, examines patterns of network formation taking a microorganism widely employed in food processing (lactic acid bacteria) as its focal case. By tracking biotech patents since 1980 it is obvious that the European rate exceeds that of the USA. Competing theories on systems of innovation are examined to explain the global organizations of this field. Using formal network analysis this chapter suggests novel ways of differentiating technology systems and national systems of innovation as distinct, yet interrelated, causal mechanisms. These interrelationships have implications for understanding the responsiveness and flexibility of institutions, particularly those associated with production and dissemination of scientific knowledge.

Chapter 8, ‘Future imperfect: the response of the insurance industry to the emergence of predictive genetic testing’, by Stefano Brusoni, Rachel Cutts and Aldo Geuna, addresses the challenges of modern biotechnology to insurance companies. This chapter examines how firms cope with building new capabilities as a rejoinder to changes in the knowledge base and in consumer-driven industries. The survey of firms located in the UK (but often with international customers) concludes that especially large insurance firms are actively learning about the new knowledge field of genetic testing, both through internal efforts and collaboration. In addition to firm size and characteristics of the final market, the type of insurance involved affects the firm’s involvement in learning as well as their strategies for integrating outside competences into the main business.

Chapter 9, ‘Emergent bioinformatics and newly distributed innovation processes’, by Andrew McMeekin, Mark Harvey and Sally Gee, argues that developments within bioinformatics clearly demonstrate a distributed innovation process, based on new and old elements. As such, their chapter functions as a transition between ‘Challenging the existing’ and ‘Forming the new’. Supported by a meticulous case study of a bioinformatics firm

located in various European countries and globally, this chapter analyses how new classes of economic agents emerge as a response to innovation opportunities as well as the dynamics of evolving coordination mechanisms and collaborative patterns.

‘Forming the new’, (Chapters 10, 11, 12 and 13) takes up issues directly related to the development of new business and economic activities around modern biotechnology. These four chapters particularly focus on forming the new – but as part of specialization and competition within global developments and/or as part of spatial bounded network patterns. Hence, these chapters analyse economic dynamics both in terms of historical trajectories as well as relative specialization within specific regions and countries. The chapters address one or both of the following: (1) the extent to which innovation processes are spatially dependent and/or emerge as long-term specialization within specific sub-fields; and (2) the effects of local (regional) networks on firm formation and performance. The four chapters in ‘Forming the new’ thereby follow on from ‘Challenging the existing’, by providing an insight into how and why the ‘new’ are linked to the historical trajectories.

Chapter 10, ‘The dynamics of regional specialization in modern biotechnology: comparing two regions in Sweden and two regions in Australia, 1977–2001’, by Johan Brink, Linus Dahlander and Maureen McKelvey, examines whether regional specialization requires a co-evolution of scientific, technological and business activities at the regional level, or whether firms are simply tied into global trends. This analysis is based on arguments to examine whether knowledge formation within specific sub-fields of modern biotechnology influences long-term trajectories of specialization at the regional level. Data are presented about scientific, technological and business activities over 25 years within two regions in Sweden and two regions in Australia. The results reveal that, relative to global trends, the regional economic transformation is a process that can be described as path-dependent in terms of specialization over time, but with points of rupture and change. The question remains how, why and when diverse types of actors may provoke those points of rupture. Interestingly, knowledge externalities in modern biotechnology between disciplines and industrial sectors implies that analysts and practitioners must understand the patterns of specialization for interrelated activities and sectors, and not just the knowledge base.

In Chapter 11 ‘On the spatial dimension of firm formation’ Annika Rickne takes a somewhat different twist, by focusing on the process of firm formation within spatially delimited ‘regions’, relative to specific features of science, technology and innovation. This chapter is based on an in-depth case study analysis of biomaterials-related firms in Sweden, Ohio and

Massachusetts. It argues that the volume and profile of the firms which are established, as well as their propensity for co-location, are related to characteristics of the technological regime, the profile of the regional science base, and, most importantly, to the specificity of pre-firm activities and networks.

Chapter 12 ‘Examining the marketplace for ideas: how local are Europe’s biotechnology clusters?’, by Steven Casper and Fiona Murray, asks the question of why some clusters are more successful than others in commercializing biosciences. The chapter examines the emergence of two European clusters (Cambridge and Munich) and one American (Boston) along three dimensions: the source of technology, scientific linkages and access to labour markets. It is concluded that the European clusters are too small to support purely local cluster development. Therefore, this view has conclusions that differ from many existing policy recommendations. Rather than supporting local networking, effective policies should centre on the development of institutions that attract firms and other actors from outside the region and enhance the local actors’ ability to build up geographically dispersed collaborations.

Chapter 13, ‘Creation and growth of high-tech small- to medium-sized enterprises (SMEs): the role of the local environment’, by Corinne Autant-Bernard, Vincent Mangematin and Nadine Massard addresses the question of whether the determinants of firm creation as well as growth of high-tech firms can be found at a regional level. Through econometric analysis of high-tech SMEs in France during the 1990s, the authors argue that new business creation is promoted by regional activity, especially by diversity (rather than quantitative potential) of scientific competences, patterns of public–private interactions and market agglomeration effects. In contrast, the growth potential of firms in the region depend by and large on internal characteristics and strategic choices of the firms.

‘Conclusions’ constitutes Part V. In Chapter 14, ‘Reflections and ways forward’, Hannah Kettler, Maureen McKelvey and Luigi Orsenigo reflect on the contributions of the book and suggest future avenues for social science research. In addition to revisiting the four paradoxes, the chapter highlights the specific issue of applying these perspectives to human health care in developing countries. Finally, the chapter reflects on the challenges of modern biotechnology to our conceptual understanding of the economic dynamics of knowledge.

NOTES

1. Economic transformation refers to evolutionary change processes at many levels, which, in turn, influence flexibility and stability of society and the economy. The relative degree of flexibility and stability – as well as reasons for different outcomes – can be analysed at various levels, such as within firms, industries, national economies and so on. Based on neo-Schumpeterian and evolutionary economics, the argument would be that economic transformation relies on qualitative (and not such quantitative) change among inputs, outputs and transformative intermediates like business organizations and technology.
2. Most chapters in the book provide evidence of Europe, or more correctly, of the diversity of Europe through a variety of evidence of firms, sectors and countries. Hence, this book provides a multitude of evidence for what is ongoing in Europe – as related to global trends – but especially as related to theoretical and conceptual issues. This implies that the book as a whole does not purport to provide one ‘holistic’ picture of ‘the’ situation in Europe – indeed, if such a thing is possible. Individual chapters here instead provide a series of ‘snapshots’ – or rather, moving pictures – of trends in development within Europe.
3. Social science is here used as a broad term, including both economics and business studies.
4. Neither the firm alone nor an ‘innovation system’ as such can explain the interactions among knowledge and markets. The theoretical structure required must include institutional settings as well as incentives, decisions and actions by a diverse set of actors.
5. The implication is that modern biotechnology involves a variety of different types of innovations.
6. The definition and the five categories were developed in *ad hoc* meetings. They can be found explicitly on the OECD’s homepage under ‘definition of biotechnology’ and under electronic documents. The OECD (2001) document that followed on from these meetings does not provide these exact wordings, but is based on these discussions. See OECD (2002) and OECD (2003).
7. The argument is that emerging organizational structure will lead to an increasing importance of innovation networks, since cooperation gives possibilities for complementary resources and activities rather than specialization within the firm.
8. The ‘challenges to the existing’ can be seen through, for example, changes to traditional innovation processes, new organizational structures, the emergence of new types of actors, the need for incumbent firms in existing industries to renew their knowledge base and modify routine ways of doing things and so on.

REFERENCES

- Drew, J. (1999), *In Quest of Tomorrow’s Medicine: An Eminent Scientist Talks About the Pharmaceutical Industry, Biotechnology, and the Future of Drug Research*, New York: Springer Verlag.
- Ernst & Young (2002), *Beyond Borders: The Global Biotechnology Report 2002*, Toronto: Ernst & Young.
- Granberg, A. and R. Stankiewicz (2002), ‘Biotechnology and the transformation of the pharmaceutical value chain and innovation system’, paper presented at workshop The Economics and Business of Bio-Sciences and Bio-Technologies: What can be Learnt from the Nordic Countries and the UK?, September 25–27, Chalmers University of Technology, Gothenburg, Sweden.
- Katz, J. and D. Sattelle (1991), *Biotechnology for All*, Cambridge: Hobsons Scientific.
- McKelvey, M. (1996), *Evolutionary Innovations: The Business of Biotechnology*, Oxford: Oxford University Press.

- OECD (Organisation for Economic Co-operation and Development) (2001), 'Biotechnology statistics in the OECD member countries: compendium of existing national statistics', STI working paper no. 2001/6, Directorate for Science, Technology and Industry, OECD.
- OECD (2002), 'Statistical definition of biotechnology', website <http://www.oecd.org/EN/document/0,,EN-document-617-1-no-21-31006-617,00.html>, viewed May 2003.
- OECD (2003), Report on *ad hoc* meeting in 2001 in Paris, website <http://www.oecd.org/doc/M00003000/M00003698.doc>, viewed May 2003.
- WHO (World Health Organization) (2001), *WHO Health Report 2001*, website www.who.int/whr 2001, viewed 10 May 2003.