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The Firm as a Darwin Machine:Organizational Learning as an Evolutionary Process

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This paper examines the foundations of organizational capabilities by considering such capabilities as the result of organizational learning. The paper provides a rigorous treatment of organizational learning as an evolutionary process on the basis of the notion of 'generalized Darwinism' and its application to knowledge. This results in an explanatory framework that is subsequently applied to the work of Nelson and Winter, Penrose and Burgelman. The paper argues that organizational learning needs to be understood as an evolutionary process, and that on such understanding organizational capabilities have to be distinguished from the knowledge that underwrites them. This knowledge not only resides in the members of the organization, but also in collective organizational characteristics that are not reducible to individuals as such.

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1. Introduction

Knowledge-based, competence and capabilities-based, and dynamic capabilities views have become increasingly popular in both organizational economics and the managerial literature. What these theories share is a view of the firm as a repository of productive knowledge. But where does this knowledge come from? The answer, presumably, is that productive knowledge is the result of organizational learning. But how do organizations learn? And where does the resulting organizational knowledge reside?

Because of their respective theoretical aims, the three streams of theory development that have discussed capabilities have given limited attention to learning as the basis of capabilities. Evolutionary economics aims to explain population level phenomena (e.g. Nelson and Winter, 1982), the knowledge-based view (e.g. Kogut and Zander, 1992; Foss, 1993, 1996; Grant, 1996; Spender, 1996) aims to explain the existence of firms, and the resource-based and dynamic capabilities views of the firm (e.g. Barney, 1991; Peteraf, 1994; Teece et al., 1997) aim to explain performance differentials between them. Understanding organizational capabilities as the result of a learning process is secondary to these aims.

This paper is motivated by the idea that explicitly considering the learning process that leads to organizational capabilities can help us better understand the nature of these capabilities. However, learning processes pose a major challenge for theory construction. Simple causal explanations of the type 'X causes Y' fall short of capturing the feedback loops and multi-level dynamics that are central to learning. This problem is illustrated by the way in which theories of organizational knowledge and learning tend to be constructed. While the purpose of theories of organizational learning is indeed to explain how organizations develop knowledge, the causal structure of the theories often remains implicit.

Note that knowledge, the dependent variable of a theory of organizational learning, is a *state* of the organization, and that this state results from the *process* of learning. In other words, the explanation of knowledge does not rest on an independent variable (or a set of those variables), but rather on a process in time. This makes the explanatory structure of the theory more complicated than the typical explanation of the type 'X causes Y'.

The purpose of the paper is twofold. First, it demonstrates that Darwin's theory of evolution offers a way to deal with the theoretical complications inherent in conceptualizing learning. As the paper will show, the explanatory structure of Darwinism is especially well suited to deal with the multi-level

dynamics and feedback loops that are central to learning processes. Darwinism offers a general definition of knowledge in terms of adaptive fit that helps us disentangle cause from effect. And by specifying the generic mechanisms that explain adaptive fit, it allows us to better understand the process of learning.

The second purpose of the paper is to apply the explanatory structure of Darwinism to organizational learning by considering the firm as a Darwin machine that adapts to its environment as a result of the interplay of variation, selection and retention mechanisms. We reconsider the work of Nelson and Winter (1982) in this light, contrast it with insights from Penrose (1959), and Burgelman (1991), and ask what these different contributions tell us about where organizational knowledge resides.

PART I: LEARNING AS AN EVOLUTIONARY PROCESS

2. Generalized Darwinism

The argument that organizational learning is an evolutionary process is based on the notion of 'generalized Darwinism' (Campbell, 1960, 1965; Lewontin, 1970; Cziko, 1995; Dennett, 1995; Hull et al. 2001; Hodgson, 2002; Knudsen, 2002; Stoelhorst, 2005; Hodgson and Knudsen, forthcoming). Generalized Darwinism is the idea that the explanatory structure that is central to Darwin's theory of evolution applies to the evolution of all open, complex systems. A complex system can be defined as a system that is composed of a number of interacting elements (cf. Simon 1981). An open system can be defined as a system that requires resources from its environment to function. Firms are open, complex systems, and if we accept the claim of generalized Darwinism, it follows that their evolution can be explained in Darwinian terms.

So what, exactly, is the nature of Darwin's theory? In its most general form, a Darwinian theory of evolution involves mechanisms to introduce variations, a consistent selection process, and mechanisms for preserving and/or propagating the selected variants (Campbell, 1960, 1965; Plotkin, 1994). The claim of generalized Darwinism is that the explanatory structure of the triumvirate of 'variation', 'selection' and 'retention' holds across domains. In itself, the Darwinian logic is substrate neutral, and the specific mechanisms of variation, selection and retention can be expected to differ between systems. In general, a Darwinian theory can therefore be understood as a specification of how variation, selection and retention work for the system in question.

The idea that Darwin's theory may be applied outside biological evolution has a long history.[2] In organization studies, it has been taken up and applied to firms by scholars from a variety of disciplinary backgrounds (e.g. Hannan and Freeman, 1977; Aldrich, 1979, 1999; Weick, 1979; Nelson and Winter, 1982; Burgelman, 1991; Baum and Singh, 1994; Barnett and Burgelman, 1996). Most of these applications either use Darwinism as a metaphor for the competition between firms, or take inspiration from analogies to biological evolution to elucidate how firms change over time. But generalized Darwinism is *not* based on biological metaphors or analogies, but on the claim that on a sufficiently general level of abstraction all evolutionary processes are ontologically similar (cf. Hodgson, 2002; Hodgson and Knudsen forthcoming). In the words of Plotkin: '*The actual mechanisms in each case*, of course – and one cannot repeat this point often enough – *are entirely different*' (1994, p.100, emphasis in original). But the explanatory structure provided by Darwin is universal and holds *regardless* of the nature of variation or the mechanisms for retaining favorable variations.

As Dennett (1995) has pointed out, a Darwinian explanation is in essence an algorithmic explanation: if there is a consistent selection process, and if there are mechanisms for introducing variations and retaining the favorable ones, evolution *will* occur. What has received much less attention in the applications of Darwinism in economics and organization theory is what the phrase 'evolution will occur' means. Its most basic interpretation is simply that the system in question changes over time, and this is the way in which the term is typically used by economists and management scholars. But Darwin's theory does more than explain how change can come about. It explains *adaptive fit*, or why systems are so remarkably well adapted to the environments in which they function. It is this feature of Darwin's theory that makes it relevant to understanding organizational learning.

3. Learning as a Darwinian Process

Given bounded rationality, the variation-selection-retention logic of generalized Darwinism is the only logically consistent and complete explanation to account for adaptive fit. Adaptive fit is the state that allows an open, complex system to extract the resources necessary for survival from its environment, and may involve any number of adaptations to that environment. Adaptations are simply features of the system that allow it to function successfully. Adaptations come about through the interplay of

[2] It starts with Darwin himself, who applied it to the evolution of language, and includes Social Darwinism, the movement that has brought it into disrepute, and more recently, Sociobiology, Evolutionary Psychology, and Memetics. For a balanced review of these different strands of evolutionary theorizing see Laland and Brown (2002).

mechanisms to introduce variation in the ways a system interacts with its environment, a consistent selection process, and mechanisms to retain those variations that work. The effect of the combination of the three Darwinian mechanisms will be that the system in question is a quite literal sense informed by its environment (Plotkin, 1994).

Adaptations can thus be understood as beneficial features of a system shaped by interaction with the environment. Two features of adaptations are important. The first is their goal-directed nature. Every adaptation is 'for' something. The second is their relational quality. Every adaptation is some form of organization of the system relative to some feature of environmental order. Adaptations simply cannot be seen in isolation from the environmental factors that have provided the selection pressures for them. Plotkin (1994) convincingly argues that given these two characteristics adaptations and knowledge are essentially the same thing. '[A]ll adaptations are instances of knowledge, and human knowledge [as commonly understood] is a special kind of adaptation' (p.117). The goal-directed property of adaptations can only result if adaptations are 'in-formed' by features of the world; 'they are highly directed kinds of organization, and not random, transient structures that may or may not work. Adaptations do work, and they work precisely because of this 'in-forming' relationship between organismic organization and some aspect of the order of the world' (p.118).

The insight that adaptations are knowledge, and vice versa, is crucial for the argument that learning as an evolutionary process. If learning is the process that leads to knowledge and evolution the process that leads to adaptations, then equating knowledge and adaptations means that learning is an evolutionary process.

Plotkin (1994) uses the concept of a 'Darwin machine' to underscore the point that learning is an evolutionary process.[3] A Darwin machine is any system whose transformation over time through successive adaptive states is explained by a process of variation, selection and retention. Populations of entities without any capacity for individual learning can function as a Darwin machine, as long as selective pressure from the environment affects the differential propagation of these entities over time. This is how natural selection in biology works on populations. Variations in the genotype of the population lead to differences in the phenotypes that constitute the population, and the genetic information of the phenotypes that do not reproduce is lost, while the genetic information of those phenotypes that do successfully reproduce is retained. In other words, natural selection causes differential reproduction and thus provides the necessary feedback loop to make the Darwinian algorithm work. Note that in the case of biological evolution, genetic mechanisms are the source of both retention and variation, in the sense that the stability of the genotype in space and time requires replication of the DNA in which the genetic information is encoded, while small copying errors during replication are the source of the necessary variation. However, the specific way in which information on what works is retained in biological evolution is an artifact of the simple fact that individual organisms have a finite lifetime, so that the information needs to be passed on to a next generation to retain it through space and time. There is no logical imperative that other open, complex systems should make use of similar mechanisms, and it is not just possible, but indeed likely, that their evolution involves separate mechanisms for variation and retention.

There are in fact, a number of other systems that can be understood as Darwin machines and that have been described as such. These include the immune system, the brain, and the scientific enterprise (Plotkin 1994; Cziko 1995; Dennett 1995). What is particularly relevant for the adaptation-selection debate is that over the years, many authors that have studied individual learning in its various guises, from operant conditioning of pigeons to the fully conscious thought involved in science, have taken to modeling it as a Darwinian process (e.g. Skinner 1981; Campbell 1974; Popper 1972). In each case, of course, the specific mechanisms of variation, selection and retention are different, but the general Darwinian logic still applies.

The tenets of generalized Darwinism suggest that if different types of individual learning can be understood as a Darwinian process, we may follow a similar route when modeling organizational learning. After all, organizations, like organisms, are open complex systems that depend on scarce resources from the environment for their survival. Modeling organizational learning as a Darwinian process that leads to behavioral adaptations would ground theories of organizational learning in a proven logic and solve the problem of tautology that plagues definitions of knowledge in terms of the

[3] The term Darwin machine is originally from William H. Calvin.

learning process from which it results. But before we undertake this task, we need to further clarify the nature of this logic.

4. The Explanatory Structure of Darwinism

The notion of adaptation (note that we are here referring to the noun, not the verb), is closely linked to functional explanation, which has had its share of criticism because it can easily lead to evolutionary 'just-so' stories that reek of Panglossian pan-adaptationism where 'everything is for the best in the best of all possible worlds'. A normal scientific explanation would explain a phenomenon in terms of its cause, whereas a functional explanation explains the features of a system (say, the wings of a bird) in terms of its function (flight). Vromen (1995, p.90-91) discusses the classic objection to functional explanations of the existence of a feature, which hinges on the recognition that functions are not causes but effects. A functional explanation therefore seems to reverse the logic of cause and effect: flight does not cause wings; it is having wings that makes flight possible. The problem is that wings are a sufficient, but not necessary condition for flight: there may well be functional equivalents that could have provided the same function.

Elster (1979, 1983) recognizes this problem and argues that functional explanations can only explain the persistence, and not the existence, of features. Moreover, they can only do so if a feedback loop is specified that links the beneficial effect of having a feature to its prolonged existence. In biology, natural selection provides this feedback loop. It restores the logic of cause and effect by specifying how natural selection trims the set of available body plans to those that work best in the given environment. Note that this does not imply optimality, and that only the combination of natural selection with a source of variation and retention can fully explain how adaptive fit comes about over time. Without a mechanism to replenish the set of body plans in a way that provides the necessary variation for selection to act upon, adaptations would not result.

We have so far established that both theories of environmental selection and organizational adaptation purport to explain adaptive fit, and have argued that the logic of generalized Darwinism is the only logically consistent and complete explanation to account for adaptive fit. Adaptive fit is the state that allows an open, complex system to extract the resources necessary for survival from its environment, and may involve any number of adaptations to that environment. Adaptations are simply features of the system that allow it to function successfully. Adaptations come about through the interplay of mechanisms to introduce variation in the ways a system interacts with its environment, a consistent selection process, and mechanisms to retain those variations that work.

Let us now try to further unravel this logic. We are dealing here with a functional explanation that accounts for the state of a system in relation to its environment in terms of the algorithmic process that has led to this state. There are three necessary conditions for a functional explanation. A behavioral pattern X is explained by its function Y for system Z if and only if: [4]

(1) Y is an effect of X;
(2) Y is beneficial for Z;
(3) Y maintains X by a causal feedback loop passing through Z.

The third condition needs further clarification and brings us to the distinction between genotype and phenotype. In biology the phenotype is the combination of the organism's morphology and behavioral repertoire that determines the way in which it interacts with its environment. The organism's phenotype is derived from the genotype, the genetic information that codes for the way in which the phenotype develops. The genotype both enables and constrains the organism's interaction with its environment. The distinction between genotype and phenotype is essential to the way in which the Darwinian algorithm works. Over time, there needs to be a causal feedback loop from the phenotype to the genotype. In biology, this causal feedback loop is provided by differences in reproductive success. The fact that some organisms are more successful in propagating their genes will change the composition of the genotype from one generation to the next.

The distinction between genotype and phenotype is a fundamental part of a Darwinian explanation. For the Darwinian algorithm to work, there must be way to retain information about what has worked in the past, and this information must underwrite the way in which a system interacts with its environment. It follows that we need to understand open, complex systems in terms of the way they interact with their environment, or their *behavior*, and in terms of what 'codes' for that behavior, or their *codex*.[5] This codex can be understood as the accumulated information about what has worked in the past. The notion of 'Y maintains X by a causal feedback loop passing through Z' can thus be

[4] These conditions are derived from Elster (1979, p.28), who derives five conditions for a functional explanation in the social sciences. His formulation is as follows. An institution or behavioral pattern X is explained by its function Y for group Z if and only if: (1) Y is an effect of X; (2) Y is beneficial for Z; (3) Y is unintended by the actors producing X; (4) Y (or at least the causal relationship between X and Y) is unrecognized by the actors in Z; (5) Y maintains X by a causal feedback loop passing through Z. However, given the premise of generalized Darwinism, conditions 3 and 4 are superfluous. The Darwinian algorithm also works when intentionality is involved.

[5] We adopt this term from Wilkins (2001).

generalized to: the relative success of different behaviors in the interaction with the environment changes the codex of the system so that the likelihood that the system displays successful behaviors increases.

The idea of a codex that underlies a system's behavior brings us to a final point about the causal logic of Darwinism that goes back to Ernst Mayr's (1961) classic paper on the concept of causation in biology. If Darwinism is about explaining adaptive fit, and if adaptive fit is about behavior that allows a system to function in its environment, then Darwinism is about explaining behavior. But there are two types of explanation of behavior in biology, which Mayr termed 'proximate' and 'ultimate'. A proximate explanation would explain an animal's behavior in terms of how the behavior occurs. Such explanations are typically cast in terms of the environmental cues that trigger a certain behavior. For instance, migratory species of birds may begin their migration because the length of daylight in a twenty-four-hour period drops below a certain value. Such explanations should be distinguished from ones that are cast in ultimate causes of behavior. Ultimate explanations are not about *how* an animal's behavior comes about, but about *why* it does. Ultimate explanations assess the adaptive value of behaviors and establish why a certain behavior may have evolved. In the case of migrating birds, their behavior may be the result of a long history of selection caused by a decline in the insect population during the autumn and winter months, which may have made migration to warmer climates with more numerous insect populations an adaptive reponse. In biology, ultimate causes concern the *encoding* of information into the genotype, whereas proximate causes deal with how *decoding* that information results in phenotypes with specific structural and functional features.

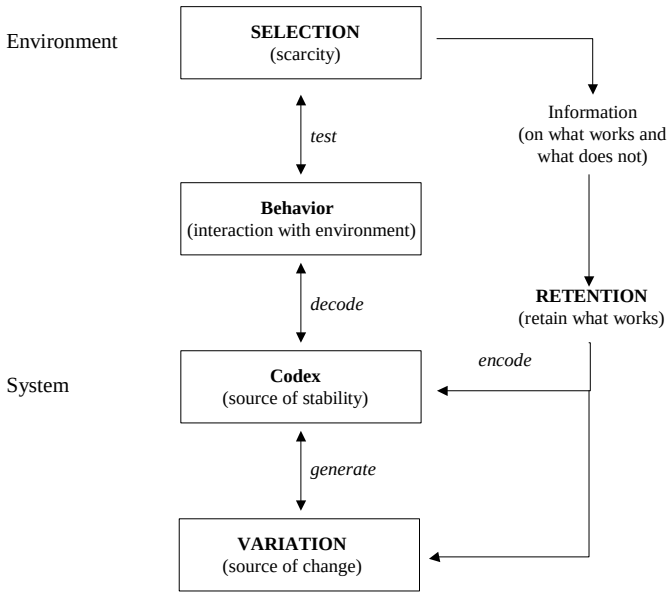

Figure 1: A Generalized Darwinian Framework

We now have all the necessary building blocks to generalize the Darwinian logic. These building blocks are (1) the Darwinian algorithm consisting of the interplay between variation-selection-retention mechanisms; (2) the genotype/codex – phenotype/behavior distinction; (3) the three necessary conditions for a functional explanation, central to which is the feedback loop; (4) the distinction between proximate and ultimate causes of a system's behavior and their relationship to encoding and decoding knowledge. Figure 1 shows how these building blocks combine to explain how open, complex systems become adapted to their environment.

The logic of the figure is as follows. Open, complex systems consist of different components and need resources from their environment to function. To secure the necessary resources an open system needs to interact with its environment. This interaction is what we call behavior, the act of doing something to have an effect upon the outside world (cf. Plotkin 1994, p.104). The system is subjected to selection pressure to the extent that the resources it requires to survive are scarce. Information on the ways of interacting with the environment that work and don't work is fed back into the system and accumulated in its codex. Decoding this accumulated information makes it more likely that behaviors that were successful in the past are repeated in future interactions with the environment. The codex of a system is a necessary source of stability in the evolutionary process. Complex systems consist of interacting components and necessarily involve information that specifies the components of the system and a design that specifies the way they interact. Random changes in these specifications are

more likely to negatively affect the functional integrity of the system than to improve its performance. Yet in the long run, there needs to be a way for the system to vary its behavior if it is to be able to adapt to changing environmental conditions. Such variation can only result from changes in the system's codex, either by changing the components that make up the system, or by changing the way they interact.

To summarize, we have argued (1) that knowledge and adaptive fit are one and the same concept, (2) that generalized Darwinism offers a rigorous theory to explain adaptive fit, and, by extension, knowledge, and (3) that learning can therefore be understood as a Darwinian process. Darwin machines learn as a result of the interplay of variation, selection and retention mechanisms. This interplay establishes a feedback loop by which information about which behavioral interactions with the environment work is encoded in the system so that cues that trigger future interactions are more likely to result in functional behavior. The second half of the paper will apply this explanatory framework to explore the nature of organizational capabilities.

PART II: THE FIRM AS A DARWIN MACHINE

Two questions were posed in the introduction of this paper: how do organizations learn and where does the resulting organizational knowledge reside? On the basis of the discussion in the first part of the paper, we can now answer these questions, albeit it in very general terms. Organizations learn as the result of the interaction of variation, selection and retention mechanisms, and organizational knowledge resides in the codex of the organization. To consider the firm as a Darwin machine, the task we face is to detail the nature of the mechanisms of variation, selection and retention that shape the firm's evolution, as well as the nature of the codex that provides for stability in the firm's interaction with the environment over time.

This is not unlike the task that Nelson and Winter set themselves in '*An Evolutionary Theory of Economic Growth*', and this will therefore serve as the natural starting point of an attempt to consider the firm as a Darwin machine. However, as will become clear below, when considered in light of the Darwinian framework discussed above, there are a number of ambiguities in Nelson and Winter's treatment of organizational change. Additional insights in organizational learning and the codex of the firm can be derived from a number of other sources whose perspective on organizational change is different from that of Nelson and Winter, yet compatible with the notion of the firm as a Darwin machine. We will consider the work of Penrose (1959) on the growth of the firm, and Burgelman

(1991) on internal corporate venturing. For each of the theories discussed we ask the following questions: What does the theory suggest about the mechanisms of variation, selection and retention that drive organizational change and adaptation? And what does the theory suggest about the nature of the codex of the firm, in other words the elements that make up the firm and the way in which these elements interact to enable functional behavior?

5. Nelson and Winter: Genes, routines, and organizational memory

When discussing the way in which Nelson and Winter's work helps us understand the process of organizational learning we should first of all note that it was not developed for this particular purpose. Nelson and Winter set out to develop a theory of economic change that is first and foremost concerned with explaining phenomena at the level of industries. Yet, one of their important achievements was that they grounded their theory in a rich discussion of the inner workings of the firm, and another that they framed this discussion in explicitly Darwinian terms.[6] We may therefore expect their work to also be able to shed some light on the questions that concern us here.

Given that they explicitly use this terminology, let us first consider what Nelson and Winter say about the mechanisms of variation, selection and retention that shape organizational change. The central concept in Nelson and Winter's work is that of an organizational routine. Routine is their 'general term for all regular and predictable behavioral patterns of firms' (p. 14), and it is this regular, predictable and recurrent behavior that is the centerpiece of an evolutionary logic in which 'routines play the role that genes play in biological evolution' (p.14). In other words, routines provide the necessary stability in behavior over time that is required for the Darwinian algorithm to work. More specifically, it is by exercising routines that an organization retains its productive knowledge. In addition, of course, there needs to be a consistent selection pressure and a source of variation. The first is provided by the scarcity of resources for which firms compete in the market, and the second by higher level 'search' routines by which firms look for ways to modify their lower level routines, or operating characteristics.

How does this view of the firm map unto the Darwinian logic discussed above? Unfortunately, this is not at all clear. As has been pointed out elsewhere, there are some ambiguities in Nelson and Winter's treatment of routines (Hodgson 2002; Becker 2005). If routines were the analogue to genes, we would

[6] This is despite calling their theory Lamarckian. For a convincing discussion of why Nelson and Winter's work can be appropriately viewed as Darwinian see Hodgson (2002).

expect them to be what codes for functional behavior and not to be defined in terms of the behavior itself, as Nelson and Winter do. The notion of 'routines as genes' would mean that we are talking about the firm's codex, yet the definition of routines as recurrent patterns of behavior immediately shifts our focus to what is actually selected by the market. In other words, the notion of organizational routines conflates the codex and behavior of the firm. What we are left with is a view of the firm as a set of recurrent action patterns that are subject to selection by the market. What the source of variation in these patterns is, or how they are retained through time is not entirely clear.

Whereas it is easy to distill the three Darwinian mechanisms from Nelson and Winter's work, it is not immediately clear how we can derive insights about the codex of the firm from their work. To better understand the nature of the codex we need to specify both the sources of variety and the sources of stability in the behavior of firms. Merely using the notion of routine as shorthand for the claim that there is such stability over time will not do. Rather, we have to unearth the actual mechanisms that give rise to recurrent action patterns (Becker, 2005). Nor does invoking higher-level routines as a source of change in lower level routines help much in understanding the source of variety in the behavior of firms. This is a way of hiding individual behavior and initiative in the folds of an infinite regress of ever-higher levels of routines. This way of treating the sources of variety is ironic for a theory that professes to be 'unabashedly Lamarckian', because it does away with the need to incorporate intentional behavior in an explanation of how firms learn. In fact, as the nature of their formal models shows, the resulting explanatory logic works equally well with an entirely stochastic generation of variety. By modeling the codex of the firm in terms of a hierarchy of routines and by thus putting all the explanatory power of the theory in the collective phenomenon of routines, the role of individual behavior in shaping the actual behavior of firms is lost.

The fact that Nelson and Winter conflate codex and behavior and view the codex of the firm in terms of a hierarchy of routines is best understood in light of their goal to construct quantitative models of industry-level phenomena. The problematic notion of routines in fact hides a much more subtle discussion of the internal workings of the firm that can give us some more detailed pointers to the mechanisms that may account for the simultaneous stability and change in the behavior of firms. In their discussion of 'routine as organizational memory' they discuss individual members of the organization as the locus of much of the information that is required for the performance of organizational routines, but emphasize that organizational memory is not reducible to the memories of individuals. This would 'overlook, or undervalue, the linking of those individual memories by shared experiences in the past, experiences that have established the extremely detailed and specific communication system that underlies routine performance' (p. 105).

This would seem to establish two points. First, individual behavior does matter in understanding the routines of firms. Second, individual behavior can become part of a recurrent pattern of coordinated behavior by responding to an 'extremely detailed and specific communication system'. It would seem that it is this communication system that we need to unravel to really understand the nature of the codex that provides the stability in coordinated behavior. This idea is reinforced by Nelson and Winter's remark that to establish a new routine where non existed before, 'organization members have to learn the system of coordinating messages. They may have to add new skills to their individual repertories, and they need to achieve a first reconciliation of their expectations regarding the distribution of costs and benefits in the new situation' (p.112).

The comment about a reconciliation of expectations relates to their discussion of 'routine as truce'. Again we see an explicit consideration of how individual behavior becomes part of a coordinated action pattern. Whereas the 'routine as organizational memory' considers the cognitive aspect of how individuals behave (do they know what to do, and how to do it), the 'routine as truce' considers the motivational aspect (do they actually choose to do what is required of them in the routine operation of the organization as a whole). Nelson and Winter emphasize that 'routine operation should not be confused with performance according to the nominal standards of the organization' (p.108). 'The usual mechanisms of internal control are, of course, a part of the context that helps define the *de facto* contracts that individual members make with the organization' (p.108-9). But '[w]hat signals the existence of an accommodation is not the conformity of behavior to standards of performance laid down by supervisors or codified in job descriptions, but that members are rarely surprised at each other's behavior …' (p.108). 'In routine operation, the combined effect of the rule-enforcement mechanism and other motivators is such as to leave the members content to play their roles in the organizational routine – but content only in the sense that they are willing to continue to perform up to their usual standard …In short, routine operation involves a comprehensive truce in intra-organizational conflict' (p.110).

We may conclude that Nelson and Winter's idea of routines as the building blocks of organizational capabilities is problematic, because both routines and capabilities are defined in terms of behavior, and not in terms of the knowledge that underlies and enables that behavior. The idea of a hierarchy of routines, while useful as a modeling tool, does not help us to unravel where organizational knowledge is stored so that functional behavior can be reliably repeated over time. The notion of routines as the genes of organizations as such does not tell us anything about how individual behaviors can become part of coordinated behavior patterns. However, the discussions of 'routine as organizational memory'

and 'routine as truce' begin to convey a picture of individuals adapting to a complex intraorganizational environment consisting of a 'system of coordinating messages' (p.112), an 'organizational dialect' (p.104), and 'a peculiar symbolic culture' (p.111). Moreover, routines can also take on the quality of norm or target, and be 'imposed on a continually changing set of resources' (p.113). Such ideas can be found in more developed form in the work of Penrose and Burgelman.

6. Penrose: Resources, productive services and the administrative framework

There is an obvious irony in discussing the work of Penrose (1959) in Darwinian terms, because she wrote a seminal critique of the invocation of biological analogies in economics (Penrose, 1952). But our discussion of generalized Darwinism has given us two reasons to proceed along these lines. First, Penrose's main objection to the use of evolutionary analogies, that intentional behavior cannot be readily accommodated in an evolutionary framework, can now be seen as misconstrued. Second, the generalized notion of a Darwin machine makes developmental processes amenable to an evolutionary analysis. Since '*The Theory of the Growth of the Firm*' is arguably the seminal statement of organizational change in developmental terms, this makes it interesting to see how it maps unto the Darwinian logic.

Although Penrose repeats her criticism of biological analogies in the introductory chapter on the growth of the firm, she does use evolutionary terminology metaphorically. The term growth is used to denote 'an increase in size or an improvement in quality as a result of a process of development, akin to natural biological processes in which an interacting series of internal changes leads to increases in size accompanied by changes in the characteristics of the growing object' (p. 1). And 'growth is essentially an evolutionary process and based on the cumulative growth of knowledge, in the context of a purposive firm' (p. xiii). It is this qualitative change that is her interest, and the size of the firm is seen as 'but a by-product of the process of growth' (p.2). Her theory explains the direction of expansion of the firm as driven by its 'inherited resources' (p.5) and its perception of productive opportunities, and the rate of expansion as limited by its capacity of experienced managerial resources.

As we may expect given her criticism of biological analogy, Penrose does not explicitly develop her theory of the growth of the firm in terms of variation, selection and retention. She is, however, quite explicit about the elements of the firm that are central to her analysis of how firms change: firms are seen as a collection of resources governed by an administrative framework. With this definition, her view of the codex of the firm is immediately clear: the specific resources in the firm's possession and

the way in which they are administered provide stability to the firm's activities. However, the resources are also the source of variety in the firm's activities over time. This is because each resource can provide a variety of productive services. Whenever there is excess capacity of resources and the firm perceives a productive opportunity, it will expand its activities. The resources of the firm thus both enable and constrain its growth.

Resources come in two forms: they include the employees of the organization as well as any other productive resources. Managerial resources are central to the argument: there needs to be an excess capacity of experienced managerial resources for firms to pursue new productive opportunities. The specific productive opportunities that are in fact pursued depend on the way managers perceive the competitive environment. 'The environment is treated, in the first instance, as an 'image' in the entrepreneur's mind of the possibilities and restrictions with which he is confronted' (p.5). This results in a quite voluntaristic argument. '[T]he environment is not something 'out there, fixed and immutable, but can itself be manipulated by the firm to serve its own purposes' (p.xiii). It is therefore not demand that limits the growth of firms, but the internal developmental process: 'a firm's rate of growth is limited by the growth of knowledge within it, but a firm's size by the extent to which administrative effectiveness can continue to reach its expanding boundaries' (p. xvii).

Penrose's theory offers us a markedly different view of organizational change than Nelson and Winter in number of ways. First, whereas Nelson and Winter take their starting point in routines, or what firms *do*, the point of departure in Penrose's analysis is resources, or what firms *have*. Second, whereas Nelson and Winter subsume individual behavior in their notion of collective routines, Penrose explicitly sees managerial experience and perception as the drivers of organizational change. Third, whereas Nelson and Winter's firms are single product firms, Penrose's firms are explicitly multi-product. Fourth, while Nelson and Winter are very much concerned with how external market pressures mold the firm, Penrose is primarily concerned with how managers determine the size and shape of the firm from within. These differences lead to a view of organizational change that nicely complements that of Nelson and Winter by focusing on the resources underlying the activities of the firm and by giving more explicit attention to the role of individual perception and action in shaping organizational change.

Restated in Darwinian terms the firm's resources serve as the source of stability in its activities, their differing productive services as a source of variety, and managerial perceptions of the environment as the source of selection. However, what the Penrosian theoretical structure is missing to qualify as a fully developed Darwinian account of learning is the feedback loop by which information on what

works and what doesn't work is fed back into the firm. This is already clear in the introductory chapter, where she addresses the 'alleged tautological problem which some have feared is inherent in a theory of the growth of firms concerned only with firms that can successfully grow' (p.7). What follows is a not entirely convincing argument in which she states that here concern is merely to answer the question: 'assuming that some firms can grow, what principles will then govern their growth, and how fast and how long can they grow?' (p.7). The rest of the book, of course, develops an admirable answer to this question. But the argument would have certainly gained in strength if it had also incorporated the population level logic of Nelson and Winter and included a more explicit analysis of the effects of competition between firms on their relative success. In the Penrosian view, the experienced manager almost takes the form of an omniscient designer. It is his 'image' of the productive opportunities in the environment that matters 'for it is, after all, such an 'image' which in fact determines a man's behavior; whether experience confirms expectations is another story.' (p.5). However, a Darwinian account means also telling that other story.

7. Burgelman: Strategic initiatives and the internal selection environment

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Burgelman is a management scholar who has used Darwinian terminology to address how organizations change (Burgelman 1983, 1991; Barnett and Burgelman, 1996). Because his analyses are explicitly framed in terms of variation, selection and retention mechanisms, it is relatively easy to map his work unto the Darwinian logic. The source of variation in firms comes from strategic initiatives taken by the firm's employees. These initiatives are selected in the internal selection environment of the firm, and those that are successful are retained in the firm's official strategy.

Burgelman distinguishes two types of initiatives that may play a role in shaping the activities of firms: there are initiatives that are induced by the official strategy of the firm, and there are so-called autonomous initiatives that fall outside the official strategy. The organization is seen as 'an ecology of strategic initiatives which emerge in patterned ways, and compete for limited resources so as to increase their relative importance' (1991, p. 240). 'Structural and strategic contexts, together, constitute selection processes operating on strategic initiatives' (1991, p. 250). Strategic initiatives that succeed in attracting limited resources like investment funds and managerial attention shape organizational change. Successful initiatives are retained by incorporation in the official strategy of the organization that articulates the character, goals and domains of the organization.

This view has a number of implications for our understanding of the nature of variation, selection and retention, and the nature of the codex of the firm. Most importantly, in addition to being subject to

selection pressures from the market, the firm can itself be seen as a selection environment in which individuals compete for career advancement on the basis of strategic initiatives. Selection can thus be seen to simultaneously operate on two levels: within the firm, and on the firm as a whole. The central question is 'how internal selection may combine with external selection to explain organizational change and survival' (1991, p. 239). 'The effectiveness of internal selection processes may depend on how closely they correspond to the selection pressures exerted by the current external environment, while simultaneously allowing new environments to be sought out' (1991, p. 250).

Like Penrose, Burgelman is primarily concerned with detailing how processes internal to the firm cause organizational change. However, in light of the Darwinian framework, there are three important contributions in Burgelman's work. First, there is the recognition that in addition to the available resources, the details and outcome of the strategy process are important determinants of the specific activities undertaken by firms. Second, the account of the inner workings of the firm is explicitly framed in selectionist terms. Whereas Penrose seems to sidestep the inherent conflicts of interest that accompany the choice between the different productive services that resources can render, these are central to the view of the firm as an internal selection environment. Third, Burgelman explicitly considers how internal selection may combine with external selection to explain organizational change and survival. Like Penrose, Burgelman's view of the firm is somewhat voluntaristic. Firms can seek out new environments, and adapt their strategies to changing market pressures. However, such successful reorientations are likely to have been preceded by internal experimentation and selection processes. Organizations that create enough slack in their strategy process to allow for autonomous initiatives and hence stimulate variety are more likely to successfully adapt to changing selection pressures from the market.

The main strength of Burgelman's perspective is that it is explicitly multi-level and thus establishes a link between Nelson and Winter's concern with selection by the market with Penrose's concern for internal developmental processes. The necessary feedback loop is provided by the strategy processes in which the relative success of the firms activities is fed back into the firm's strategy 'based, at least in part, on retrospective sense making and attempts to capture top management's learning about the basis for the organization's success' (1991, p. 243).

The main weakness of Burgelman's perspective is that its focus on strategy and strategic initiatives puts the explanatory burden exclusively on cognition and decision-making, or on what firms *want* to do, and abstracts from the activities that are actually performed. This is most obvious in his view of the firm as an ecology of strategic initiatives. What is missing from this view is a detailed analysis of

the actual capabilities on the basis of which firms compete and of the productive knowledge that underlies them.

	Variation	Selection	Retention
Nelson & Winter	Routinized Search	Competition in the market	Exercising routines
Penrose	Productive services	Image of productive opportunities	Resources
Burgelman	Strategic initiatives	Internal selection environment	Strategy

Table 1

	Elements of the codex	Interaction of the elements	Feedback loop
Nelson & Winter	Routines	?	Profitability of activities
Penrose	Resources	Administrative framework	?
Burgelman	Strategic initiatives	?	Strategy process

Table 2

Tables 1 and 2 summarize the review of the three theories in light of the Darwinian framework.

8. Discussion

The first part of this paper made use of generalized Darwinism to better understand the nature of knowledge and learning. A rigorous treatment of learning as an evolutionary process shows that we need to distinguish knowledge from behavior. Knowledge is what enables functional behavior. For such knowledge to develop, there needs to be a source of variation in behavior, and there needs to be a feedback loop to what codes for that behavior. This feedback loop needs to have the effect that it increases the likelihood that behaviors that worked in the past are repeated in future interactions with the environment. Barring an omniscient designer, a source of variation, a selection mechanism, and a way to retain what works are both necessary and sufficient conditions for learning to occur.

The relevance of this general framework for understanding organizational capabilities is that it both helps specify what organizational capabilities are and where they come from. The notion of organizational capabilities has been widely used in theories that view the firm as a repository of productive knowledge, but that have typically not been much concerned with where this knowledge comes from. If we want to do more than merely postulate the existence of organizational capabilities, we need to understand them as the result of a learning process. And to do this in a rigorous way, we need the Darwinian framework.

The Darwinian framework suggests that to understand organizational learning as the source of organizational capabilities we should disentangle these capabilities from the knowledge underlying them. Organizational capabilities are functional behaviors, and organizational knowledge is what enables those behaviors. This knowledge results from an evolutionary process, in which information about the functionality of different behaviors is fed back into the system in such a way that behaviors that work are retained. The essential task in understanding organizational capabilities, then, is to understand how organizations are able to achieve this selective retention of functional behavior. Where in the organization does the information about what works reside?

The general term for where knowledge resides in the Darwinian framework is the codex of a system. The codex can be understood as the specification of the elements of the system and the way in which they interact to produce functional behavior. The codex is what both enables and constrains the behaviors of the firm. The second part of the paper has considered three theories that offer a number of clues about the nature of the codex of a firm.

Penrose provides a baseline specification of the constituents of the firm and the way they interact. Firms are a collection of resources and these resources are 'bound together' in an administrative framework. Resources come in two forms: they include the individual members of the organization and the (im)material assets that are owned by the firm. These resources both enable and constrain the behavior that the firm is capable of. The administrative framework governs how they interact to produce that behavior.

What is not immediately clear from the Penrosian framework is how firms are able to adapt to their environments and develop functional behaviors. To qualify as a theory of organizational learning, the theory of the growth of the firm lacks an explicit feedback loop. This feedback loop is clearly specified in the work of Nelson and Winter with its emphasis on selection by the market. In their formal models, the relative profitability of the activities of the firm determines the expansion or contraction of the firm's activities. However, by simply postulating the existence of operational routines and search heuristics to modify them, these models sidestep how this is achieved.

To better understand how information about what works becomes encoded in the firm, we need to look beyond the mere notion of routinized behaviors as the building blocks of organizational capabilities. This is in the spirit of Nelson and Winter's appreciative theorizing in part II of their book, which offers some pointers to the mechanisms that allow firms to retain behaviors that work. However, to qualify as a theory of organizational learning, their evolutionary theory of economic change lacks the multi-layered structure needed to distinguish behaviors from the knowledge that enables them. This is most obvious in the way in which they subsume individual behaviors in the notion of organizational routines.

Both Penrose and Burgelman do accord the behavior of individuals the attention it requires. In so doing they are able to specify more clearly what the sources of variation in the collective behavior of the firm are. Ultimately, the behaviors of individuals, and only these behaviors, are the sources of variation. While the resources of the firm can indeed provide a variety of productive services, it is the employees of the firm that decide how to deploy them. In the Penrosian view, this is rather simply determined by the perception of productive opportunities by the firm's management. In Burgelman's view, this is determined in a much more elaborate and subtle strategy process in which members of the organization take strategic initiatives that compete for managerial attention and resources in the internal selection environment of the firm.

What are the implications of these views for modeling the firm in terms of the Darwinian framework? It would seem that we need to combine three views of the firm, which all have equal currency in addressing important aspects of organizational learning as a source of organizational capability. The first view is of the firm as a social entity. In this view, the firm is seen as a collection of individuals, whose behaviors underlie the way in which the firm interacts with its environment. From this point of view, we need to understand how individual behaviors are coordinated into the functional and recurrent collective action patterns that we call organizational capabilities. The second view of the firm is an economic entity. In this view of the firm, the firm is seen as an entity that competes with other entities for scarce resources, and whose success (or lack thereof) in this competition determines its survival and growth. From this point of view, we need to understand how information from the market is fed back into the system so that competitive behaviors that work can be retained. What connects these two views of the firm is the concept of the codex. In the view of the firm as a social entity, the codex is a source of selection pressure. It is the internal selection environment to which individuals adapt their behavior. In the view of the firm as an economic entity, the codex is a source of functional behavior. It is where organizational knowledge resides. The third view of the firm is as a managed entity. In this view of the firm, the codex is seen as a target of intervention that can be manipulated to change the firm's routines and hence improve or expand its capabilities.

Given these three views of the firm and the various roles of the codex in them, what do the theories discussed above suggest about the nature of the codex? What are the constituent elements of firms and what determines how they interact? The essential constituent elements are two types of resources: the individual members of the organization and the material and immaterial assets that it owns. Both types of resources can provide a variety of productive services. The productive services that the individual members of the organization can render depend on their behavioral repertoires Underlying each member's repertoire of functional behaviors is individual knowledge. The administrative framework determines how the members of the organization and its assets interact. The administrative framework serves two essential tasks: it determines both which productive services are called upon and how they are coordinated into collective action patterns. The first of these tasks is served by the firm's strategy, or the shared purpose of its members, the second by its internal organization, or the collection of coordinating mechanisms to which the individual members of the organization respond.

This results in a relatively straightforward definition of the codex of a firm. The codex of a firm is the combination of individual knowledge, assets, coordinating mechanisms, and shared purpose. These are what enable and constrain the behavior of the firm. They both represent the internal selection environment to which individuals adapt their behavior, and the source of the recurrent functional

collective behaviors we call organizational capabilities. It is in these four elements of the codex that organizational knowledge resides. Organizations learn by either consciously or unconsciously changing one or more of these four building blocks, and feeding back the effects of these changes on the success of the firm in the market so that changes that work are retained.

9. Conclusion

This paper has argued that if organizational capabilities are about productive knowledge, asking where this knowledge comes from may help us better understand what the foundations of organizational capabilities are. It was demonstrated that generalized Darwinism offers a rigorous structure to explain how complex systems develop knowledge of their environment. Barring an omniscient designer, a combination of variation, selection, and retention mechanisms is both a necessary and sufficient condition for learning to occur.

The application of this framework to organizations means that organizational learning is best understood by studying the firm as a Darwin machine that adapts to its environment through a combination of variation, selection and retention mechanisms. Organizations develop knowledge of their environment by varying the way in which they interact with their environment and by feeding back information about behavior that works into the organization so that future interactions with the environment are more likely to be successful.

To understand the firm as a Darwin machine, it is crucial to distinguish the behaviors that are selected by the environment from the knowledge that underlies these behaviors. This leads to a definition of organizational capabilities as functional and recurrent collective action patters. The crucial question for a better understanding of the foundations of such capabilities is where does the knowledge that enables them reside? Contrary to Nelson and Winter, organizational knowledge does not reside in routines. Routines are the building blocks of organizational capabilities and are therefore themselves activities in which knowledge is expressed. Organizational knowledge resides in what enables functional activities, or in terms of the Darwinian framework: in the codex of the firm.

We combined insights from Nelson and Winter, Penrose and Burgelman to unravel the codex of the firm into its four constituent elements: individual knowledge, assets, coordinating mechanisms and shared purpose. It is in the specific combination of these four things that organizational knowledge resides. This means that while individual knowledge is a crucial building block of organizational

knowledge, there are also collective properties that are an essential part of organizational knowledge. Without a shared purpose and a collection of coordination mechanisms, organizations cannot sustain functional behaviors. The foundations of organizational capabilities can therefore not be entirely reduced to individual traits.

In the final analysis, organizational capabilities can only be understood when we are willing to acknowledge that firms are both social and economic entities. As a social system firms coordinate the behavior of individuals. As an economic system firms compete with other firms on the basis of their capabilities. There aren't many theories that are able to combine these two views of the firm and bridge the micro-macro divide that has bedeviled the social sciences for so long. It has recently been argued that evolutionary theory offers a perspective that can help build the necessary bridges (Richerson and Boyd, 2005), and perhaps a Darwinian view of the firm can help fulfil this promise. On this view, the codex of the firm is both a source of selection pressure on the behavior of individual members of the organization and a unit of selection in the competition between firms.

Bibliography

Aldrich, Howard A. (1979), *Organizations and Environments*, Englewood Cliffs, NJ.: Prentice Hall.

Aldrich, Howard A. (1999), *Organizations Evolving*, London: Sage.

Barnett, William P. and Robert A. Burgelman (1996), Evolutionary Perspectives on Strategy, Strategic Management Journal, *17, p.5-19.*

Barney, Jay B. (1991), Firm Resources and Sustained Competitive Advantage, *Journal of Management*, 17, p. 99-120.

Baum, Joel A.C. and Jitendra V. Singh (1994), *Evolutionary Dynamics of Organizations*, Oxford University Press, NY.

Becker Markus, C. (2005), The Concept of Routines: Some Clarifications, *Cambridge Journal of Economics*, 29, p. 249-262.

Burgelman, Robert A. (1983), A Model of the Interaction of Strategic Behavior, Corporate Context, and the Concept of Strategy, *Academy of Management Review*, 8(1), p. 61-70.

Burgelman, Robert A. (1991), Intraorganizational Ecology of Strategy Making and Organizational Adaptation: Theory and Field Research, *Organization Science*, 2: 239-262.

Campbell, Donald T. (1960), Blind Variation and Selective Retention in Creative Thought as in other Knowledge Processes, Psychological Review, *67(6), pp. 380-400.*

Campbell, Donald T. (1965), Variation and Selective Retention in Socio-Cultural Evolution, In: H.R. Barringer, G.I. Blanksten, and R.W. Mack (eds.), *Social Change in Developing Areas: A Reinterpretation of Evolutionary Theory*, Cambridge, MA: Shenkman, p. 29-49.

Campbell, Donald T. (1974), Evolutionary Epistemology. In: P.A. Schilpp (ed.), *The Philosophy of Karl Popper, Vol. 14, I & II, The Library of Living Philosophers*, LaSalle, Ill: Open Court Publishing, 14-I: 413-463.

Cziko, Gary (1995), Without Miracles: Universal Selection Theory and the Second Darwinian Revolution, *Cambridge, MA: MIT Press.*

Darwin, Charles (1859), On the Origin of Species by Means of Natural Selection or the Preservation of Favoured Races in the Struggle for Life, *London: John Murray.*

Dennett, Daniel C. (1995), Darwin's Dangerous Idea: Evolution and the Meanings of Life, *London: Allen Lane, (1996) London: Penguin Books.*

Elster, Jon (1979), *Ulysses and the Sirens.* Cambridge, Cambridge University Press

Elster, Jon (1983), Explaining Technical Change, *Cambridge, Cambridge University Press*

Foss, Nicolai J. (1993), Theories of the Firm: Contractual and Competence Perspectives, Journal of Evolutionary Economics, *3(2), p. 127-144.*

Foss, Nicolai J. (1996), Knowledge-based Approaches to the Theory of the Firm: Some Critical Comments, Organization Science, *7(5), p. 470-476.*

Grant, Robert M. (1996), Toward a Knowledge-based Theory of the Firm, Strategic Management Journal, *17(Winter special issue), p.109-122.*

Hodgson, Geoffrey M. (2001), 'Is Social Evolution Lamarckian or Darwinian?', in John Laurent and John Nightingale (eds.): Darwinism and Evolutionary Economics, *Cheltenham: Edward Elgar, pp. 87-118.*

Hodgson, Geoffrey M. (2002), 'Darwinism in Economics: From Analogy to Ontology', Journal of Evolutionary Economics, *12 (3), pp. 259-281.*

Hodgson, Geoffrey M. and Thorbjoern Knudsen (forthcoming), Why we Need a Generalized Darwinism And Why a Generalized Darwinism is Not Enough, Journal of Economic Behavior and Organization.

Hull, David L., Rodney E. Langman and Sigrid S. Glenn (2001), A General Account of Selection: Biology, Immunology and Behavior, Behavioral and Brain Sciences, *24, pp. 511-573.*

Knudsen, Thorbjoern (2001), 'Nesting Lamarckism within Darwinian Explanations: Necessity in Economics and Possibility in Biology?', in John Laurent and John Nightingale (eds.): Darwinism and Evolutionary Economics, *Cheltenham: Edward Elgar, pp. 121-159.*

Knudsen, Thorbjoern (2002), 'Economic Selection Theory', Journal of Evolutionary Economics, *12, pp. 443-470.*

Kogut, Bruce and Udo Zander (1992), Knowledge of the Firm, Combinative Capabilities, and the Replication of Knowledge, Organization Science, *3(3), p. 383-397.*

Laland, Kevin and Gillian Brown (2002). *Sense and Nonsense: Evolutionary Perspectives on Human Behaviour,* Oxford: Oxford University Press.

Lewontin, Richard C. (1970), The Units of Selection, Annual Review of Ecology and Systematics, *1, pp. 1-18.*

Mayr, Ernst 1961. Cause and Effect in Biology. Science, *134(3489): 1501-1506.*

Nelson, Richard R. and Sidney G. Winter (1982), An Evolutionary Theory of Economic Change, *Cambridge, MA: Harvard University Press.*

Penrose, Edith (1952), 'Biological Analogies in the Theory of the Firm', American Economic Review, *42 (5), pp. 804-819.*

Penrose, Edith T. (1959), *The Theory of the Growth of the Firm,* Oxford: Oxford University Press.

Peteraf, Margaret A. (1993), The Cornerstones of Competitive Advantage: A Resource-based View, *Strategic Management Journal*, 14, p. 179-191.

Plotkin, Henry C. (1994), Darwin Machines and the Nature of Knowledge, *Harmondsworth: Penguin.*

Popper, Karl (1972), Objective Knowlegde: An Evolutionary Approach. *Oxford: Clarendon.*

Richerson, P.J., Boyd, R. (2005), *Not by Genes Alone: How Culture Transformed Human Evolution*, Chicago: University of Chicago Press.

Simon, Herbert A. 1981[1962]. The Architecture of Complexity. In: Herbert A. Simon, *The Sciences of the Artificial, Cambridge* MA: The MIT Press, 2nd edition. Originally published in: *Proceedings of the American Philosophical Society*, 106 (December 1962): 467-482.

Skinner B.F. 1981. Selection by consequences. Science, *213: 501-504*

Spender, J.-C. (1996), Making Knowledge the Basis of a Dynamic Theory of the Firm, Strategic Management Journal, *17(Winter special issue), p. 45-62.*

Stoelhorst J.W. (2005), The Naturalist Perspective on Universal Darwinism: An Application to the Evolutionary Theory of the Firm, In: John Finch and Magali Orillard (eds.) Complexity and the Economy: Implications for Economic Policy, *Aldershot: Edward Elgar.*

Teece, David. J, Gary Pisano and Amy Shuen (1997), Dynamic Capabilities and Strategic Management, Strategic Management Journal, *18(7), p. 509-533.*

Vromen, Jack J. (1995), Economic Evolution: An Inquiry Into the Foundations of the New Institutional Economics*. London: Routledge.*

Weick, Carl (1979), *The Social Psychology of Organizing*, 2nd edition. New York: Random House.

Wilkins, J.S. (2001) The Appearance of Lamarckism in the Evolution of Culture, in Laurent, J., and Nightingale, J. (eds), (2001), *Darwinism and Evolutionary Economics*, Cheltenham: Edward Elgar, pp.160-183.

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