EVOLUTIONARY LEARNING: SIGNIFICANCE FOR BUSINESS ORGANIZATION AND STRATEGY

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Introduction

The purpose of this working paper is to provide a bridge between the literatures of evolutionary and organisational learning (Astley and Van de Van, 1983; Shrivastava, 1983; Huber 1991, Easteby-Smith 1997). Although there are substantial parallels between the two literatures, as yet, there is no adequate account of evolutionary aspects of organisational learning. This paper is divided into two sections, the first section examines various aspects of the evolutionary outlook. It includes a sketch of important concepts relevant to evolutionary learning (summarized in Table 1), it also outlines the application of these concepts in the literature on the *evolution of organizations*. The second section examines specific processes of *evolutionary learning* in organizations. The section begins with a summary of important concepts in evolutionary learning (Table 2). A discussion of applications of these concepts follows.

At its root, processes of evolutionary learning are concerned with the adaptation of populations of entities in dynamic environments, where the environment impacts on and is impacted by the entities. In essence, entities are attempting to appropriate resources or '*earn a living*' in their environment. The domain of corporate strategy shares many of these features. Given an environment of rapid technological change and intense competition, firms continuously seek sustainable sources of competitive advantage: core competencies and dynamic capabilities. The ability to learn and adapt is a key feature in this quest, how can these faculties be built into organizational processes and behaviour? The answer that they must be built into organizational routines and architectures (Dosi, Nelson, and Winter, 2000) is not convincing: they are equally capable of stifling the development of the new. In fact a paradox exists. In a dyanamic environment, adapative capabilities are prized. However, the market-selection process tends to favor organizations whose structures (strategies) are difficult to change (Hannan and Freeman, 1984). The routines required to produce a good reliably, tend to lead to structural and strategic inertia, as the construction of routines to achieve this leads to an increase in the complexity of the patterns of links between organizational (Hannan and Freeman, 1984; Levinthal, 1991b). As organizations seek better environment-structure congruence, their systems become increasingly specialized and interlinked, making changes to their activities become costly and difficult. Adopting a populational unit of analysis, evolutionary learning can be considered to stem from the birth and death of companies, as it does from adaptation within companies. This possibility focusses the mind on the extent to which learning is driven by forces external to the organization and how far internal mechanisms can be created that enable self adaptation to take place.

The Evolutionary Outlook

This section begins with a table that sets out the main evolutionary concepts that feature in the literature on evolutionary approach to organizations. More detailed discussion of the concepts in an organizational context follows Table 1.

CONCEPT	DEFINITION	SELECTED REFERENCES
Evolution.	The gradual process of change from one form to another, as in the evolution of the universe from its formation to its present state, or in the evolution of life on Earth. In biology, it is the process which life has developed by stages from single-celled organisms into the mutltiplicity of animal and plant life.	(Baum and Singh, 1994).
Ecological View	Seeing the environment in terms of an interaction between organisms, or groups of organisms (species), that compete for resources.	(Hannan and Freeman, 1977), and Carroll (1988) with little or no adaptation.
Environmental Selection	Selection of the fitter by the environment.	(Hannan and Freeman, 1977), and Carroll (1988) with little or no adaptation.
Carrying Capacity	The maximum number of animals of a given species that a particular area can support. When the carrying capacity is exceeded, there is insufficient food (or other resources) for the members of the population. The population may then be reduced by emigration, reproductive failure, disease or starvation.	For cases of no competition: (Hannan and Carroll, 1992).
Darwinism	Chance variation and natural selection are the roots of Darwin's evolutionary theory. Darwin's theory of natural evolution by selection asserts that variation in the survival and fertility of organisms in their environment gradually leads to the evolution of species and the diversity of life forms. Neo-Darwinian theory has the following premises: • Variation: there are variations in the morphological, physiological and behavioral characteristics of organisms. • Heredity: Characteristics are partially inherited, so that on average offspring resemble their parents – more than they resemble unrelated organisms. • Proliferation: Organisms multiply and reproduce. Their population will explode unless checked by limitations. Selection: some characteristics are more favorable to living than others, and organisms possessing them will produce more offspring.	McKelvy (1982); (McKelvy and Aldrich, 1983) (Hannan and Carroll, 1992); (Hannan and Freeman, 1989).
Lamarkian View	Lamark is associated with the idea that	Singh, (1990) ; (Singh and

	characteristics acquired during the lifetime of an individual can be inherited. He observed that animals changed under environmental pressure, and (incorrectly) believed that they could pass on such changes to their offspring.	Lumsden, 1990).
Mendel	Darwin's concept of chance variations is based on the assumption of heredity. Darwin assumed that the biological characteristics of the children are a blend of those of the parents, with both parents contributing in almost equal parts. This meant that offspring of a parent with a useful, fit chance variation, has only a 50% chance of inheriting the new characteristic, and a 25% chance of passing it on to the next. Thus rapid dilution takes place. Darwin recognized this as a serious flaw in his theory. The gap was filled by Mendel who deduced that the units of heredity, genes, did not blend in reproduction, but were transmitted from generation to generation without changing their identity. With Mendel's discovery it could be assumed that random mutations would not disappear within a few generations, but be preserved, to be reinforced or eliminated by natural selection.	
Density dependence or Legitimacy	Any factors that regulates the size of a population under natural circumstances by acting more severely on a population when it is large than when it is small. Thus as number increase so does competition for scarce resources, e.g. food or nesting material. Such factors can affect either the birth rate or the mortality, but the latter is more usual. At high densities of populations some organisms have fewer young, or the mortality rate (brought about by predation, disease or food shortage) might be higher than at low densities. The factors tend to cause population numbers to be maintained at a relatively constant level over long periods of time.	
Founding	The birth rate of forms. Death occurs when the carrying capacity is reached.	(Hannan and Carroll, 1989); (Baum and Oliver, 1992).

Adaptation	Any change in the structure or function of an organism that allows it to survive and reproduce more effectively. In the Darwinian scheme, adaptation is thought to occur as result of random variation in the genetic make-up of organisms coupled with natural selection. Species become extinct when they are no longer adapted to their environment for instance, if the climate suddenly becomes colder.	(Cyert and March, 1963); (Levitt and March, 1988); (Levinthal and March, 1981), March (1988).
Synthesis	The formation of a substance or compound from more elementary compounds. The synthesis of a drug can involve several stages from the initial material to the final product; the complexity of these stages is a major factor in the cost of production.	Kauffman (1995) White et al. (1998)
Variation	The difference between individuals of the same species, found in any sexually reproducing population. Variations may be almost unnoticeable in some cases, obvious in others.	
Retention	Continuation of successful traits until change becomes necessary.	Aldrich (1979).
Crossover	A chromosomal exchange process taking place during reproduction, which produces offspring that have gene combinations which while drawn from their parents, are different from either of their parents.	Strickberger (1996)
Mutation	A change in genetic makeup of an organism. It is brought about by a change in the DNA that makes up the hereditary material of all living organisms. Mutations, the raw material of evolution, result from mistakes during replication (copying) of DNA molecules.	(Levitt and March, 1988).
Emergent properties	Emergent properties, which are global properties of the system that the separate parts do not have. For example, no single neuron has consciousness, but the human brian does have consciousness as an emergent property. Likewise, a uniform price can emerge in an efficient market of many buyers and sellers.	(Belew and Mitchell, 1996)
Fitness Landscapes	Adopting a visual metaphor, evolution can be considered to consist of a species searching a 'landscape' for peaks of high	Wright (1932), Ahouse (1990), Bruderer (1993) and McPherson (1990).

	fitness, corresponding to sucessful survival and reproduction. Improvements in a species fitness arising correspond to a move 'uphill' on their fitness landscape.	
Coevolution	Evolution of those structures and behaviours within a species that can best be understood in relation to another species, For example, insects and flowering plants have evolved together: insect have produced mouthparts suitable for collecting pollen or drinking nectar, and plants have developed chemicals and flowers that will attract insects to them.	(Baum and Singh, 1994), Lumsden (1990).
Phenotype and Genotype	Phenotype describes the observable features and behaviours of an individual organism and genotype describes the genetic makeup. The phenotype results from interaction between the genotype and the enviroment in which development occurs.	

Table 1. General Concepts of Evolution

Darwinian And Lamarckian Views Of Organizational Evolution

The Neo-Darwinist view is that the inertia of existing organizations reaches a point when change becomes necessary and new members are founded. These new organizations introduce variation into the pool of competencies held by the population. (McKelvy,1982; McKelvy and Aldrich, 1983) The newly founded successful organizations are positively selected though their forms exhibiting higher founding rates or lower failure than existing forms. (Alexander and Amburgey 1987) For Darwinists and Neo-Darwinists natural selection is *blind* even through nature itself is blessed with a degree of self-organisation (White et al. 1997). Lamark (1809) maintained, incorrectly in biological terms, that characteristics acquired by an individual during its lifetime could be inherited. However in organizational studies Lamarckian inheritance of characteristics or competences is plausible, because they are stored in one way or another in organizational memory: routines, architectures, traditions are forms of memory, or at least means of storing what is learned from the past. Organizations replace less favoured competencies or simply add the new competencies to the old ones. Organic growth or takeovers of other organizations can spread the acquired characteristics. Whereas the dominant approach in organizational ecology (Hannan and Carroll, 1992; Hannan and Freeman, 1989) exemplifies the Darwinian view, the Lamarckian view (Singh, 1990; Singh and Lumsden, 1990) in which intergenerational transfer of *acquired learning* is possible, is best exemplified by Nelson and Winter (1982) and research on *organizational learning* by March (1988). The Schumpeterian view is predominantly Darwinian. One interpretation of the Darwinian view is that survival of the organization or the individual is in a sense irrelevant, at least to the preservation of the species: indeed capitalism can be considered a species whose survival is independent of the survival of particular firm, organizations or individuals so long as they are replaced by more able or fitter versions.

Organizations that follow Lamarckian evolution will adapt much more quickly to their environment than their Darwinian counterparts because Lamarckian evolution preserves *learned traits*. However, as (March, 1991; Levinthal and March, 1993) pointed out, quick learning is a mixed blessing because firms may adopt to the first, well-functioning organizational traits that are discovered, and not take time to explore potentially better ones. Put in different words, the quick learning capability of Lamarckian evolution can again lead to premature convergence within an organizational population[1].

Synthesis of Adaptation and Selection

Kauffman (1995) finds sole reliance on Darwinism inadequate: *'Whether we are talking about molecules cooperating to form cells or organisms cooperating to form ecosystems or buyers and sellers cooperating to form markets and economies, we will find grounds to believe that Darwinism is not enough, that natural selection cannot be the sole source of the order we see in the world. In crafting the living world, selection has always acted on systems that exhibit spontaneous order'*. White et al. (1997) have researched the biological origin of ecology. Quoting new research, they find inconsistencies the biological foundation of ecology. On the other hand they resort to the biologist Campbell, who strengthens self-organization and adaptation by introducing *evolutionary drivers [force or energy*] and *evolutionary directors [pathways]*. Weakened ecology and strengthened adaptation, however, does not necessarily melt the two together easily. They consider that the physicist David Bohm provides a synthesis: Bohm's relationship between *mind and matter* links blind selection and self adaptation. *Mind and matter are two parallel streams of development arising from a common ground. Mind grows out of the matter and matter contains the essence of mind. These two are really both abstractions from the whole: relatively invariant subtotalities created by our thought….the evolution is the sign of the intelligence of matter exploring different structures that go far beyond what is needed for survival* (Bohm). Thus if there is mind in all matter adaptation can have both *intention* and *direction*.

Self-organisation explored in detail by Kohonen (1995). Proponents of synthesis do not often speak from the lofty position of common essence; they are pragmatic and typically focus on different levels of analysis and organizational features Scott (1987); Singh, et al (1986); Astley and Van de Ven (1983). Burgelman (1991), noted that an ecological perspective could be applied within an organisation, as well as between organisations. Therefore organizational form may evolve as the outcome of environmental selection among strategic initiatives generated within a particular firm. Significant adaptation occurs through peripheral changes and restores to the organization at least a measure of self-determination. Similarly (Usher, and Evans, 1996) studying the evolution of 'gas' stations in the US, they find use for Darwinian outlook at population level change and for Lamarkian view in preparing the ground for such changes[2].

Environmental Selection

Selection occurs principally through *competition* among the alternative novel forms that exist, and f*actors* in the environment select those forms which optimize or are best suited to the resource base of an environmental niche. (Hannan & Freeman, 1977) Thus, in this work, amid activity and competition the blindness of natural selection and absence of adaptation is well hidden. As Carroll (1988), points out 'Organizational ecology is the one new perspective that does not subscribe to the adaptation model of organizational change…Adaptive change is not impossible, or even rare, but it is severly constrained'. According to this outlook, organizations are inert and subject to selection by the business environments. For example, Aldrich and Pfeffer, (1976) believe that managers ability to adjust flexibly is limited. Size is a factor. According to Aldrich (1979), small organizations have little choice but to be selected out. Large organizations are selected out rarely (Edwards, 1979). Moreover, due to sunk costs, historical precedent, political resistence to change, and so on, which amount to

[1] See Learning cost and Synthesis below.
[2] For a wider view of synthesis of debates in organizational change involving six pairs of debate see Astley and Van de Ven 1983

'structural inertia' organizations are 'selected out' and new organizational forms are 'selected in' (Hannan & Freeman, 1977, 1989). *Random variation* and *density* of population, burdening the carrying capacity, lead to *founding* and death.

Density, Death, and Founding

Mortality has been attributed to density, change, uncertainty etc. Density of organisations, similar to demographic density, has attracted parallel Malthusian interest into their de-selection (death) and founding (birth). (Hannan & Carroll, 1992 ; Baum & Oliver 1992). Death occurs when the density of population reaches the *carrying capacity*, as selection processes only operate once there is a shortage of resources. The effect of social ties in preventing, delaying, or for that matter, hastening death which has been lacking in most ecological works has been emphasised by (Baum and Oliver, 1991) and Granovetter (1985). Japanese *Keiretsu,* Korean *chaebol*, and Taiwanese *Jituanqiye* are examples of such social embededness (Amburgey and Hayagreva 1996). It is likely that these organisations were responsible for the considerable delay in the discovery of the Asian crisis. *Organisational Founding* or the birth rate of organisations is seen by ecologists as a process depending on ecological forces such as population density and resources, institutional constraints, size and market power of the existing organisations, and interaction between sub-populations. (Freeman and Lomi, 1994). Ecologists, according to (Dellacroix and Hayagreeva, 1994) describe the whole history of organisation forms in relation to density as a convex curve, only departing from it for the growth part of the curve, attributing it to institutional reasons. (Dellacroix and Carroll, 1983) criticise the *exclusion of unsuccessful foundings* (survivor bias) from most ecological work. (Aldrich and Woodward, 1986) see the exclusion as an understatement of *diversity of founding*. Swaminthan (1994) studying American breweries and Argentine newspapers show that with increasing age, organisations founded under conditions of high adversity, experience a lower death rate than those founded under low adversity. Hannan & Carroll (1995) have used the concept of Density dependence for vital rates and in arguing for the endogeniety of legitimacy. However, density is not limited to the birth and death rates. It is often used to identify the *legitimacy* of the form in adaptation and learning, in particular *mimetic learning*. For a neo-institutionalist view Zucker (1989). Barnett & Amburgey (1990) have distingushed the impact of large organizations as mass dependence. There are also interesting debates around density-dependence as a public good versus its reputation (Mathew effect) See Rao (1994). The most clear-cut opposition to the ecologist view of density dependence appears in (Delacroix and Rao, 1994) and in co-evolutionary discussions as *density - independence*[3]**.**

Adaptation

Complexity theories are divided into two main camps: ecology and adaptation. Astley and Van de Ven (1983) believe that the adaptation view has historically dominated organization theory. They trace these views to Buckley's 'complex adaptive systems' (Buckley, 1968). Advocates of adaptation propose that organizations are flexible and adapt to their environments by changing their routines and standard operating procedures (Cyert and March, 1963; Levitt and March, 1988; Levinthal and March, 1981, March, 1988). And if they fail in doing so it is for reasons such as the problem of catching up with rapid change. (White et al, 1997) and Kauffman (1988) extend the discussion to consider co-adaptative processes. For an illustration of adaptation see: (Constant, 1987). He comments that when turbojet engine began to dominate the aeronautical market, ships and off-shore oil industries also had to adapt to this kind of engine. In biological terms, adaptation takes place both at population level (genotypes) and at phenotype level.

Population Ecology Vs Adaptation

[3] See Coevolution below

Within a general evolutionary framework, on-going argument in organisational science exists as to the relative importance of adaptionist versus market-selection pressures (Burgelman, 1991; Lewin and Volberda, 1999). Makadok and Walker (1996) note that a central question in organisation theory over the past 30 years is '…whether search behaviour by an organisation confers a selection advantage..' (p. 39). The view that organisations engage in goal-directed search has a long providence (March and Simon, 1958; Cyert and March, 1963). Adaptationists or advocates of strategic choice (Porter, 1980, 1985; Simon, 1993; March, 1981), broadly consider that managers or dominant coalitions scan the relevant environment for opportunities and threats, formulate strategic responses and adjust organisational structure appropriately (Child, 1972). Therefore, strategic direction and organisational form are determined by managers, and market selection acts to maintain organisations which are good 'adaptors'. Under this view, an organisation's fate is largely in its own hands and organisational research efforts are appropriately focussed on individual firms and individuals within those firms as units of analysis. The adaptationist argument presupposes that organisations are capable of adapting at least as fast as their environment changes (March, 1981; Makadok and Walker, 1996). If firms are incapable of responding to environmental changes in a similar time-scale, adaptation (or learning) processes will not enhance organisational survival (Hannan and Freeman, 1984).

Adaptationists branch into two main classifications, rational adaptationists who consider that organisational variability reflects designed, intentional, change responding to environmental influences, threats and opportunities, and random adaptationists, who posit that while firms do respond to exogenous influences, the responses are only loosely coupled with those influences. This grouping notes the difficulties in organisational adaptation processes, including suggestions that due to bounded rationality, most adaptation processes are the result of local search (March, 1991), and that internal knowledge transfers are imperfect and subject to 'stickiness' (Szulanski, 1996).

In contrast, populational ecologists have a pessimistic outlook on the strength of organisational adaptation abilities and consider that the primary driver of organisational change processes is market selection. Foster and Kaplan (2001) point out that markets have no past experience or favoured mental models[4]. Markets blindly select and deselect organisations, products and structural forms as environmental conditions alter. The selection process operates through competition for scarce resources. Firms which can generate a financial surplus tend to attract capital and labour resources, whereas less successful firms lose resources over time (Schumpeter, 1934; Lewin and Volberda, 1999). The primary research agenda of population ecologists adopts a populational unit of analysis in order to explain why structural diversity exists amongst organizations (Hannan and Freeman, 1977; Carroll and Hannan, 1995). Consequently, specific research projects concentrate on studies of the processes of organisational foundings (of both new organizational forms and new organizations), growth, decline and failures (mortality) of organizational forms and organizations (Singh and Lumsden, 1990; Carroll and Hannan, 1995; Chang, 1996; Levinthal, 1991), adopting a population level unit of analysis.

The population ecology school was initially popularised by Hannan and Freeman (1977), who saw it as providing a critical alternative view on organisational-environment relations, to that proposed by the dominant adaptation school. Hannan and Freeman (1977) did allow that organisations had some ability to adapt to environmental changes and noted that 'leaders of organizations do formulate strategies and organizations do adapt to environmental contingencies' (p. 930). However, they argued that the ability of firms to accurately and consistently adapt in a world of high uncertainty, where connections between means and ends are unclear is problematic (Hannan and Freeman, 1984; Carroll and Hannan, 1995). In addition to the difficulties posed by uncertainty, the ability of organisations to adapt is highly constrained because of 'structural inertia', stemming from a variety of internal and external sources including sunk costs, internal political constraints, organisational structure,

[4] Mental models are defined by Foster and Kaplan (2001) as 'the core concepts of the corporation, the beliefs and assumptions, the cause-and-effect relationships, the guidelines for interpreting language and signals, the stories repeated within the corporate walls' (p. 44-45).

organisational history, barriers to industry exit and legitimacy issues (Hannan and Freeman, 1977). Under the population ecology view, differences between firms arise mainly at time of founding as a result of 'imprinting forces' (Boeker, 1989). These include dominant initial strategy, distribution of influence and degree of management ownership (Boeker, 1989). Although selection processes select the most 'fit' firms in a given environment, firms are fit because of their initial intentional design, or luck, rather than because of post-birth adaptation (Barnett and Hansen, 1996). Hannan and Freeman (1984) extended the discussion of structural inertia by positing that it is a consequence of the selection process, claiming that 'selection processes tend to favor organizations whose structures are difficult to change.' (p. 149). The basis of this claim is that organisations which can produce a good or service 'reliably' (consistently of a minimum quality standard) are favoured by other firms and therefore by market selection processes. The routines required to produce a good reliably tend to lead to structural inertia. Hannan and Freeman (1984) and Levinthal (1991) suggest that building these routines leads to an increase in the complexity of the patterns of links between organisational subunits. Tushman and O'Reilly (1996) note that structural inertia is rooted in the size, complexity and interdependence of the firm's structures, systems, procedures and processes, and claim that as systems get more complex and as the firm seeks better environment-structure congruence, systems become increasingly interlinked and changes become costly and difficult. Theoretical support for these assertions, that increasing organisational complexity can lead to adaptation difficulties, is found in Kauffman (1993) and Rivkin (2000), as the heightened degree of interconnection within the firm would increase the 'ruggedness' of the strategic choice landscape faced by an organisation.

Critical Evaluation Of The Population Ecology Perspective

Perhaps the strongest argument for adopting a populational unit of analysis is that it facilitates longitudinal studies concerning the success or failures of organisational strategies and structures (Carroll and Hannan, 1995) and provides large samples facilitating the use of statistical techniques in testing specific hypotheses. In addition, the environment faced by an individual firm consists primarily of other organisations and the dynamics of this environment cannot be studies by restricting attention to a single organisation, rather the population and its associated 'turnover' (births and deaths) must be considered (Aldrich, 1979). Case studies of single firms, or small numbers of firms, risk drawing incorrect causal inferences due to ex-post storytelling.

The population ecology school is underpinned by a Darwinian explanation for organisational diversity. If this is to prove plausible, the existence of three mechanisms must be demonstrated (Campbell, 1969):

(i) occurrence of variations in the unit of selection
(ii) consistent selection criteria which result in differential survival of units of selection
(iii) preservation and propagation of positively selected variants

Underlying all of these mechanisms is a definition of the unit of selection. Population ecologists employ a populational definition, but altering the definition casts light on a multiplicity of evolutionary processes. Thus, population ecology is best considered as a subset of a much larger evolutionary school. Alternative definitions of the unit of selection include products, divisions of organisations, organisations or networks of organisations (Barnett and Burgelman, 1996), individual strategic projects or human resources[5] within the firm (Lovas and Ghoshal, 2000), routines[6] (Nelson and Winter, 1982) and communities of populations (a collective of interacting organizational populations) (Singh and Lumsden, 1990).

[5] Staff may compete to be assigned to specific projects and projects may compete within the firm for skilled staff.
[6] These are defined by Nelson and Winter (1982) as '…characteristics of firms that range from well-specified technical routines for producing things, through procedures for hiring and firing, ordering new inventory, or stepping up production of items in high demand, to policies regarding investment , research and development (R&D), or advertising, and business strategies about product diversification and overseas investment.' (p. 14).

A viable definition of the unit of selection requires that (Lovas and Ghoshal, 2000):

(i) there is variance in the unit which the selection mechanism can act on
(ii) the units of selection be independent of one another
(iii) the units of selection must come to the attention of the actors in the (social) system who act as agents of selection / retention

If there is no means of generating variations in the unit of selection, an evolutionary process cannot exist. In an organisational setting, variation could result from organisation foundings or through intentional / random adaptation in existing organisations. If units of selection are not independent, the interpretation of the selection process is problematic, as it is unclear what is actually being selected. The third requirement differentiates biological evolution from evolution in social systems. In social systems, selection criteria are socially influenced (Aldrich, 1979) and are applied by social actors (investors, customers, suppliers and staff). Unless the unit of selection is visible, at least indirectly, to these actors, it cannot influence their selection process.

The choice of a suitable unit of selection will be governed by the research question of interest. However, in organisational settings, the distinction between various units of selection is not always clear-cut. If a firm changes substantially between t_0 and t_x, for example an organisation undergoes a substantial change of management, staff, investors and product lines, does the change represent the result of an adaptation process in a firm or does the change more closely resemble a death and birth process? Similar problems arise when defining populations. To what extent can a population be considered to exist over a long time-horizon, especially if an industry has undergone substantial changes in technology and products? The clarity of the distinction between units of selection and the selection environment is also open to debate, as they may interact (Birchenhall, Kastrinos and Metcalfe, 1997). Firms select the environment in which they operate and can modify that environment, particularly in concentrated markets. The latter effect in essence, recognises the co-evolutionary nature inherent in both biological and social systems.

Having considered the issues surrounding the unit of selection, attention is now turned to the selection criteria within the evolutionary process. To coherently impact on the population of organisational designs / strategies, selection processes must remain broadly stable over time. In an organisational setting, selection processes revolve around the ability of a unit of selection to attract resources in order to propagate its existence. Under a Schumpeterian approach, successful organisations will attract resources, unsuccessful organisations will lose them. Preservation and propagation of successful variants may occur through organisational growth and through selective diffusion wherein routines and structures within organisations seen as prospering would tend to be imitated (Campbell, 1969).

Finally, the question arises as to whether it is appropriate to expand Darwinian metaphors, drawn from biology, into social systems. Most authors in the evolutionary school of organisational theory, including population ecologists, are careful in rationalising their choice of an evolutionary framework. Even ardent proponents of an evolutionary model recognise that there are distinct differences between biological and organisational adaptation relating to direction mechanisms, the source of selection criteria and the possibility of Lamarckian processes (Nelson and Winter, 1982). Typically, it is pointed out that no claim is made for a biological metaphor, that firms behave like biological entities, rather the claim is that an evolutionary perspective provides a general conceptual framework, which if appropriately tailored, may provide insights into the change behaviour of organisations or the populational properties of organisations (Singh and Lumsden, 1990; Hannan and Freeman, 1977).

Synthesising The Adaptationist And The Selectionist Approaches To Organisational Change

The ecological perspective has produced new insights on organizational change. It has also triggered debates concerning the importance of environmental determinism versus strategic choice, and the related question of the relative importance of selection and adaptation processes in explaining organisational change and survival. Following polarised arguments on these questions between early population ecologists and adaptationists, recent literature has seen a recognition that neither adaptation or selection processes provide a complete explanation of organisational strategy or structure (Lewin and Volberda, 1999). Rather, each focus on different levels of analysis (Bruderer and Singh, 1996) and both can be usefully incorporated in an evolutionary framework (Burgelman, 1991). Simon (1993) noting that organisations exist in a co-evolutionary environment and hence play a role in determining the nature of selection pressures facing them, argues that ‘each organization competes with the others for scarce resources and their fates must consequently be decided by some combination of natural selection and rational adaptation’ (p. 132). The idea that strategy can be considered as a means of ‘guiding’ evolutionary processes is gaining increased attention (Lovas and Ghoshal, 2000; Lewin, Long and Carroll, 1999).

The understanding of the interaction of selection and adaptation processes at a populational level can be complemented by considering the nature of intra-organisational adaptation processes. It can be argued that organisational adaptation partly arises from intra-organisational ecological processes, whereby successful adaptation of a firm is preceded by internal experimentation and internal selection (Burgelman, 1991). This idea posits that an organisation consists of an ecology of strategic initiatives which compete for limited organizational resources so as to increase their relative importance within the organization[7]. Strategy emerges through the operation of *internal* selection and retention processes acting on the internal variation associated with strategic initiatives (Burgelman, 1991). Thus, strategic initiatives rather than individuals become the appropriate unit of analysis. This combination of selection and strategic choice serves as a useful counterpoint to the extreme views of blind natural (external) selection or comprehensive strategic planning (choice). The first misses the idea of internal selection, second misses the idea of ecology (Burgelman, 1994).

The latest perspectives on the integration of adaptionist and selectionist views stem from the field of complexity sciences. White, Marin, Brazeal and Friedman (1997) argue that organisations are nonequilibrium systems with inherent (non-directed) self-ordering processes. Selection can only act on organisations once they are in existence, and the creation and initial imprinting of organisations are the result of directed processes. Once formed, the organisations are subject to self-ordering mechanisms. As these processes are not independent of the external selection environment, the market does not blindly select but rather shapes-and-selects organisations. Thus selection does not operate independently of managerial choice and self-organising processes, but rather all three combine.

Organisational Learning

In their classic review, Levitt and March (1988) view organisational learning as routine-based, history-dependent and target-orientated. Organisations learn by encoding inferences from history into routines[8] that guide behaviour, enabling learning to be passed to future generations of employees (Pascale, Millemann and Gioja, 2000). This encoding can take many forms, ranging from formal rulebooks and tacit knowledge, to firm culture which is maintained through systems of socialisation and control (Belew, 1990). The encoding of past learning so that it is available even after employee turnover is referred to as creating an organisational memory (Levitt and March, 1988). In a wider social setting, Belew (1990) notes that in humans, learning takes place at three levels. The results of

[7] The control system within an organisation can serve to determine the degree of internal variation generated, the resource allocation system can be viewed as a selector (Barnett and Burgelman, 1996).

[8] Nelson and Winter (1982) define routines as ‘…characteristics of firms that range from well-specified technical routines for producing things, through procedures for hiring and firing, ordering new inventory, or stepping up production of items in high demand, to policies regarding investment , research and development (R&D), or advertising, and business strategies about product diversification and overseas investment.’ (p. 14)

evolutionary learning processes is encoded in genetic structures, individual learning is encoded in neural structures and societal learning is encoded in cultural artifacts. Culture allows individual learned knowledge to improve the evolutionary fitness of other conspecifics (members of the same species). This perspective demonstrates the tangled complexity of social learning. Cultural learning arises from an interplay of evolutionary and individual learning, in turn, individual learning is influenced by evolution and culture. In an organisational setting, biological evolutionary processes are replaced by organisational adaptation and market selection forces. The interplay of these forces in technology search is poorly understood (Levinthal, 1997). Although learning is generally considered to arise when knowledge or experience is accumulated, Levinthal and March (1981) construct an alternative framework which focuses on the processes of learning.

The optimal rate of learning for an organisation is poorly understood. Intuitively, faster learning would appear preferable, particularly in view of the rapid dissemination of technological innovations. Mansfield (1985) estimated, based on an empirical study, that detailed information on a new product leaks within 12 months of its introduction. Unfortunately, learning processes have significant limitations as a means of information transfer (Levinthal and March, 1993). The ability to learn successfully presupposes that experience is correctly interpreted in terms of cause and effect relationships and that 'superstitious learning' (March, 1981) is avoided. The value of past learning can be negated by environmental change. Levinthal and March (1981) note that fast learning means quick adaptation to new signals. This may result in quick adaptation to incorrect signals. This has obvious implications when applied to 'tipping' industries (Arthur, 1989). Fast adaptation also reduces the time spent exploring possible alternatives.

Role Of Absorption Capacity In Organisational Adaptation

Although they were not the first to address the idea (Winter, 1984), Cohen and Levinthal (1989) drew a useful distinction between internal innovation and the ability of a firm to assimilate useful external innovations. This ability is termed an organisation's 'absorption capacity'. The greater this capacity, the greater the organisation's ability to imitate new product or process innovations and to exploit knowledge from external basic research findings. The level of absorption capacity of an organisation has two primary components. Initially, the organisation must capture the relevant information from its environment (external learning) and then must be capable of communicating it internally (internal learning) (Simon, 1991). The internal transfer of information can be difficult or 'sticky' (Szulanski, 1996) due a lack of internal absorption capacity. The success of absorptive learning depends critically on gatekeeping and boundary-spanning roles within the firm (Cohen and Levinthal, 1990), as well as the degree of causal ambiguity associated with the information being transferred. The internal learning component of absorption capacity suggests why it can be difficult to successfully 'buy-in' the relevant expertise if an unforeseen technology emerges. Effective absorption capacity requires that individuals understand both the new technology and the internal structure of the organisation. New employees may be less effective at communicating internally.

This points to two interesting trade-offs. Increasing employee diversity, both in terms of background and prior working experience will tend to increase the potential for external absorption capacity (Simon, 1991). However, increasing employee turnover may decrease the ability of an organisation to assimilate innovations internally. The second trade-off concerns the degree of interconnection within an organisation. Even if an organisation has high quality information capturing processes, absorption capacity may be lessened if it has many highly interconnected routines. Such processes are more time-consuming and expensive to change (Bruderer and Singh, 1996, p. 1330) and inherently stifle initial trials of innovative processes.

Fitness Landscapes.

The concept of strategic and organisational adaptation as a search process is well-developed (March 1991; Simon, 1996; Fleming and Sorenson 2001). Implicitly, this assumes a search-space, in other words, a *landscape*. The landscape metaphor (*'surfaces of selective value'*) was first introduced by Wright (1932). The metaphor sought to explain Darwinian evolution (Darwin, 1859) as a search on a landscape, where the base of the landscape is defined by a species' genetic composition and 'height' on the landscape corresponds to a measure of the '*fitness*' of the species as determined by its success in surviving and reproducing in its environment. In this framework, biological evolution represents a search over genotypic space, in a effort to enhance phenotypic fitness. Translating this into organisational terms, strategists trawl across a landscape of possible organisational designs and strategies, searching for peaks, corresponding to profitable strategies, and avoiding low-lying regions, corresponding to poor strategies. These landscapes are not fixed, but deform over time

- As linked landscapes alter (those of suppliers, customers)
- In response to Red-Queen affects
- In response to technological change

Hence, in a Schumpeterian fashion, 'standing still' is never a viable long-term strategy. Although search and landscape metaphors closely parallel the concept of seeking sustainable competitive advantage (Porter, 1980, 1985), it is only in recent years that the landscape metaphor has been explicitly recognized in organisational science (Beinhocker, 1999; Kitts, Edvinsson and Beding, 2001; McCarthy and Tan, 2000; Rivkin, 2000, 2001; Gavetti and Levinthal, 2000). Landscapes can be considered at differing levels of granularity, either at a macro-level of species (industries) or a micro-level of individual firms. For example, fitness landscapes can be used to depict how the U.S. car industry fell into a "competency trap" during the 1970s and early 1980s because "it got stuck on the local performance hill of producing large cars for the U.S. market[9]".
Random variation, sometimes dubbed as blind variation, is essential for founding in ecology. The work of Freeman and Hannan (1984), that regards foundings as discrete random values, despite being anathema to adaptation and learning, has opened the way for many empirical research and simulations in the domain of learning. On the other hand co-evolutionary writers Van De Ven and Garud (1994) show strong ecological leanings when they attribute founding primarily to novel technical form. Variation is sometimes viewed identical to the birth of organizational forms as a carrying-out of new combinations (Lumsden and Singh, 1990; Schumpeter, 1934; Van de Ven and Grazman, 1994). Variation through *crossover* is borrowed from biology. In relation to organisations variation through crossover is analogous to innovation defined as recombination or a new combination of existing routines (Kogut and Zander, 1992; Lumsden and Singh, 1990; Schumpeter, 1934; Van de Ven and Grazman, 1994). Takadama et al. (1997) view crossover as a means of transforming local communications into a global one (see learning cost). The genetic operator, crossover (recombination), effectively creates plausible new organizational forms because they are combinations of previously successful organizational building blocks. Davis (1991: Ch. 3) discusses advantages and disadvantages of different crossover methods, such as two-point crossover and uniform crossover. For treating crossover operators as a combination of probabilistic linear decompositions and a randomized search see Aizawa (1998).

Utility Of Landscape Metaphors

Landscape models represent tropes. Tropes are departures from literal language which convey meaning (Smith, 1998, p. 250). Examples of tropes include, metaphors, similes and metonymys[10]. When landscape models were initially developed, the intention was to enhance understanding of evolutionary processes. Later, the metaphors were translated into non-evolutionary settings as it

[9] Levitt & March, 1988, For competency trap see Levinthal and March 1981.
[10] Most authors on complexity theories do not distinguish between these and simply refer to 'metaphors'. This convention is adopted in this working paper.

appeared that they could provide useful insight into a range of problems. To the extent that the metaphors assist rather than hinder understanding, these applications are useful. As noted by Lissack (1996b), meanings and metaphors matter. Language, both verbal and visual, is the vehicle through which ideas are transmitted and understood (Smith, 1998, p. 246). It is not neutral. Language helps convey patterns from mind to mind and pattern recognition plays a key role in human decision making. Many decisions are unique in that the precise circumstances will never be repeated, for example, consider the myriad of decisions faced by a car driver. Yet despite this, pattern recognition capabilities allow the driver to take a decision based on past experience. Metaphors act as a pattern recognition device, allowing decision makers to conceptualise unique decisions in terms of the chosen metaphor. They shape how a decision-maker sees the world. New metaphors can create a new reality but it must be noted that the choice of metaphor may be value-laden.

The meanings ascribed to a firm, its products and competitors determine the range of strategic options which management consider. In a discussion of complexity theory, Lissack (1996a) comments that 'what complexity science metaphors do for an organisation is give its members access to both new worlds and new possibilities for action' (p. 122). Thus, 'word choice in usage delimits possibility space and helps to determine the adjacent possible' (p. 122). New metaphors are useful to the extent that they free management from older, restrictive mental models.

Mutation

Mutation is a novel kind of variation. Variation through mutation parallels playful experimentation (Levitt and March, 1988) and incorrect transmission of routines (Nelson and Winter, 1982). It behaves secretively. For the 'secret handshake' of ostensibly docile mutants see Robson, (1995.) The genetic operator, mutation, which infrequently and randomly changes some information, can reinstall lost or novel information. Mutation is important if a given population is small (relative to the number of routines) or if the population faces a continuously changing environment, because mutation can prevent premature convergence toward an inferior organizational design. In those cases, mutation plays the role of shifting an evolutionary search from exploiting existing routines toward exploring new routines (Holland, 1992; Levinthal and March, 1993; March, 1991).

Retention

Retention is the last in the chain of variation-selection-retention[11]. Retention involves the forces (including inertia and persistence) that perpetuate and maintain certain technical and institutional forms that were selected in the past.(Aldrich 1979)

Two forms of mutual adaptation

a) ***Co-evolution.***

The concept of coevolution arises from the limited perspective of one-population ecology. Two populations reliant on common resources can influence each other directly or indirectly through resources. Coevolution may involve more than two populations and include some sub-populations, becoming nearly a community. In turn, communities can be viewed as a case for coevolution[12]. Coevolution may involve technology and government. For a typical study of coevolution involving day care centers and nurseries in Canada involving public financing see (Baum and Singh, 1994.) The *counterintuitive* phenomenon that the increased Government assistance may actually reduce the population size in one category, instead of increasing it, motivates the authors to examine the positive and negative feedbacks extensively. The results lead them to argue that '… as a result of higher order feedback processes the effects of changes in one variable frequently belay intuitions based on simple

[11] See application in co-evolution below.
[12] See community evolution below

cause-effect logic of linear relations between independent and dependent variables'. Clearly as one moves to more complex phenomena the system properties such as feedbck become more important. Changes in one variable are caused endogenously by changes in others. This requires co-evolution. (Singh, 1990; Singh and Lumsden, 1990).

Other studies involve the coevolution of technical and institutional events (Van de Van and Raghud 1994), or that of technology and organization (Rosenkopf and Tushman (1994); Van de Van and Raghud, 1994) study the development of hearing aid (cochlear) in which one group of businesses, led by House-3M alliance, and some official support, develop and market the one-channel device. Others, led by Nucleaus and encouraged by university research, focus on the multichannel device. In the end the latter win. The development pattern is summarized by the authors: 'Technical *variations* peak in 1986-87, institutional rule-making (*selection*) events in 1988-89, and rule-following (*retention*) events sometime later'. But worried about possible causality implication they add: 'The aggregate temporal sequence does not indicate causality… at a micro level these events even may co-produce each other'. (Rosenkopf and Tushman 1994), observe a two-stage cycle of technological *Fermentation* (uncertainty, chaos and variation) followed by *Convergence* (reorientation to dominant design). 'Nonesupporters of dominant technology reorient or vanish, and interorganisational agreements around the dominant systems are strengthened. This period also brings the predominance of institutions that elaborate and retain technology such as standards bodies, educational curricula, and professional societies'. At this stage there is a tendency to monopoly and emphasis on prices. This tendency has institutional support: The dominance of transistor based components of radio over vaccum tube transmitters supported by the Navy during the War is the case in point. The concept of coevolution is growing rapidly and has spread from the academia to business applications.[13]

b) Community Evolution.

Coevolutionists do not segregate their territory whereas the communal evolutionists prefer to distinguish themselves in a Durkheimian sense in terms of scope and integrative processes. Barnett (1994) defines communities as 'collectivities of organisations united through the bond of *commensalism* or *symbiosis*'. Britain (1994) has studied the population of semi-conductor populations using an extended version of Lotka-Volterra predator-prey model of density. His main finding is that when the constraint of resources (carrying capacity) is relaxed both entry and exit rates tend to increase inviting the wider influence of the environment. Thus provacatively he replaces the density-dependence of ecologists with *density-independence* in the title of his article. Barnett's (1994) study of independent telephone companies versus the monopoly power of Bell displays a similar outlook. The study could be regarded as a coevolution between the community of independents and the giant Bell. But he prefers the community context probably to test Hawley's theorem that the development of community structure through symbiotic organizational forms lessens the vulneribility to the exogenous environment: 'If that structure is poorly coordinated the fitness of the entire community is reduced '. He attributes the lengthy period of recovery (16 years) after the technological shocks to the symbiotic cohesion. The direct effect of technology and the indirect impact through Bell provide a similar frame of complexity to (Baum and Singh 1994)[14], porac (1994), who appreciates Barnett, statistical work, is, however, critical of his attachment to the ecological emblical cord. In order to emphasise the role of social, economic and institutional influences as a methodology of 'higher conceptualisation' Porac argues that: 'fitness is an issue but it would be very clear that an ecological analysis is an abstract overlay on a complex *psychosocial* reality.

The central notion here (2) is that organizational learning is a means by which they evolve.

Evolutionary Learning

[13] (Boyd and Smith 1996). Elcoteq, a Nordic electronics company, has welcomed coevolution with a statement (Lähdesmäki 1998). It has also opened a niche in A-Life Research.
[14] See Coevolution above

Table 2. General Concepts of Evolutionary Learning

CONCEPT	DEFINITION	AUTHORS
Random Learning.	Learning without plan	(Hannan and Freeman, 1984, and 1989).
Baldwin Effect .	Learning alters the shape of the search space in which evolution operates and thereby provides good evolutionary path towards sets of co-adapted *alleles (*different forms of the same gene).	(Hinton and Nowlan, 1987).
Cost of Learning	Increased average fitness in phenotypes (learning), blunts the genotype differentiation thus hindering the evolution (also called ***Hiding Effect***).	Mayley (1997).
Classifier Systems	(CS) A system's knowledge could be represented as a population of competing condition-action rules ('classifiers'), subject to reproduction, variation, and selection resulting in gradual system improvement.	(Holland 1986, 1992); Wilson (1995,1997) adds accuracy and generality to CS.
Efficiency: Performance and Aspirations	In the short run, efficiency results from failure, and innovation from success (slack). Performance in the long term is a function of search (learning) propensities and increased variations.	(March 1981) and Lant (1989).
Attainment Discrepancy	Aspirations attributable to business optimism overtakes performance.	Lant (1989).
Exploration and Exploitation.	Exploitation the situation in which one organism gains at the expense of another. Exploration is search for new possibilities.	March (1992) March (1993). Warglen (1995)
Convergence and Reorientation.	Long-term incremental change and adaptation, which elaborate structures, systems, controls and resources toward increased co-alignment.	Tushman and Romanelli (1985) Lant & Mezias (1992).
Fermentation and Congruence.	Technological breakthroughs trigger a discontinuous but relatively short period of competition between alternative technological regimes (***fermentation***). This era closes when social and political dynamics select a dominant product design from among competing alternatives.	(Utterback & Abernathy. 1975); For an interesting application see (Rosenkopf and Tushman, 1994)
Mimetic Learning.	Partial or complete imitation of other forms in contrast to creating novel organisational forms as re-combinations of existing forms.	(DiMaggio and Powell, 1983); Lant and Mezias, 1990, 1992); (Mezias and Lant, 1994), modifying them slightly. Hannan

		& Freeman, (1989).
Docile Learning	Simon (1990) believes that a simple and robust mechanism, based on human docility and bounded rationality can account for the evolutionary success of genuinely altruistic behaviour.	Simon (1996)
Evolutionary Engineering.	The use of genetic-algorithm-based models to make normative judgements on how to more effectively guide the evolution of complex modern firms.	Bruderer, (1993); March, (1994); Van de Ven and Grazman, (1994).

Natural selection and Learning

The connection between natural selection and learning was first proposed a century ago by two biologists (Baldwin, 1896; Morgan, 1896) and has recently been rediscovered by Hinton and Nowlan (1987) and Belew (1990). While admiring Hinton and Nowlan's (1987) *elegant work*, Belew adds culture to their model, *an element which is badly missing in the literature*. Both Baldwin and Morgan proposed that in the case of biotic evolution, only some of the inherited traits are genetically fixed; others are unspecified and must be learned during an organism's lifetime. Organisms that inherit poor unspecified traits - that is, poor learning capabilities - will not survive the evolutionary race. In contrast, organisms that inherit good unspecified traits will be able to learn traits crucial for survival. Learning and selection are fundamentally interdependent processes because adaptation enhances inertia, even as inertia accelerates the process of environmental selection and organizational evolution (Levinthal 1991). Selection will favor the capacity to acquire traits whether heritable or not (Bruderer and Singh, 1996) For organizational learning as an example of adaptation [15]

Learning and Flexible Evolutionary Search

A key argument in (Hinton and Nowlan, 1987) is that an evolutionary process is more effective if new organizational forms inherit only some fixed routines from previously successful organizations, while letting others remain open to organizational learning. To quote them " it is positively advantageous to leave some decisions to learning rather than specifying them genetically"[16]. This openness allows firms to initially choose some of their key routines incorrectly. Because those routines can be changed later, the organization may eventually discover the correct form. Thus, organizational learning constructs a region of increased fitness around the maximum fitness, transforming it into a gentler hill. A hill can be searched more effectively by an evolutionary process because the process is constantly guided toward the top of the hill, where fitness is greatest. 'It is like trying to find a needle in a haystack with continual feedback provided about whether one is getting closer' (Hinton and Nowlan, 1987)[17].

Learning can Guide and speed up Evolution

Hinton and Nowlan (1987) note that learning is not just a matter of survival; it guides and leads the search. "Learning alters the shape of the search space in which evolution operates and thereby

[15] Cyert & March, 1963; Levitt & March, 1988. For *Random Learning* which does not yield to rational planners.
[16] See also Harley 1981
[17] For a chaotic model of innovative search with feedbacks see Koput (1997).

provides good evolutionary path towards sets of coadapted *alleles*[18]". For a parallel outlook see Maynard Smith (1987). Learning not only guides but also speeds it up.(20 times according to Hinton and Nowlan (1987), and many times more for Bruderer (1996). The impact on the evolutionary path is through increased fitness. Thus, routines that contribute to a high fitness level in an organizational form spread rapidly through a population (Holland, 1992).

Cost of learning (search)

In (Hinton and Nowlan 1987), the cost of learning is not an issue. Learning costs in terms of research expences for refinement and innovation is mentioned in (Levinthal and March 1981) and their followers[19]. The maladaptive Red Queen effect is also some kind of cost that optimists should bear in mind. (Barnett and Hansen 1996) have argued that considerable number of Illinois banks suffered failures because of this effect. In essence the Red Queen effect involves competitors in a rat race of learning which can be sometimes reinforcing but can also be ruinous.

More recently the cost of learning is viewed more directly in terms of complexity costs. Apart from the $ cost of chasing the best traits we are faced with an evolutionary or complexity cost. It is argued that mass learning of the best traits has a *hiding effect,* which counters the Baldwin effect. Learning of these traits takes place in the phenotype space whereas population evolution takes place at the genotype space. Without learning there is a correlation between phenotypic ascent and genotypal adaptation, but learning, despite raising the average fitness in phenotypes blunts the differentiation and thus hinders the evolution (Johnston 1982, for biological review; Turney 1996, Anderson 1995, and Mayley 1996, for A-Life literature). This hiding effect is regarded as a cost by Mayley (1997). By simulating centroids of genotypal generations and their correlation, he finds patterns of declining centroid motion (or increasing costs) that result from learning. Similar graphs are produced for epistasis, which has parallel effects to costs. The two provide a motley of hindrances to the Baldwin effect. In this work there is no letup except for the compensatory effect of lower epistasis[20].

Complexity

Robson's (1995), argument that equilibrium evolution ends up in abandoning evolution and *complexity* gently because it is *expensive* is a clear example of complexity cost. In a similar vein Seth (1997), reveals a cost of complexity. This is the fitness cost of *long genotypes*. With 8 runs of simulation he shows that the high cost deadens complexity into monotony but complexity flourishes with low costs. In cases of high cost, environmental noise is thought to kick-start complexity. He concludes that the gains of learning and acquiring fitness in complexity is well worth the small costs - if not a large tariff. Recently organisational costs are also looked at from control and communication angle. Takadama et al. (1997), studying organisational learning of robot groups have distinguished between the cost of global and local learning. They say it is easier to evaluate action by employing a global function as an outside control. Except that it is costly to communicate in this way.
Kauffman's (1993, 1994) work in this field is seminal. He asserts that random selection is unlikely to produce evolutionary changes because of the large numbers of possible configurations, if search space is examined ergodically. Hence he argues for some form of self adaptation.

Classifier Systems

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12 Alleles also called allelomorphs, are any one of two or more genes that may occur alternatively at a given site (locus) on a chromosome.

[19] see Learning Efficiency below

[20] Most generally *epitasis* exists when the effect of two or more non-allelic genes in combination is not the sum of their separate effects. Larousse Dictionary of Science and Technology 1995)

Classifier systems involve parallel, message passing, and rule-based systems, in which many rules are active simultaneously. The rules in a classifier system are the counterpart of interacting standard operating procedures (Holland 1992): in a condition action form, so that a rule comes into force as soon as the condition exists – typically posting a message that brings rules into play.

Learning Efficiency: Performance and Aspirations

Cost often comes to light with efficiency. In their influential work, Levinthal and March (1981) emphasise efficiency only in relation to the short-term view, downturn in business, search for refinement, and allocation of resources. The opposite environmental condition is the long-term view, upturn in business, innovation, and *slack* which means available rent. But this is all first order response. The second order response is more complex: The environment is full of ambiguity and uncertainty. Now the goal posts begin to move and behaviour is constantly adapted to changing goals, resulting from success and failure and subjective aspiration levels. At this level they find efficiency problematic as the optimum returns form the basis for efficiency are ambiguous. Four main findings at this level are:

- Performance in the long term is a function of search propensities.
- Variation increases as the propensity to search develops.
- Quick Learners adapt quickly to current signals: they also adapt quickly to false signals which if acted upon can deplete the useful stock of experience. So the relationship between learning rate and performance is complicated.
- Uncertainty reduces the frequency of subjective success when the technology is improving and reduces the failure when the technology is declining.

March (1988), takes up the success history of organisations discussed in the previous paper to give more prominence to history dependence and the dialectics of decay and renewal: Accumulated success and reputation by analogy reduce risk taking and make efficiency seeking based on the old knowledge a prominent concern. Failure on the other hand enhances risk taking and the chance of renewal.

The concept of aspiration levels (targets), discussed in both these papers, is taken up by Lant (1989). She finds Levinthal and March's (1981), adaptive aspirations to be tantamount to rational expectation which may lead to the assumption that aspiration levels and performance undergo equivalent changes. In Lant, in contrast, aspirations take the upper hand resulting in *attainment discrepancy* attributable to business optimism. Despite some inconclusive statistics she hits on an interesting finding: At early stages learning is dominated by attainment discrepancy but at later stages of experience in all four industries there appears to be a hint of rational expectations driving the discrepancy to zero. Lant (1989), uses *Markstrat* complex game involving teams of top management who are assigned roles to play.

Mezias and Glynn (1993) also heavily rely on Levinthal and March's (1981) innovative work. They manage to operationalise the source work's main tenets by a flowchart: The search decision starts with search experience which is followed by the assessment of this experience in terms of success and failure. The next stage is performance which is followed by assessment in terms of meeting the targets. Meeting targets or aspirations lead to refinement and failure to variance with ultimate potential of innovation. In judging failure and success they rely on more elaborate cost estimations. The interesting finding of the work is that organisational learning is more cost-effective with *evolutional* approach than with *institutional* and *revolutional* perspectives.

Types of Learning:

Exploration and Exploitation

This is an off-shoot of ecological selection and adaptation. Exploitation of old certainties is pitched against exploration of new possibilities. By examining two situations:

- learning for competitive advantage.
- learning between the members of an organization and the organizational code.

March (1992) argues that: adaptive processes by refining exploitation more rapidly than exploration are more likely to be effective in the short-run but self-destructive in the long-run. This tendency of self-destruction is ameliorated by new entrants and diversity. For a balance between exploration and exploitation[21]. Warglen (1995) tries to bring about a balance by consciously synthesizing the two: The interactions among different process levels within the firm lead to the emergence of an adaptation style by dynamically tuning explorations efforts and exploitation opportunities. "In complex environments this results in waveform process of discovery and learning, which may be subject to competence and memory traps"[22], for confidence traps. The rise of competence replication along innovation cycles result in singling out the organization's traits and their modification.

Convergence and Reorientation

There is another dilemma parallel to that of exploration and exploitation: convergence and reorientation. (Tushman and Romanelli 1985) defined convergence as periods of equilibrium characterised by 'relatively long time spans of incremental change and adaptation, which elaborate structures, systems, controls and resources toward increased co-alignment'. (Lant and Mezias 1992) take up the idea and, despite considerable agreement with those authors, introduce some modifications. They explain convergence with *single loop learning* and reorientation with *second loop learning*, terms coined by Senge (1990). The concept is illustrated by the development of GenRad from the convergent stage of sticking to routines to the stage of innovation.
The transition stems from the environmental change but is driven by the dichotomy between performance and competence level. The adaptation of aspirations to routines, which complicates the dynamics of stability and change, is seen as a *complexity* issue. They arrive at the following propositions to explain this complexity:

- Organisational change will increase following environmental change and will decrease during environmental stability.
- Organisations with adaptive search routines will be more responsive for environmental change than those with imitative or *Garbage Can* routines.
- Firms with high change potential are more likely to change in response to environment than firms with low potential.
- High-performing firms will exhibit fewer changes than low performing firms.
- Large firms will be more inert than small firms.
- Ambiguity between performance and organisational traits reduces responsiveness.

By testing this complex relationship they distinguish themselves from (Tushman and Romanelli 1985), in concluding controversially that learning and innovation are the outcome of routines and there is little scope for top management[23].

Fermentation and Congruence

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[21] see Levinthal and March (1993)
[22] See Levinthal and March (1993)
[23] For a comprehensive study of routines see also Cohen and Bacdayan (1994).

This model posits that technological breakthroughs are variations which trigger a discontinuous but relatively short period of *ferment* and competition between alternative technological regimes. This era of fermentation closes when social and political dynamics select a dominant product design from among competing alternatives. The selected dominant design subsequently evolves through a relative long retention period of incremental process improvements (*congruence*), which in turn is interrupted by the next technological discontinuity or round of product innovation. This process is called The Cyclical Model of Technological Change, Utterback and Abernathy. (1975); Rosenkopf and Tushman 1994), provides the example. Three distinct types of continuous wave variants emerged: alternator, arc, and vacuum-tube transmiters, but the latter came to dominate the market. In the American photographic industry, eras of incremental change ended with the introduction of collodion plates, gelatin plates, and roll films (Jenkins, 1975)

Mimetic Learning

This method of learning puts more emphasis on routine learning rather that risking for innovation. For an understanding of routines it is useful to know that genetic transmission of organizational routines happens when:

- A new organization is created.
- Parts of other organizational forms are imitated (DiMaggio and Powell, 1983; Nelson and Winter, 1982)
- Parts of a company are acquired or divested (Winter, 1990).

Instead of creating novel organizational forms as recombinations of existing forms, termed the Schumpeterian mode of variation, it has been argued that entrepreneurs imitated entire organizational forms, DiMaggio and Powell (1983); Lant and Mezias (1990), (1992); Mezias and Lant (1994), modifying them slightly. Hannan and Freeman (1989) call this *mimetic variation*. Mezias and Lant (1994) assign an original role for *mimetic learning* by arguing against ecologists and institutionalists: Hannan and Freeman (1984) contention that change is random with respect to future value implies that the study of insert firms replacing each other is all that is necessary in order to understand the evolution of organisational populations.” They concede that the search process based on learning from large firms is institutional but argue that there are still 20% mimetic firms who survive long-term transformation of core routines. Makadok and Walker (1996), have argued that most of the average money market funds 'are not so lucky to mimic', and will have to adjust to the growth patterns.

Equilibrium None-Equilibrium evolution

Dosi et al (1995) has made an interesting criticism of convergent learning and equilibrium-seeking evolution. Their basic point is that these models avoid incorporating innovation, which is a complex issue. They come out with a stochastic model for *learning dynamics* classified as Schumpeter Mark II.

Simulation and Learning

Simulation has been used to understand how individual organizations learn (Herriott, Levinthal, and March, 1985; Levinthal and March, 1981; Lounama and March, 1987; Morecroft, 1985), and to show how populations of organizations evolve (e.g., Lant and Mezias, 1990, 1992; Mezias and Lant, 1994; Nelson and Winter, 1982; Mezias and Glynn, 1993) have modelled individual firms for routines. Hinton and Nowlan (1987) find simulation for Lamarkian outlook more difficult compared to Darwinian tradition. The "exploration versus exploitation" model by March, (1991) is in Darwinian mode. Organizational behaviour as a set of routines is typical computer modelling. (Cohen, 1981; Cohen, March, and Olsen, 1972; Cyert and March, 1963; Lant and Mezias, 1990, 1992; Mezias and

Glynn, 1993; Mezias and Lant, 1994). Most models have rested on the assumption that entire new organizational forms are imitated at a rate proportional to their frequency in the population (Lant and Mezias, 1990, 1992).

Social Learning

A critical aspect of human learning is that it is 'social' or 'distributed. Such phenomon transcend human social systems. Inspired by studies of social insects and studies of flocking behaviour of birds and fish a recent stream of research has emerged in the social science which concentrates on the application of a 'swarm' metaphor to social systems (Kennedy, Eberhart and Shi, 2001). The essence of insect / flocking behaviour is that the resulting social systems exhibit flexibility, robustness and self-organization (Bonabeau, Dorigo and Theraulaz, 1999). Although these systems can exhibit remarkable coordination of activities, this coordination does not stem from a 'centre of control' rather it is self organised. The emergent, collective behaviour that emerges from a group of social agents has been termed 'swarm intelligence' (Bonabeau and Theraulaz, 2000).

Extending the metaphor to human systems, Kennedy, Eberhart and Shi (2001) argue the importance of social interactions for learning and evolutionary advance, noting that individuals are not '…isolated information-processing entities…' (Kennedy, Eberhart and Shi, 2001, p. xv). Rather they learn from each other. The affect of this social behavior is to assist individuals to adapt to their environment, '... by providing individuals with more information than their own senses can gather'. (p. xv). Communication (interactions) between individuals in a social system may be direct or indirect. An example of the former could arise when two organizations trade with one another. Examples of the latter include

- The observation of the success (or otherwise) of a strategy being pursued by another organization,
- 'Stigmergy' (Bonabeau and Theraulaz, 2000) which arises when an organization modifies the environment, which in turn causes an alteration of the actions of another organization at a later time

Altruism, Docility, and Learning

Simon (1996) argued that it is difficult to account for true altruism, defined as behavior that reduces the fitness of the altruist but increases average fitness in society. He believes that a simple and robust mechanism, based on human docility and bounded rationality can account for the evolutionary success of genuinely altruistic behavior. Because docility, receptivity to social influence, contributes greatly to fitness in the human species, it will be positively selected. Docile people *learn* and avoid risk. "They do not have to learn about hot stoves by touching them" (Child similarly argued that you do not have to be devoured by bears to learn that they are vicious animals). Simon (1996). says for gaining that benefit they can be 'taxed' as long as it is not too heavy to cancel the advantages of docility. Limits on rationality in the face of environmental complexity prevent the individual from avoiding the "tax" (Simon, 1990). In Simon's framework, specific learning capabilities, such as docility, lead to an evolutionary advantage and will be positively selected over time.

Evolutionary Engineering

Evolutionary change is often viewed as emergent and non-intentional for an individual organisation. But as March (1991), argued premature convergence by losing variety within its gene pool of routines can be detrimental to organizational evolution. To avoid convergence trap and stimulate a balanced evolutionary path some possibilities have been suggested:

- Recombining of the existing parts of firms and internal resources (Burgelman, 1991).
- Using and experimenting with slack resources as a buffer against organisational controls (Cyert and March, 1963).
- Promotion of risk-takers (March,1981; 1988).
- Loose coupling (Weick, 1979), suggests, in what is called a portfolio approach, ' .. seeding many diverse projects and many diverse experiments'.

In these ways managers are seen as evolutionary engineers guiding the process of "breeding" high-performing, novel organizational forms (Bruderer, 1993; March, 1994; Van de Ven and Grazman, 1994). They can use genetic-algorithm-based models to make normative judgments on how to more effectively guide the evolution of complex modern firms. Computer simulations can readily generate a large number of possible evolutionary scenarios from which managers can choose the more effective ones for implementation in the real world. Computational model may illuminate when organizations might do well to increase or decrease their capability to learn, contingent upon different degrees of turbulence in the business environment. Bruderer (1996). The ECAL papers (1997) provide a good source for further update research on evolutionary engineering.

Evolutionary Learning and Institutional Factors

Amburguey (1996) believes that study of how population levels change is jointly shaped by efficiency considerations and institutional processes are sorely needed to enrich the dialogue among those positing economic, ecological, and institutional models of organisations. This is a correct assessment. Judging by (Mezias and Glyn, 1993) treatment of 'Institutional Paradoxes', where institutional impact is packaged away as beurocratic and convergent, it is clear that genuine interaction is not frequent. Some efforts, however, are taking place: In Groenwegen's collection *Transaction Cost Economics and Beyond,* Dietrich (1996), argues that learning helps reduce transaction cost. Transaction Cost Economics for him is a 'comparative static' which is complemented by *institutional influence*, justifying the word *beyond* in the title. Nooteboom (1996), provides a learning-based model of transactions, and Pitelis (1996), by studying labour costs in the Athens attributes most transaction costs to institutional factors. The choice of profit instead of *efficiency* for consideration seem to guide his argument. Economics works with complexity slant are now cognisant of the need to be attentive to institutional matter. (Anderson, Arrow, and D. Pines, 1988; Tisdell 1996; Day and Chen, 1993).

However, to generalise a little, it is obvious that despite huge developments in the evolutionary fields multidisciplinary work does not progress smoothly. This is probably because the social scientists have still difficulty with the biological roots of the evolutionary science. Krugman (1996), for instance, despite his work 'Self-Organising Economies' finds much of the 'bio-babble' difficult to absorb. Mirowski (1996), one of the contributors to the Keynesian Malvern collection, provides a brief history of *Santa Fe***,** and its main actors, outlining the delayed application of biological findings to economics. He believes the economists of *Santa Fe* do not reflect the innovative nature of evolutionary physics and biology and are the optimisers of the old school.
On the other hand (Low and Simon, 1995), object to the sloppy application of biological terms to economics and management, for instance they argue *efficiency* is irrelevant in biology but is vitally important in organisational management

Conclusions And Discussion

It was argued that evolutionary learning is establishing itself as a viable and growing branch of organisational learning. It is no longer limited to natural phenomena and human populations; evolutionary learning is now being applied to neural networks and Artificial-Life both in industry and finance. As evolutionary learning gains momentum, the eternal debate of ecology versus adaptation, which used to be limited to biology with the ecological view taking the upper hand, is once again rekindled. This is because adaptive learning in industry and commerce has brought dazzling results. Bearing in mind the pervasive role of this debate in evolutionary learning, whether at behavioral or theoretical level, considerable weight was given to the basic concepts of this debate. Despite credible efforts by major scholars to synthsize the two elements of evolution, the dichotomy keeps manifesting itself. Due to the density of content in this paper, the conclusion will have to content itself with three grounds of interplay between selection and adaptation.

Self-Organisation And Adaptation

The two schools of thought, ecology versus selection and their synthesis were discussed in terms of Neo-Darwinian and Lamarkian views. For synthesis, it was shown how ideas from physics, biology and human organisations are brought together to provide a convincing picture of the compromise. Self-organisation, by introducing a sense of knowledge in local interactions, serves as a building block in arguments for synthsis. This type of synthesis is promoted by Kauffman (1995) and is discussed by White et al (1998) at some length. Reflecting these approaches, Takadama's self-organising robots, for instance, receive the same information from the environment but in local interactions they know what actions to avoid. Self-organisation, however, is an ecological tool; it involves competition. In Kohonen (1995), despite uniform input, self-organising network of cells are in lateral competition. In Best (1997), unlike the predator/prey relationship, competing populations tend to avoid each other which according to Pianka (1981), becomes a source of diversity and exploration. If that is the case then David Bohm's 'mind of the matter' as a tool of synthesis between Darwinian selection and adaptation would certainly make sense.

Behaviourist Works On Organisational Learning

A multidisciplinary approach is common to most evolutionary workers. Some, despite their multifaceted thinking, have produced a set of works which can be classified as behaviourist. The cooperation of Simon, Levinthal, March, and Cyert in MIT over many years resulted in a fruitful combination of economics and management science in an evolutionary framework. Operationalization of Baldwin's biology by Hinton and Nowlan in a learning context propelled application of evolutionary learning by these thinkers and their close followers to social sciences. Competition, economic cycles, psychlogy of economic agents, and efficiency mingle imperceptably with history-dependent decision making, bottom-up management etc. Most evolutionary learning follow in their path. Despite innovation and interesting applications, the followers' method of mimetic imitation can itself be a case in evolutionary research. When detached from the biological and A-Life sources of learning imitation of behavourists by behaviourists can reproduce the evolutionary dilema of exploitation versus exploration. [24]

Simon (1990); Levinthal and March (1981), took up the idea of genes as routines and focused their learning theories on these mundane procedures rather that the grandure of top management declarations. They expressed efficiency in terms of sticking to procedures especially in lean times. But they also showed the limits of exploiting the successful traits for the longterm, which necessitates exploration suitable in slack times. This basic view of learning types has had wide following which have produced several parallel learning types such as fermentation and convergence, convergence and reorientation, mimetic learning and so on. These studies show the limits of learning and what they can achieve. The compromise is a reflection of the general selection-adaptation discussion outlined above. Adaptation is obviously preferred to selection by all these writers; companies are never lined up in a death row. While the followers demonstrate clear preference, the founders of behaviourist evolutionary thought tend to be more cautious. The economic cycles are the decisive environment and managers adapt to these waves through a complex web of feedbacks and responses.

[24] The use of *Markstrat* complex games consisting of top management roles by a follower, even if played by rank and file, may still weaken the rhetoric of ignoring the top management.

Institutions As A Means Of Adaptation

Self-organisation is an active and interactive way of seeking adaptation. With institutions adaptation is exogenous. A decision by governments for instance to support a certain technology imposes adaptation. As turbojet engine began to dominate the aeronautical market, ships and off-shore oil industries also had to adapt to this kind of engine (Constant, 1987).
Competition-avoidance and adaptivity to institutions might be behind the survival of many financial institutions in crisis-ridden Asia or identical banks in the UK.

Contribution Of Artificial- Life To Learning

More recently similar debates on learning have resumed in A-Life studies showing what learning can achieve and yet create problems. The discussions began with Hinton and Nowlan's view that learning can enhance and speed up evolution. This argument, based on Baldwin, has further been developed by Holland (1992) through his *classifier systems*, and has witnessed considerable advances by Wilson (1995, 1997), and Japanese researchers led by Takadama et al. (1997). In this arena too the ecologist influence has manifested itself through costs and efficiency. The debate is not about the R&D costs or even the opportunity cost of learning. It is about loosing diversity and complexity because of learning. Mayley (1996, 1997) attributes the phenomenon to the phenotypic-genotypal dichotomy caused by universal learning. Work in A-Life however is not all ecological. Works on co-evolution and communication is quite prevalent. At the moment research in A-Life shows considerable loyalty to the frames of thought generated by biology and complexity. It would be surprising if future research in A-Life did not gravitate to adaptive learning at the expense of ecology.

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