1 Managing new product development: An evolutionary framework

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1. Introduction

The purpose of this chapter is to introduce a theoretical framework that integrates research from various disciplines on different areas of New Product Development (NPD) in a common context. NPD encompasses a large number of topics and challenges in a firm, such as strategy formulation, deployment, resource allocation, and coordinated collaboration among people of different professions and nationalities, and systematic planning, monitoring, and control. In that light, NPD has long been an important topic for several business research disciplines, certainly economics, marketing, organizational theory, operations management, and strategy.

Each of these very different topics represents a field of inquiry, and each has developed its own ‘micro-theories’ that focused on explaining and predicting phenomena pertinent to this field. To our knowledge, no ‘theory of NPD’ exists, and there is no consensus on whether one can and should exist. For example, a project-scheduling researcher and a researcher on alliances in technology strategy will find very little commonality between their core research questions, limiting the possibility of a fruitful exchange.

However, parallel work in strategy, organization theory, operations and economics (search theory), psychology, and anthropology suggests that a theory exists with the potential to describe a large part of NPD phenomena in a comprehensive causal framework. We propose multi-level evolutionary theory as a candidate for such a theory. It considers the evolutionary dynamics at multiple nested levels of aggregation (Sober and Wilson 1999, 101). In this chapter, we argue that an evolutionary process is present at the level of an industry (with a population of firms), at the level of a firm (with a population

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1 This chapter has benefited from comments and suggestions by Manuel Sosa and Raul Chao.
of procedures, rules, and processes), and at the level of the NPD process (with a population of innovation ideas). The evolutionary framework allows characterizing commonalities across the different levels of aggregation, and at the same time provides enough flexibility to accommodate the differences between the aggregation levels in the units of the population and the laws of their evolutionary dynamics.

For example, in an industry, firms are born by partially serendipitous ideas (such as Bill Gates starting a software company or Michael Dell assembling computers in a college room), they are selected by market success, and they may (through imitation and competition) cause changes in the structure of their industries. Eventually, they may ‘die’ (go bankrupt or be acquired), and they leave inherited traces in the companies into whom they have merged or into which groups of their employees have migrated (Hannan and Freeman 1977). Within a firm, processes and structures arise partially randomly (e.g., because new employees are hired, or because individual employees invent new rules to improve their daily reality), compete, and are selected based on efficiency and success (but success may be socially defined rather than ‘objective’), and inherit traces in future process generations (Nelson and Winter 1982).

Within a given process, such as the NPD process, innovative ideas arise, sometimes randomly through unforeseeable recombinations of existing but separate knowledge. The innovations compete for resources and are selected (based on ‘success potential’); the successful ones enter the market and inherit improved competencies and know how in trajectories of product generations (Basalla 1988, Mokyr 1990, Fleming 2001).

Thus, at all three levels of aggregation – the industry, the firm, and the (NPD) process – all three characteristics of evolution are present: (partially random) generation of a variety of organisms, selection according to some criteria that are stable for a while, and elaboration and inheritance (Dawkins 1996). Evolutionary theory, therefore, offers a set of causal explanations, which allow the identification of robust, recurring patterns at all three levels of aggregation. At the same time, evolutionary theory allows for the acknowledgment that the replicating entities, the rules of generation, selection and inheritance, and the dynamics differ across the three levels of aggregation. Moreover, evolutionary theory accommodates a description of the dynamics not only of Darwinian evolution (in which the inheritance of successful traces happens only across generations) but also of cultural evolution (in which changes propagate horizontally also within the same generation through social learning, Boyd and Richerson 1985 and 2005).

To establish the evolutionary framework, we need to use a common vocabulary. Therefore, we first define ‘new product development’, and then present evolutionary theory and apply it to the three levels of aggregation of NPD (industry, firm, and NPD process). Finally, we outline a ‘map’ of the chapters, to illustrate how they fit within the framework.
2. What is new product development?

Ulrich and Eppinger (2004:2) define NPD as ‘the set of activities beginning with the perception of a market opportunity and ending in the production, sale, and delivery of a product.’ With a small modification, this definition includes also new service development (NSD): in contrast to a manufactured product, a service is co-produced with the customer, and therefore, NSD must include a customer interface mechanism. Still, this definition focuses on individual new products, while the NPD activities within a larger firm must consider a stream of multiple ideas and products, selection among them and their evolution over generations.

Addressing this larger context, Wheelwright and Clark (1992: Chapter 1) defined NPD as ‘the effective organization and management [of activities] that enable an organization to bring successful products to market, with short development times and low development costs.’ Clark and Fujimoto (1991: 7) add that ‘performance results from consistency in total organization and management.’

We build on these definitions, while making the evolutionary perspective more explicit:

New product development (NPD) consists of the activities of the firm that lead to a stream of new or changed product market offerings over time. This includes the generation of opportunities, their selection and transformation into artifacts (manufactured products) and activities (services) offered to customers, and the institutionalization of improvements in the NPD activities themselves.

The definition emphasizes the offering of either products or services, and it distinguishes NPD from pure (or scientific) research, which, in contrast to NPD, may neglect commercialization of the output.

The definition implies that an NPD system has three fundamental elements: generation of variants, selection, and elaboration with inheritance. We add one element that does not follow from the definition of evolution but is an outcome of evolution among higher animals that solve the most complex adaptive problems: NPD activities are distributed always (except in very small companies) over multiple parties. In parallel to higher animals (such as social insects, large sea mammals, and primates), the problems solved by NPD are too complex to be done by a small group. Therefore, we add an element of NPD that ensures co-ordination and exchange among those parties. This is summarized in Table 1.1.

While the elements of the NPD system follow a fundamental evolutionary logic, they occur in myriad different forms and shapes in different organizations. Thus, NPD research has also been performed with many different theoretical lenses and study approaches. In the remainder of this Chapter, we try to argue that evolutionary theory can represent the fundamental functions
Table 1.1
Fundamental elements of new product development

- A variant generation process, which identifies new combinations of technologies, processes, and market opportunities with the potential to create economic value. Variants are generated by directed search and ‘blind’ combination of unrelated elements (creativity).
- A selection process, which chooses the most promising among the new combinations for further investment (of financial, managerial, physical, and/or human resources) according to consistent criteria.
- A transformation process, which converts (‘develops’) opportunities into economic goods and codified knowledge (embodied in a design) – products or services to be offered to customers.
- A coordination process, which ensures the information flow, collaboration, and cooperation among multiple parties, involved in the NPD activities.

of NPD elements, while encompassing a large variety of variant generation mechanisms, selection criteria (e.g., driven by market conditions as well as stakeholder collations), and transformation and inheritance rules (e.g., reflecting technical constraints).

3. Viewing NPD in an evolutionary framework

It must not be forgotten that although a high standard of morality gives but a slight or no advantage to each individual man and his children over the other men of the same tribe, yet that an increase in the number of well-endowed men and an advancement in the standard of morality will certainly give an immense advantage to one tribe over another. (…) This would be natural selection. (Darwin 1871, 166)

Evolution can be characterized as the ‘slow, cumulative, one-step-at-a-time, non-random (because driven by natural selection) survival of random variants’ (Dawkins 1996, 79). Darwinian evolution involves three steps: first, the generation of variation produces a potential for improvements. The variants do not have to be directed, they may be (partially) random or ‘blind’. Second, the selection according to a set of criteria that remains stable over some period, which introduces a direction. Third, retention (inheritance) maintains the selected features into the next generation of artifacts and enables the cumulative capability of the system (Dawkins 1996). Evolutionary theory describes how the population level frequencies of variants change over time, driven by how variants are created, selected, and what they inherit (Boyd and Richerson 1985, 6).
Natural selection operates at more than one level of the biological hierarchy (Sober and Wilson 1999), as the citation of Darwin’s discussion at the beginning of this section suggests. Individual organisms are derived from genes that interact with one another and with the environment; and populations are subdivided into competing social groups with limited exchange of members. Thus, Darwinian evolutionary theory can be applied (at least) at the level of genes, individuals, and groups (Boyd and Richerson 2005, 256). In addition, Darwinian evolutionary theory can be broadened to include the creation of variants not only between generations (through, e.g., chromosome crossovers, sexual mixing, and mutations) but also culturally, through the exchange of ideas, knowledge, and decision rules horizontally among members of one generation (Boyd and Richerson 1985 and 2005).

It has long been known that evolutionary theory applies to innovation systems, and thus to NPD which produces product innovations. A common definition of an innovation is something novel that is (economically) useful and actually implemented in processes or artifacts (Campbell 1960, Simonton 1999). Innovations are therefore like adaptations in an evolutionary system, in which artifacts that are more complex are produced over time via ‘cumulative finding’ (Dawkins 1986, see also Fleming and Ming in this volume). For example, Mokyr (1990) showed that in the history of technology, the generation of variants was undirected and random. A selection of innovations was constantly at work, and the resulting artifacts exhibited a strong continuity across generations. Indeed, ‘technology trajectories’ have been observed regularly in the technology management literature, referring to the continuity of many product innovations (Utterback 1994).

Once we accept an evolutionary view of innovation, we can adopt a hierarchically nested set of theories, as in biology and anthropology. Indeed, the evolution of innovations can be analyzed with existing theories of cultural evolution. We start with identifying three distinct levels, analogous to Boyd and Richerson’s (2005) levels of gene, individual, and group. A process, consisting of procedures, rules, and norms, i.e., ‘the way things get done,’ and it corresponds to an ‘individual’: in the context of building a framework of NPD. We anchor our view at this level, where an NPD process is one of a population of processes that together make up the firm. At the (‘gene’) level below, individual innovations are generated, selected, and evolve, and a population of innovations lives and evolves within an NPD process. At the aggregated level above the process, a firm corresponds to the group (the firm is made up by a population of processes together with the people), and the population of firms forms an industry that evolves over time. The three levels of evolution are described in more detail in Fig. 1.1.

2 Certain body cells also develop in a Darwinian fashion during the body’s growth, e.g., brain cells and immune system cells (Edelman and Tononi 2000).
Variety generation
- New firms (e.g., startups)
- "Mutated" firms (e.g., new business units, new business models/strategy)
- Market entry from other industries

Environment: legal and political systems, demographics, factor availability, climate, geography.

Industry Level
Population of firms

Variety generation
- Gradual change through learning
- New processes sourced externally
- Large change (e.g., business process engineering, IT changes, new technologies)

Firm Level
Population of rules and processes

Inheritance
- People
- Culture
- Brand equity
- Infrastructure

Variety generation
- Gradual change through learning
- New processes sourced externally
- Large change (e.g., business process engineering, IT changes, new technologies)

Selection
- Criteria: acceptance, performance, cost, strategy...
- Discontinuation
- Lack of usage
- Gradual change

NPD Process Level
Population of innovation opportunities ("projects")

Inheritance
- Knowledge and competences
- Systems ("legacy")
- Design principles, "culture" of process use

Selection
- Criteria: acceptance, performance, cost, strategy...
- Discontinuation
- Lack of usage
- Gradual change

Inheritance: architecture, carry over components, design principles, technologies used

Figure 1.1
Three-level evolutionary view of NPD.
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For the sake of this discussion, we take the industry’s environment as given; a discussion of how innovations change the environment over time (e.g., innovation makes some natural resources more valuable or allows market entry) is beyond the scope of this book. The three levels of evolution interact: the lower level ‘makes up’ the next higher level (e.g., the industry is the population of firms), and in turn, the structure of the higher level influences the creation, selection criteria, and inheritance of the lower level. The levels may contradict one another: what is adaptive at one level may not be adaptive for the higher level (Sober and Wilson 1999, 27). In anthropology, selfish behavior by individuals may reduce the survival chance of the group. In the NPD context, short-term profit maximization by firms may depress the growth of the industry because of the focus on ‘cash-cow’ projects. Safe innovation projects may also reduce the selective fitness of the NPD process because it has become too incremental.

At the most aggregate evolutionary cycle in Fig. 1.1, an industry, a population of interacting firms evolves as firms are created, grown, and developed or are selected out. In the context of NPD, this is relevant in two ways. First, both the environment and the structure of the industry influence the firms. The creation of new firms and the type of innovations they pursue is influenced by the regulatory and legal environment, and by the availability of capital and qualified labor. For example, the Bayh-Dole Act provided a major boost of new firm creation by allowing the commercialization of federal funded university research. The selection criteria for firm survival depend on the life cycle stage of the industry (architecture driven in the beginning, and moving toward process efficiency as the industry matures). Work in industrial organization has examined how the environment and the population itself influence the strategies and the number of firms that can survive.

Second, the individual firm chooses a strategic position and behaves in response to the industry selection criteria imposed by the industry. The firm strategy refers to the ‘battle plan’ that aims to outperform competition on the selection criteria and to endure the threatening environmental shifts.

At the intermediate level, the processes and routines that make up a firm arise and are chosen in the company in a way that is not fully conscious and ‘strategic’ (Nelson and Winter 1982). Processes are imposed by change projects or arise from the imitation of outside benchmarking examples (sometimes without a full understanding of the implications). Thus, creation is partially random. Processes are selected by their performance, which is often difficult to measure (success is stochastic, causally ambiguous, and can be assessed only in the long term), thus selection is noisy. Processes that are ‘selected out’ may be officially discontinued or fall in disuse. Processes have strong inheritance that persist over a long time – recall the example of the two men that ‘hold the horses’ next to World War I cannons long after horses had been abandoned (Morison 1966).
The lowest-level evolutionary cycle operates within the NPD process of a firm. A population of new products and process opportunities (ideas) are created through (at least partially) random idea combinations from differing areas of expertise and knowledge. The structure of the NPD process (the higher-level evolutionary system) constrains and biases the idea creation. Ideas are then selected for more resource access by explicit strategic decision-making (such as formal portfolio analysis) or by (possibly implicit) value judgments in the organization. Funded innovations are developed and elaborated in a sequence of experimental cycles, and design styles and technologies are inherited across product generations. The transformation of ideas into products, e.g. in the process of design companies such as IDEO, visibly exhibits the evolutionary steps of creativity to produce many ideas, selection (by voting), and inheritance in artifacts and through a technology database (Thomke 2003).

The multi-level evolutionary theory framework sets the stage for grouping and comparing the different theories that have studied NPD phenomena. Section 4 briefly summarizes these theories and argues that they are at least compatible with the evolutionary framework, if not explicitly consistent with it. Thus, evolutionary theory could indeed serve as an organizing logic for understanding NPD in its entirety.

4. Theories relevant to NPD research

4.1. Past overviews of NPD research

It is not surprising that a field of study as important as NPD has seen efforts to organize research into frameworks. Among the many overviews, we mention three influential framework papers: Deshmukh and Chikte (1980), Brown and Eisenhardt (1995), and Krishnan and Ulrich (2001).

Deshmukh and Chikte (1980) considered the R&D management decisions within the firm, viewing them primarily from a normative (decision theory-based) standpoint. While leaving out organizational issues, this framework was one of the first to attempt a comprehensive classification of NPD research. Figure 1.2 summarizes the ideas of the framework, which center on resource management in the product development process. Resources influence all relevant tasks and activities in R&D; therefore, two main decisions require special attention: investment in resources that specialize in different tasks, and allocation of resources across the various activities. This approach allows examining questions about the necessary capabilities that a firm should build as well as the methods and tools that enhance resource efficiency.

Brown and Eisenhardt (1995) classify NPD research depending on its methodological approach. They aggregate previous empirical results of NPD project success drivers into a framework that emphasizes a strategic management angle. This framework does not focus on normative approaches (see Fig. 1.3).
Figure 1.2
The Deshmukh and Chikte (1980) process model.
Involvement

Customer Support

Subtle control

Senior Management

Power
Vision
Management skill

Project Leader

Involvement

Team Composition

Suppliers

• Involvement

Team Organization of Work

• Cross-functional
• Gatekeepers
• Moderate tenure

• Planning & Overlapping versus iteration, testing & frequent milestones

Team Group Process

• Internal communication
• External communication

Process Performance

• Leadtime (Speed)
• Productivity

Financial Performance

• Profit
• Revenues
• Market share

Product Concept Effectiveness

• Fit with market needs
• Fit with firm competencies

Market

• Large
• Growth
• Low competition

Team Organization of Work

Team Composition

Suppliers

• Involvement

Team Group Process

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• Revenues
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Product Concept Effectiveness

• Fit with market needs
• Fit with firm competencies

Market

• Large
• Growth
• Low competition

Figure 1.3

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The main results of Brown and Eisenhardt emphasize the organizational drivers of success and revolve around the top management characteristics and the communication capabilities of the firm. Management control systems and executive power are shown to robustly impact the project success both through planning and through efficiently communicating policies, decisions, and project-specific information. At the same time, this work highlights the features of the organizational structure (e.g., gatekeepers, cross-functional project teams) that facilitate the flow of information and contribute as fundamental enablers to product development success. In this sense, Brown and Eisenhardt complement the Deshmukh and Chikte (1980) framework.

Krishnan and Ulrich (2001) combine views from different disciplines and divide the literature in two broad categories: decisions within a development project (encompassing the major steps in the development process), and decisions in setting up a development project (including strategic and organization related decisions). They recognize two large groups of success drivers and methods in the growing body of NPD literature. The two groups are distinguished by the duration of their influence – short-term within a project versus long-term across multiple projects. Within those two categories, the authors classify research in clusters to minimize interdependencies. The clustering analysis identifies three fundamental enablers in NPD decisions: product features (market and design), architecture-related issues (also encompassing organizational issues), and portfolio-selection decisions that address the strategic aspects of development. Figure 1.4 summarizes the main finding.

In summary, each of these frameworks have emphasized certain theories and phenomena within NPD but not targeted an overall view. In particular, the three frameworks identify success drivers and normatively attractive structures of NPD decision rules and processes, focusing on the innermost evolutionary cycle in Fig. 1.1. In addition, none of the three frameworks uses the fundamental steps of variety generation–selection–elaboration and inheritance to structure the many activities and phenomena. We now turn to theories from various fields, viewed in the context of evolutionary theory.

4.2. An overview of NPD theories in the evolutionary theory framework

The three levels of evolutionary dynamics represent differing levels of aggregation and address different timeframes and questions. Thus, several disciplines have examined the various questions with a wide set of theories. Few theories to date have explicitly considered the dynamic evolutionary theory of variety generation and natural selection acting upon population frequencies, mostly in the strategy field: At the industry level, Schumpeter (1942) emphasized the selection and creation of firms in an emerging process of ‘creative destruction.’ Population ecologists (Hannan and Freeman 1977) have treated
firms as organisms that evolve through Darwinian selection, and Tushman and Rosenkopf (1992) have considered an industry life cycle of random variety creation followed by incremental elaboration (consistent with a ‘punctuated equilibrium’ model of evolution). At the firm level, Nelson and Winter (1982) adopted an explicitly evolutionary approach to the way processes and routines form in organizations. At the process level, work on search and creativity has emphasized the Darwinian nature of idea creation, selection, and elaboration (Fleming 2001).

While most work has not considered evolutionary theory, many of the theories and findings are consistent with an overall evolutionary view. Figure 1.5 summarizes some key theories, which we discuss in some more detail below.

**The external environment level**

Research in political science, political economy, sociology, and economics has examined the effects of the environment at large on innovation. The extent and sophistication of innovative activities in a country are influenced by culture, climate, and geography, and by the institutional system (the governing bodies that the society has put in place, such as laws, courts, e.g., Porter 1990, O’Sullivan 2000). In particular, the protection of intellectual property rights has an influence on innovative activity, as the current debate on innovation piracy in China attests (French 2005, Zhao 2006). Policy makers also need to
**Environment:** public sector policy and legislation (e.g. IP protection), public R&D subsidies, institutionalization of university-industry collaborations, infrastructure for startups.

**Industry Level**
- Industrial organization (IO): vertical and horizontal differentiation, R&D races, attractiveness of industries, competitive, cooperative and evolutionary game theory
- Industry life cycles, network externalities, dominant design
- Population ecology of firms (e.g. small world networks)

**Firm Level**
- Technology strategy, incl. technology sourcing, first mover advantage, NPD contribution to strategy (features, cost, variants, new markets, etc.)
- Theory of the firm, firm boundaries
- Transaction cost economics
- Architecture, platforms and product variants
- Complexity theory

**NPD Process Level**
- Search and creativity theory
- Design of experiments
- Customer need identification (e.g. conjoint analysis)
- Portfolio theory (financial portfolios, mathematical programming)
- Engineering design optimization
- Organizational structure and collaboration across functions: incentive theory, complexity theory, organization theory (culture, mindsets), information processing theory, network theory
- Project management: planning, control, risk management
- New product diffusion theory

**Figure 1.5**
NPD-related theories in the multi-level evolutionary framework.
support the production of public (non-excludable) goods, such as fundamental research, which would be undersupplied by commercial entities (Gibbons and Johnston 1975; Cohen et al. 2002).

The industry level (I): Industry evolution and populations of firms

Some strategy research has explicitly used an evolutionary framework to examine populations of firms as the unit of analysis. For example, population ecology approaches have explained a substantial amount of observed phenomena with the simplifying assumption of purely Darwinian selection: firms are born with certain gene-like endowments, go through their lives without much learning (change of this endowment), and die when the endowment no longer fits the environment (e.g., Hannan and Freeman 1977, Silverberg et al. 1988).

A large amount of work has examined the industry life cycle, the emergence, growth, maturity, and decline of product categories (Henderson 1979, Porter 1980). Abernathy and Utterback (1978) introduced the concept of dominant designs and pointed out the changing nature of innovation over the life cycle. Tushman and Anderson (1986) characterized the phases of the life cycle as a stochastic search phase, an ‘era of ferment’ (consistent with Schumpeter’s (1942) ‘creative destruction’), followed by a more predictable period of incremental fine-tuning; Tushman and Rosenkopf (1992) linked the life cycle to evolutionary theory. For overviews, see also Adler (1989), and Burgelman et al. (1995).

The theory of Industrial Organization (IO) has heavily influenced the academic fields of Strategic Management, Operations, and R&D Management. The IO is concerned with ‘the study of market functioning [...] the structure and behavior of the firms (market strategy and internal organization)’ (Tirole 1988, 3): it focuses on explaining firm boundaries and firm performance in the industry context. The IO has not taken an explicit evolutionary view, focusing rather on an understanding of industry equilibria. It has identified two key contributions of NPD to industry structure as well as the individual firm’s strategic position: (i) The amount of differentiation that the NPD offering introduces, which can be vertical or horizontal and (ii) the strong association between the resource expenditure and the competitive advantage from innovations (either this is a timing advantage, see R&D races and product diffusion, or a quality-offering advantage in the event of vertically differentiated products). The relative importance of these two drivers depends on IP protection regimes, externalities, and complementary assets. In addition to IO and strategy, the marketing field has heavily contributed to these theories (Bass 1969, Mussa and Rosen 1978, Moorthy 1984).

In the terminology of our evolutionary framework, this area of work examines the structure of the entire firm population (in the industry), and the
emerging selection criteria that this structure implies for the individual firms in the population.

The industry level (II): Technology strategy and the firm as an industry actor

A second area of work still fits the industry level of Fig. 1.1 but has focus on individual firms as the unit of analysis. At this level, the question is how the firm can maximize, through its behavior, its survival given the industry population and the selection criteria. This is the classical scope of strategy and competitive advantage.

A few works have looked at the firm’s life cycle from an evolutionary angle. Different literatures have examined different stages of the firm’s life: work in entrepreneurship has examined how firms are created and how innovativeness influences their initial success chances (Bhide 2000, Shane 2000, Gompers et al. 2005). Work in technology strategy has examined what competitive position allows larger firms to remain successful, and how the competitive position can be adjusted over time through innovation (e.g., Porter 1985, Markides 1999).

The NPD strategy literature has identified four outcomes of NPD activities that are relevant for the competitive position of the firm: product features, product variety, time to market, and first mover status, and cost position (including the cost of NPD as well as the manufacturing or delivery cost as driven by design). All these outcomes are treated as different functions of the amount and type of resources (financial, human capital, and competencies) that goes into the activities as well as the effectiveness of them realizing the output (uncertainty resolution, design architecture).

The firm level

A firm is made by the sum of its competences. They are embodied in the routines (organizational processes) that perform every function within the firm. Following Nelson and Winter (1982), a routine is the combination of rules, competencies, and resources that perform a function (e.g., the engineers, the know-how, the NPD plan and its execution stages would describe the NPD routine of a firm). Routines describe ‘how things are getting done in this organization.’

Nelson and Winter examined the evolutionary character of how the organization’s competences evolve: through (at least partially) random generation of variants, and (noisy) elaboration and selection of those variants. Strategy work in general has examined routines but has emphasized how firms should consciously, in the spirit of ‘optimization’, manage those routines over time. Leonard-Barton (1992, 1995) agrees with Nelson and Winter: she defines the organizational competence as the sum of the skills, physical systems, management systems, and values — the cultural rules of the organization.
Then she examines how a firm can evolve those competences, but her work acknowledges that this process is noisy.

Other strategy scholars have taken a more normative view of internal competences, examining how they should evolve to support a competitive position (Teece et al. 1997, Zott 2002). A stream of work has argued that architectural knowledge is a core competence of the firm, and architectural innovation (that is, innovation not in the product components but in the way they fit together) can produce a sustainable competitive advantage (e.g., Clark 1985, Henderson and Clark 1990). An extreme position claims that the quality of the employees comes first and drives the choice of strategy, as excellent employees will be able to appropriately adjust the firm’s position to the environment and competition (Collins 2001). Economists have also focused on the ‘job design’ elements that drive certain employee behaviors, such as allowing exploration and risk taking (Zwiebel 1995, Roberts 2004).

**The NPD process level**

The process level has been the focus of most NPD literature in Operations Management. An ‘optimization’ view has been typical; an evolutionary view of how products are developed is quite recent (see Chapter 5 of this book).

The first stage is the emergence of innovation ideas. Organizational search and creativity involve the organizational structures and processes that lead to project initiation, through technology search and benchmarking and creative combinations of ideas. Here, creativity theories in psychology and engineering (e.g., Simonton 1999, Pahl and Beitz 1988, Sutton 2001) combine with theories of organizational creativity from strategy and sociology (e.g., Van de Ven et al. 1989), as well as technological search in complex systems (e.g., Fleming 2001, Fleming and Sorensen 2004).

The next stage is the selection of ideas. Most approaches have tried to identify ‘optimal’ choice criteria for the firm’s success. Portfolio theories exist in Finance (emphasizing the balance between risk and return), Operations Research (mathematical programming models have emphasized the highest return use of a limited resource budget) and Strategy (emphasizing the balance of different strategic priorities in the business and product mix). For a literature overview, see Kavadias and Loch (2003) and Chapter 6 in this book.

Development of innovation ideas into products happens through projects. Project management has been early on defined as a stand-alone field of study. A well-developed theory exists in Operations Research on project planning, coordination, and scheduling (a recent overview is offered in Demeulemeester and Herroelen 2002). There is a body of work on risk management, both model-based and empirical (Chapman and Ward 2003, Loch et al. 2006). Also, novel projects fundamentally involve search and iteration, which has, again, be researched empirically as well as with decision-theory models (see an overview in Thomke 2003 and Chapter 17 of this book). Related work has
examined different configurations of processes (or PM methods), depending on the uncertainty of the project’s mission (MacCormack et al. 2001, Pich et al. 2002, Sommer and Loch 2004). Relationships of project teams with their stakeholders have been explained by network theory (e.g., Burt 2000), group identity (see, e.g., Levy et al. 2001), and their boundary spanning role (Ancona and Caldwell 1992), and empirical work on socially driven escalation of commitment (e.g., Boulding et al. 1997). In addition, work in sociology and psychology has examined team management and leadership.

Another large area of work is related to the difficulty of coordinating multiple actors in the NPD process (see Chapter 12 of this book). Starting with coordination theory (Thompson 1967, Galbraith 1973), coordination has been examined through different lenses: incentive theory (Kerr 1975, Holmström and Milgrom 1991, Feltham and Xie 1994, Gibbons 2005), complexity theory in the case of many interdependencies among actors (Terwiesch et al. 2002, Mihm et al. 2003), and the study of cultural barriers to communication (Lawrence and Lorsch 1967, Weick 1993, Dougherty 1992).

Coordination is even more difficult when it must occur across firms. Two large bodies of work can be identified. (i) Some work has identified the advantage of long standing buyer–supplier relationships in overcoming transaction costs and opportunism (e.g., Dyer and Ouchi 1993, Dyer 1996, Liker et al. 1996; Baker et al. 2002). (ii) R&D alliances or formally established R&D networks allow firms to share risks and gain access to knowledge or to markets (Doz and Hamel 1997, Goyal and Moranga 2001, Bloch 2002). Recent empirical research suggests that R&D alliances increase NPD performance (Rothaermel and Deeds 2004, Hoang and Rothaermel 2005). We refer the reader to Chapters 9 and 10 of this book.

5. What can we learn from an overview of theories in NPD?

We have outlined an evolutionary view of the NPD process, including three levels of the ‘vary – select – elaborate and inherit’ cycle, and we have identified academic theories that aim to explain the dynamics and success factors of this process. In Section 4, we have tried to demonstrate that these theories, which come from many fields, can reasonably fit into an overarching framework of multi-level evolutionary dynamics. The question arises, of course, what value the evolutionary framework brings to NPD research. Below, we list just a few questions that one may be able to ask based on the multi-level evolutionary framework.

- Biologists and anthropologists have been able to understand evolutionary dynamics at multiple levels, e.g., individuals and groups, and to learn from characterizing the nature of the evolutionary forces at each level. For
example, the ‘fitness’ (performance as compared to the selection criteria in force) of groups rests on resource control as well as cultural knowledge and cooperation of its members (in resource acquisition and in mobilization against other groups). Individual fitness, in contrast, depends on capabilities (genes), learning of cultural rules and collaboration with allies. Therefore, selection has differing characteristics for individuals. Can similar characterizations of selection and competition help to better understand NPD processes and innovations?

• If not parallel model analysis, can the characterization of variant creation-selection-inheritance in different NPD levels at least identify similar problem structures and spur comparative work? For example, complexity theory, network theory, and group identity appear in multiple sub-areas of NPD at the within-firm level. Can we explore commonalities of problem structures that have not yet been exploited to gain insight?

• Multi-level evolutionary theory may help us to better understand how the levels of aggregation interact. How do decisions at a higher level become constraints at a lower level? Looking upward, how do new variants at the lower level influence the choices at the higher level? For example, how does the variant generation of opportunities upwards influence the shape of the NPD process? How do process changes influence the firm’s selection survival? Chapter 11 overviews hierarchical planning approaches, a research tradition that has been guided by an ‘optimization’ approach and is limited by exploding complexity. Does the aggregation (upward) and constraining by selection criteria (downward) view from evolutionary theory offer new ways of understanding the interactions? For example, imagine a firm level decision to temporarily emphasize short-term projects, which leads to selection criteria implemented at the project level that, in turn, make it later impossible for the organization to return to longer-term projects. Can we characterize when multi-level interactions might lead to such spirals?

• Multi-level evolutionary theory identifies across-level tradeoffs. For example, the individual wants to be selfish to maximize its own fitness, but if everyone is selfish, the group suffers, and everyone is worse off. This is parallel to team production and public good problems in economics. However, economics assumes that rational decision makers make choices, whereas evolutionary theory allows behaviors to be selected (without the individuals necessarily making choices or understanding the emerging behavior). This view may be applicable to partnerships and supplier collaborations, where interest conflicts and tradeoffs among players are fundamental. Is there anything to be gained by asking whether certain observed behaviors in alliances are not decided but emerge through selection of practices that constitute equilibria? For example, could allowing selection alongside optimal choice in models of NPD bridge the gap
between traditional OM thinking (‘optimization’) and OB thinking (‘following norms, possibly without awareness’)?

Perhaps there is indeed no ‘theory of NPD’. However, multi-level evolutionary theory can identify patterns across a wider set of phenomena, which offers the potential of additional insights. This potential has been explored only in a few research areas, and there is much work to do. The chapters of this book show how rudimentary the identification of evolutionary dynamics is in research to date. Yet, a few of them prepare the ground for evolutionary perspectives and emphasize the need for an overarching view that bridges isolated theories.

6. Outline of the book

We have already observed that the evolutionary view has influenced only a few areas of work to date. This is reflected in the chapters – most do not use the framework because it has not been used in the respective field. The evolutionary framework is explicitly represented in Chapters 2, 5 and 15, and it is reflected in the structure of the book (Fig. 1.6). We hope that the ensemble of the chapters invites researchers to identify opportunities where an application of the evolutionary framework can generate additional insights on NPD.

The focus of the book on operations issues implies that the three evolutionary levels are not equally represented. NPD from the operations viewpoint has focused on the execution of innovation, and therefore on the firm and process levels. The external environment and industry levels have been virtually absent from operations-related NPD literature. This is reflected in the structure of the book.

Chapter 2 gives a view of Technology Strategy. It touches upon literature that looks at population of firms and the evolution of an entire industry. The focus of the chapter lies on industry life cycles and on the contribution of NPD to the firm’s strategy (reflecting the focus of past research). Two related chapters summarize important aspects of technology strategy that have seen a lot of attention in NPD literature: the contribution of NPD to the firm’s competitive positioning (Chapter 3, a view from the Industrial Organization and the Marketing discipline), and the strategic structuring of product families (Chapter 4).

The rest of the book focuses on the firm level, reflecting the emphasis in the existing work. First, the firm level view encompasses the firm’s decision rules and processes. Existing work has largely taken the approach of ‘optimizing’ process structure given the strategy. Thus, the chapters themselves do not elaborate on an evolutionary framework (except Chapter 5). We see the evolutionary framework reflected in the chapter structure: idea
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generation (Chapter 5), (portfolio) selection (Chapter 6), and elaboration and execution, the latter seen in the aggregate through the organizational structure (Chapter 7). Selection appears again in the Chapter 8 in the context of performance measurement: what are the criteria according to which the NPD function as a whole is evaluated (and thus investments in NPD are justified)? Finally, two chapters explore coordination across multiple organizations at the institutionalized process level, with suppliers (Chapter 9) and partners (Chapter 10).

The aggregate firm level is linked to the process level, the execution of individual projects, through hierarchical planning, the reconciliation between operational short-term plans and longer-term goals (Chapter 11). The remaining chapters turn to the process level, or the execution of individual projects to transform an opportunity into a new product or service.

Throughout execution, or the transformation of an opportunity into a product, multiple players are involved who must coordinate and communicate to be effective (Chapter 12). Product opportunities are created (at least in products of moderate novelty) by systematic customer input (Chapter 13); a

Figure 1.6
Structure of the book.
perceived opportunity is translated into a set of activities by product specifications (Chapter 14), which determine the link between the design and the performance targets (that come from the aggregate strategy and process levels). Appropriate and stable product specifications are very important for achieving a fast time to market and capacity utilization.

At the heart of execution, the evolutionary cycle appears again in Chapter 15, which discusses design iterations. The design and development of products evolves in iterative loops. A recent version of design iterations and testing is collaborative testing with customers (Chapter 16). Using customer insight increases the information gained from tests and is becoming widely used. In addition, project execution means risk reduction, from a poorly defined task at the outset to well defined tasks at the beginning of manufacturing or service delivery. Chapter 17 summarizes methods of risk reduction.

Chapter 18 on downstream design for serviceability is concerned with the effect of NPD on the operations of product delivery. A separate chapter describes the similarities and differences of service design as compared to the design of manufactured products (Chapter 19).

This overview shows that the evolutionary framework repeatedly appears in the structure of the book; at the same time, evolutionary dynamics are mentioned in several chapters but are not yet widely used as a common theoretical guide to understand and structure observed phenomena. We believe that this represents unused potential and a major opportunity for future improvements of our understanding of NPD. Each chapter offers some future research opportunities at a ‘micro’ level. We encourage the reader to keep in mind this overarching opportunity to discover patterns of success drivers.

References


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