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Organizational Learning as Evolution: The Promise of Generalized Darwinism for Organization Science

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The purpose of this paper is to provide a rigorous treatment of organizational learning as an evolutionary process. The paper is motivated by the believe that the notion of 'generalized Darwinism' offers a meta-theory that can draw together the diverse theoretical perspectives that comprise the extensive literature on the selection and adaptation of organizations. We clarify the notion of generalized Darwinism, and show that it provides a theoretical framework that can accommodate adaptation, selection and learning processes. This is done in three steps. First, we specify the general nature of a Darwinian explanation. Secondly, we demonstrate that learning can be understood as a Darwinian process. Thirdly, we show how the resulting theoretical framework can be applied to both organizational selection and adaptation. We discuss the implications of this view of organizational learning and conclude that the explanatory logic of generalized Darwinism demonstrates that the adaptation-selection debate is misconstrued. Adaptation and selection are simply different manifestations of the same Darwinian process.

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1. Introduction

Reviews of the extensive literature on organizational adaptation and change (Van de Ven and Pool 1995; Baum 1996; Lewin and Volberda 1999; Volberda and Lewin 2003) show that this phenomenon has been studied through a wide variety of theoretical lenses. The result has been a rather fragmented theoretical landscape, and an 'adaptation-selection' debate (Baum 1996), or perhaps rather the absence of such a debate (Volberda and Lewin 2003), about the proper role of human intentionality and different levels of analysis in explanations of organizational change.

The purpose of this paper is to propose a theoretical framework that can accommodate adaptation and selection processes involving varying degrees of intentionality at multiple, interlinked, levels of analysis. This framework is derived from the tenets of 'generalized Darwinism', the notion that Darwin's (1859) theory of evolution, when properly abstracted from specific biological content, can be applied to explain the evolution of all complex, open systems. The dependent variable that is central to the adaptation-selection debate is 'adaptive fit', and this is exactly what Darwin set out to explain. We clarify the logic of the functional explanation that is central to Darwin's theory and demonstrate the promise of generalized Darwinism as a theoretical framework to integrate the multiple perspectives that have been brought to bear on organizational adaptation.

In organization theory, Darwin's theory has typically been used to propose selectionist arguments at the level of a population of organizations that allow but a limited role for managerial intentionality (Nelson and Winter 1982), if at all (Hannan and Freeman 1977; Aldrich and Pfeffer 1976). However, the variation-selection-retention logic that is central to Darwinism has also been applied to selection processes within firms (Burgelman 1991; Baum and Singh 1994; Aldrich 1999). This paper extends this work and will demonstrate that the explanatory structure of Darwinism also applies to organizational adaptation and learning.

The dynamics of learning 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. The causal structure of the theories often remains implicit, and a proper definition of the dependent variable is typically lacking. Although this is not always stated explicitly, the purpose of theories of organizational learning is to explain how organizations develop knowledge. This makes organizational knowledge the explanandum and learning the explanans.

Note that knowledge, the dependent variable, 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’. This problem is corroborated by the fact that knowledge is often defined as the outcome of learning. This amounts to defining the independent variable in terms of the dependent variable, and leads to a tautology.

Darwin’s theory of evolution offers a way to deal with these problems. As will become clear below, its explanatory structure is especially well suited to deal with multi-level dynamics and feedback loops. It offers a general definition of knowledge in terms of adaptive fit that helps us disentangle cause from effect. And by specifying the mechanisms that explain adaptive fit, it allows us to better understand the process of learning.

The argument that organizational learning is an evolutionary process is based on the notion of generalized Darwinism and its application to knowledge (Plotkin 1994). We will argue that knowledge and adaptive fit are one and the same concept, that generalized Darwinism offers a rigorous theory to explain adaptive fit, and, by extension, knowledge, and that learning can therefore be understood as a Darwinian process. In doing so, we will clarify the explanatory logic of Darwinism and apply it to organizational learning. The corollary of our argument is that the adaptation-selection debate is misconstrued. Both organizational adaptation and environmental selection are aspects of a Darwinian process that can involve varying degrees of human intentionality.

2. Generalized Darwinism

Dawkins (1983) coined the term 'universal Darwinism' as a label for his argument that Darwin's theory of evolution by natural selection should be able to explain the evolution of any type of life that may have evolved in the universe. Since then, the term has also been used for the claim that Darwin's theory is sufficiently general to also explain evolutionary processes *within* organisms (Plotkin 1994) and in the cultural domain (Dennett 1995). Others prefer the term general selection to denote similar ideas (Cziko 1995; Hull et al. 2001. Here we will use the label 'generalized Darwinism' to denote the idea that Darwin's theory of evolution can explain the evolution of all open, complex systems. This idea is now being used to explicate the theoretical foundations of evolutionary economics (Hodgson 2001, 2002; Knudsen 2002; Stoelhorst, in press), and can also help ground evolutionary approaches in organization studies (cf. Baum and Singh 1994).

The idea that Darwin's theory may be applied outside biological evolution has a long history.[1] 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; 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 all evolutionary processes are ontologically similar (cf. Hodgson 2002). This is important in the light of a long history of criticism on the use of evolutionary reasoning in the cultural domain (Penrose 1952; Winter 1964; for a recent example from the perspective of organizational learning see Nooteboom 2000).

The main objection that has been raised to Darwinism is that the intentionality of human agents makes cultural evolution Lamarckian, rather than Darwinian. Lamarck's theory of evolution involves directed variation (organisms do not respond to changes in the environment by random variation in their behavior, but by behavior that is likely to be successful) and the inheritance of acquired characteristics (adaptations acquired during the lifetime of organisms are passed on to their offspring). This is manifestly *not* how biological evolution works, and as a result Lamarck's theory has been rejected by biologists. Yet, our ability to learn means that cultural evolution probably does involve the

[1] It starts with Darwin himself, who applied it to the evolution of language, 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 proposed by Lamarck, and this has led many to be wary of applying evolutionary reasoning in general, and Darwinian theory in particular, to cultural change. Or, alternatively, those who have applied it have typically found it necessary to state that their theory is Lamarckian rather than Darwinian (e.g. Nelson and Winter 1982).

But note that the way in which we described the tenets of generalized Darwinism above does in no way invalidate its use for constructing evolutionary theories in the cultural domain, even if Lamarckian mechanisms are involved. The core of generalized Darwinism is mechanism free. Variation, selection and retention are meta-mechanisms that need to be specified to construct a full-fledged Darwinian theory. 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. This is best illustrated by the fact that Darwin himself, unaware of Mendelian genetics, accepted Lamarckian inheritance (Wilkins 2001). The refutation of Lamarck's theory rests on August Weismann's later finding that phenotypic changes, changes in an organism's behavior and morphology during its lifetime, do not affect the genetic material that is passed on to its offspring. Weismann's barriers has become a pillar of the neo-Darwinian synthesis of Darwin's theory of natural selection with Mendelian genetics, and if we now say that cultural evolution is not Darwinian, we are really saying that it is not Weismannian (Hodgson 2001, 2002). In fact, not only are the explanatory structure of Darwin's theory and Lamarck's principles entirely compatible, it is likely that a combination of both is needed to construct adequate theories of cultural evolution, with Lamarckian mechanisms embedded in an explanatory structure that is Darwinian (Hodgson 2001; Knudsen 2001).

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, 1974; 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.

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 the adaptation-selection debate.

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 can now specify more fully what Darwinism is. The explanandum of Darwin's theory is the adaptive fit of open, complex systems, which is explained by an algorithm that combines variation, selection and retention mechanisms. A complex system can be defined as a system that is composed of a number of interacting elements (cf. Simon 1981). Such systems necessarily involve a design that specifies the system's components and the way in which they interact. An open system can be defined as a system that requires resources from its environment to function. Such systems necessarily interact with their environments to secure the resources they need to function. Adaptive fit is the state that allows an open, complex system to function in its environment, which may require any number of specific adaptations to the system's environment.

The claim of generalized Darwinism is that the explanatory structure just specified is sufficiently general to apply to all open, complex systems. Note that the specification above does not refer to any concepts that are specific to biology. Darwinism can thus be seen as a meta-theory that is applicable across domains. Its importance as such can hardly be overstated. So far, it is quite simply the only fully specified and logically consistent explanatory structure to account for adaptive fit that we know. At the same time, generalized Darwinism is not itself a fully specified theory and always needs to be complemented by a further specification of what the mechanisms of variation, selection and retention for the system in question are. For the case of firms, the disparate literatures that have touched upon the selection and adaptation of firms as reviewed by Lewin and Volberda (1999) offer many insights into the specific mechanisms of variation, selection and retention as they act both upon and within firms. The promise of generalized Darwinism, then, is that it offers a meta-theoretical structure that can help integrate the middle-level theories of adaptation, selection and learning that comprise organization science.

3. A Generalized Framework

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: [2]

(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*.[3] 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 generalized to: the relative success of different behaviors in the interaction with the environment

[2] 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.

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

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.

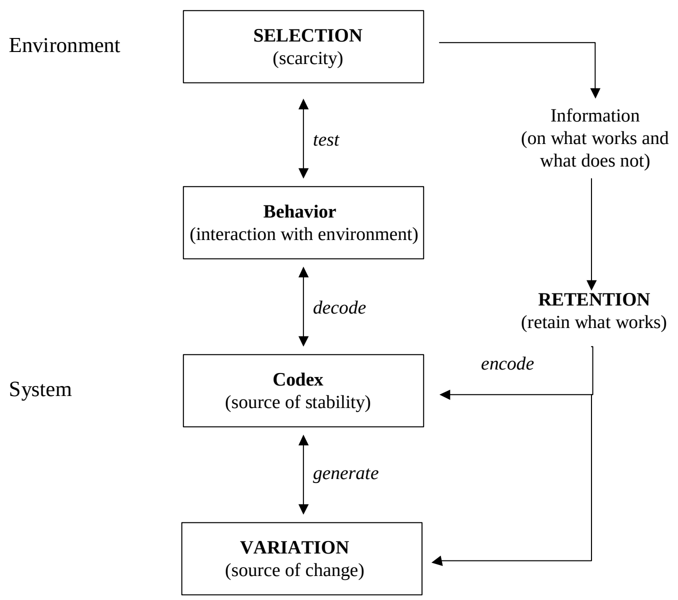

Figure 1: A generalized Darwinian Framework

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; (4) the distinction between proximate and ultimate causes of a system's behavior. 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 does need 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.

4. Knowledge as Adaptation and Learning as Darwinian Processes

It may be clear that theories of how populations of firms change as the result of market or institutional pressures take inspiration from Darwinism, although without necessarily providing a full explication of all three Darwinian mechanisms. For instance, population ecology (Hannan and Freeman 1977) puts much emphasis on the selection mechanism, but the mechanism that maintains variety (organizational founding) is exogenous to the theory and the need to specify a mechanism of retention is sidestepped by assuming inertia. In evolutionary economics (Nelson and Winter 1982) variation and retention are addressed, albeit by way of a rather problematic analogy of 'organizational routines' as the 'genes' of firms that provide stability, with a special class of 'search routines' as the source of variation.

What may not be immediately clear is that theories that emphasize the firm's ability to adapt to environmental change can also be grounded in Darwinism. A closer look at the notion of an adaptation will substantiate this claim. We have seen that adaptations are properties of a system that come about through introducing variation in the traits of a system, selective pressure from the environment on these traits, and the differential propagation of those traits that confer some advantage on the system. Selection works on the way in which systems interact with their environment. The Darwinian algorithm means that if there are mechanisms for introducing variation in the system's behavior, a consistent selection process, and mechanisms for retaining those behaviors that confer an advantage to the system in its interaction with the environment, then behavioral adaptations will result. Over time, the behavior of the system is in a quite literal sense informed by its local environment.

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 importance of this view of adaptations as knowledge of the environment is that it shows intentionality to be secondary to the overall argument. Any adaptation constitutes knowledge of the environment, and the knowledge of conscious beings like ourselves, which may involve thought and which allows us to act intentionally, is but a special kind of knowledge. The view that knowledge as commonly understood is but a special kind of adaptation means that learning can be understood as the manifestation of a Darwinian process. In other words, learning is a process of variation, selection and retention, in which information from the environment about what works and what doesn't provides the feedback loop that is necessary for the system to become adapted.

This is not to say that there aren't subtle differences between selection and learning (cf. Vromen 1995, p.119). Selection is about changes in populations. It assumes individual stasis, and can only trim the designs of the systems (individual organisms, say, or firms) that make up the population. Learning is about changes within systems. It leads to changes in the codex of systems that allow them to behave differently in their interaction with the environment. But over time, both processes lead to adaptive fit, and both processes need mechanisms of variation and retention to do so. In this fundamental sense, selection and learning are merely different manifestations of the same Darwinian logic.

Plotkin (1994) uses the concept of a 'Darwin machine' to underscore this point.[4] 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. Consider first how Figure 1 captures operant learning, or the development of adaptive behavior without thought. In the case of pigeons, some combination of cues from within the organism (for instance a feeling of hunger) and from the environment triggers them to start pecking away at its environment. These internal and external cues and the physiological effects they have on the organism are the proximate causes of the pecking behavior, while the ultimate cause for the pecking behavior is a long evolutionary history of small adaptive changes to the behavior, physiology and morphology of the lineage that comprises the organism's ancestors. When placed in the controlled environment of a Skinner box, the knowledge of the environment that has been transferred by genetic mechanisms over evolutionary history is no longer relevant for the task at hand, and the pecking behavior of a pigeon will initially be random. But learning can, and does, still take place by way of the reinforcement of behaviors that lead to desired outcomes. When the pigeon happens to hit the lever that awards it with a morsel of food, and when this initially random success makes the behavior that led to this success more likely to be repeated, as experimental results show it does, than there is a process of learning at work that can only be understood as resulting from random variations in behaviors whose relative success is fed back into the system in a way that reinforces behaviors that work. In this case the codex, of course, is not the genotype of the species, but the brain of the individual pigeon. This brain and its limited capacity is of course the result of the same evolutionary history that is the ultimate cause of the pigeon's pecking behavior, but it also allows a certain plasticity in the behavior of the individual pigeon and includes a mechanism for encoding information about behaviors that are successful. It is through this feedback loop that operant learning works.

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

Notice that this example shows that the codex of a system can be multi-layered, with a simple learning mechanism embedded in the genetic mechanism from which it evolved. Now consider how the story changes for learning through conscious thought, and note that the only difference is that the variations in behavior may no longer be random. Conscious thought may well limit the variations in behavior to a range that has a much higher chance of being successful than randomized behavior. The degree to which it does depends of course on the bounds on the rationality of the system in relation to the task at hand. But note that Darwinian framework in Figure 1 still captures the process. In fact, the only relevant difference between evolution as a result of natural selection, operant learning, and learning through conscious thought is the speed at which these processes are likely to lead to adaptive behaviors. To reiterate the point made earlier: intentionality, while interesting in its possible effects on the speed of learning, is secondary to the overall logic. Intentionality can understood as an additional feedback loop from selection to variation (the bottom part of the arrow going back from selection in Figure 1). The generalized framework in Figure 1 thus accommodates both environmental selection and conscious adaptation.

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 learning process from which it results. Moreover, understanding the way in which organizations become adapted to their environment as the result of a process of variation, selection and retention can help integrate theories that emphasize environmental selection mechanisms with those that favor explanations in terms of intentional variations in the firm's design and behavior. The Darwinian logic shows that these theories simply address different aspects of the same process.

5. The Firm as a Darwin Machine

The logic of generalized Darwinism discussed above shows that theories of organizational adaptation and learning face the same task as theories of environmental selection: they need to specify how a firm behaves in relation to its environment, where the variation in its behavior comes from, and how behavior that works is retained. Organizational knowledge is what enables the firm to act upon environmental cues. More specifically, it is what underwrites the range of functional behaviors of the firm in relation to its environment. This knowledge is the accumulation of information about what has worked in the past and results from the interplay of variation, selection and retention mechanisms. These mechanisms allow the organization to vary the way in which it behaves, to test how successful different ways of interacting with the environment are in securing the scarce resources that the organization needs to survive, and to retain those behaviors that are successful. Only the combination of these three mechanisms will result in adaptive fit.

Consider the alternatives where one of the mechanisms is missing. Let us assume a population of entities. In the case of a selection and retention mechanism without a source of variation, we have a system where unsuccessful entities get weeded out and successful ones are retained.[5] This situation is akin to choosing from among a fixed stock of things and may be termed 'subset selection' (Knudsen 2002). In a stable environment, this may lead to an equilibrium. If we have a set of apples and, for instance, blemished apples are selected out, we may end up with a set of apples that fit a selection environment favoring unblemished apples. But as soon as we allow the selection pressure to change over time, the explanation breaks down. When, for instance, the selection criterion changes to the color of the apples and only red apples are favored, then, assuming that there is variety in the color of the apples within the set of unblemished apples (see footnote 4), the only effect can be a further trimming of the set. In the limit, an algorithm consisting of a selection and retention mechanism without a mechanism to replenish variety can only result in an empty set. Next, consider the case of a variation and retention mechanism without selection. Here we have a situation where everything goes. Every variation that comes about is retained through time because there is no selection pressure. In the limit, this algorithm can only lead to an infinite set. Finally, consider the case of a variation and selection mechanism without retention. This amounts to a system without memory. Variation is

[5] Note that this situation also leads to two logical problems with regard to the assumption of there being a population of entities to select from. First, without a source of variation, where do these different entities come from? Second, given a limited number of entities in the population and without a Darwinian history involving all three mechanisms, why would there be entities among the population that fit the environmental conditions they face? This is also the problem of population ecology theory, which its proponents solve by invoking the mechanism of organizational founding, which, however, is exogenous to their theory.

generated completely haphazardly, rather than being informed by past success. Because success in environmental interaction is purely a matter of chance, in the limit such an algorithm will result in an empty set. Moreover, an algorithm consisting of only variation and selection cannot evolve any sort of complexity. Without a feedback loop to retain information about what works, there can be no accumulation of information about what works.

It follows that only the combination of variation, selection and retention mechanisms can explain adaptive fit. This is not to say that there cannot be organizational change in the absence of one of the three mechanisms. There can be variations that are selectively neutral and that do not positively or negatively affect the success of the firm in extracting scarce resources from the environment. But given scarcity and a changing environment the Darwinian algorithm is the only way in which a system can learn and evolve adaptations. This means that the adaptation-selection debate should be redirected from discussions about the relative importance of intentionality to discussions about what we know about the mechanisms of variation, selection and retention in and between organizations. Reframed in this way, the different middle-range theories of organizations that touch upon aspects of organizational learning, change, adaptation and selection come into focus as rich hunting grounds for the necessary details on how the Darwinian triumvirate works for organizations.

Population ecology, institutional theories, evolutionary economics, contingency theory and industrial organization all emphasize different aspects of the selection mechanisms that act upon firms. Population ecology (e.g. Hannan and Freeman 1977) and evolutionary economics (e.g. Nelson and Winter 1982) focus primarily on how the market selects efficient firms, while institutional theories (e.g. DiMaggio and Powell 1983) focus on the broader institutional context and emphasize how selective pressures emanating from norms and shared logics affect the firm’s legitimacy. Industrial organization and its application to competitive strategy in Porter’s (1980, 1981) five forces framework provides additional details about the sources of selection pressure in competitive markets, while contingency theory (e.g. Mintzberg 1979) puts into focus the effect of such environmental conditions as the rate of environmental change and complexity on the success of different organizational forms. In addition to these literatures, which all focus on the selection between firms, there is also work on selection within firms (Burgelman 1991; Campbell 1994).

The literatures on strategic choice, the behavioral theory of the firm, organizational learning, dynamic capabilities, and process studies of strategy have a lot to say about how variations in the behavior of firms come about. The notion of strategic choice, or the idea that organizations need not only be passive subjects of environmental selection pressures but may also have the power to reshape their environment (Child 1972, 1997) is central to that argument that managerial intentionality can play an important role in how firms achieve adaptive fit.[6] It is also central to most of the strategy literature. On the other hand, the behavioral theory of the firm (Cyert and March 1963) and process studies of strategy (e.g. Quinn 1980) emphasize that the effects of managerial intentionality on the strategy of a firm are mediated by decision processes that involve multiple stakeholders and substantial uncertainty, so that strategies may have to satisfice on conflicting political pressures and often evolve in a piecemeal manner. The theories on organizational learning (e.g. Argyris and Schön 1978) and dynamic capabilities (e.g. Teece et al. 1997) add an emphasis on the constraints on an organization's ability to change its interaction with the environment imposed by path dependency.

Finally, retention mechanisms have an important place in many theories, although they are typically not specified in much detail. For instance, population ecology (Hannan and Freeman 1977) simply assumes inertia, while evolutionary theory (Nelson and Winter 1982) goes a step further by taking recourse to a biological analogy with the notion of routines as the genes of organizations, but does not specify how behavior becomes routinized. The nature of the codex of the firm thus emerges as perhaps the central question of a Darwinian theory of the evolution of organizations. What provides an organization with the stability that it needs to function and where is information about what has worked in the past retained so that it can direct future behavior? Where, in other words, does organizational knowledge reside? Theories of organizational learning, with their emphasis on single and double loop learning (Argyris and Schön 1978, March 1991) suggest that the codex of the firm may be multi-layered, as do theories of organizational culture (Schein 1985). And the resource-based theory of the firm, with its emphasis on competencies and capabilities may also be a good starting point to further unravel the mechanisms by which firms accumulate information that helps them to adapt to their environments.

[6] Note that this notion is entirely compatible with the Darwinian logic as developed above and has its counterpart in biology, where it comes under the heading 'niche construction'.

6. Conclusion

This paper has addressed two problems. The first is the fragmentation of the literature on how firms become adapted to their environment, as reflected in the adaptation-selection debate. The second problem is the unsatisfactory way in which the literature on organizational learning has defined knowledge, often taking recourse to definitions of knowledge in terms of the learning process from which it results that border on the tautological. We have argued that these problems may be resolved by a clarification of the explanatory logic that is implicit in theories of environmental selection, organizational adaptation, and organizational learning alike. What all these theories purport to explain is adaptive fit, a concept that has been central to both the theory of organization and the theory of strategy. We have shown that generalized Darwinism provides a logically consistent causal explanation of how open, complex systems become adapted to their environment, and have argued that the Darwinian algorithm is the only explanatory logic available to theoretically ground theories of how firms become adapted to their environments. We have clarified the causal logic of a the functional explanation that is central to Darwinism and have derived a generalized Darwinian framework that can be used to ground and further develop theories of environmental selection and organizational adaptation and learning. This framework entails a rigorous definition of knowledge as adaptations to the environment that can be explained in terms of the interplay of variation, selection and retention mechanisms. The framework can accommodate varying degrees of intentionality and holds the promise of an integration of the disparate literatures on selection and adaptation. Such integration simply calls for a reinterpretation of these literatures in terms of what they have to say about how the Darwinian algorithm works for organizations.

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