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Evolution and Institutions: A Cognitive Perspective

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Abstract.

Evolution, institutions, and organisation in economic systems rest on uncertainty and the characteristics of human cognition. All processes require structure, which influences their outcomes; every structure is a pattern of selected relationships. Cognition depends on neural connections, which are genetically derived, but not determined; institutions provide frameworks; and organizations provide routines and decision premises. Responses to uncertainty include conservatism, the adoption of other people's rules, and experimentation; diversity extends the range of both defensive and imaginative practices on which selection can work; and the division of labour promotes diversity. Successful change requires 'good continuity' – a problem for transition economies.

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Introduction

In this article I shall attempt to explore the links between evolution and institutions from the perspective of uncertainty and human cognition, by emphasizing the significance of selective connections (Loasby 2001, Potts 2000). I will begin by defining ‘evolution’ broadly as a process, or cluster of processes, which combines the generation of novelty and the selective retention of some of the novelties that are generated. This basic definition is sufficient to distinguish evolution from processes that are clearly not evolutionary, without restricting ourselves to the biological model. Institutions I will also define broadly as conventions that guide thought and action, and seek to expand this definition as we proceed.

Knowledge in economics

In Nelson and Winter’s (1982) *Evolutionary Theory of Economic Change*, what is changed in the evolutionary process is one or more of the routines by which economic activity is carried on. This appears to be a natural consequence of looking for an equivalent in their economic theory to genes in biological models; but if we distance ourselves from the biological model and think of innovation as an evolutionary process in which novelty is not created by random mutations but by purposeful human activity, then we might wonder why routines should have any role in evolutionary economics – except perhaps as obstacles to be overcome. However, I wish to argue that routines, and the related phenomena of rules, which constrain but do not explicitly direct, are significant contributors to evolutionary processes in economic systems. Investment and search routines already have this role in Nelson and Winter’s theory; and routines for exploratory search may be better regarded as rules, since they do not define specific outcomes but decision premises and criteria. If such rules for innovative behaviour resemble institutions, which is not accidental, as we shall see. What makes rules, routines and institutions so important in evolutionary processes is the problem of knowledge.

An ancient theme in economics has been the unintended consequences of intentional actions. Internationality requires knowledge; but unintended consequences can appear only if this knowledge is incomplete. However, the redefinition of economics as the analysis of scarcity led naturally to a focus on rational end-means calculation and thence to the conception of equilibrium as a consistent set of individual choices that produced precisely and only consequences which those individuals had foreseen; and this appeared to demand that everyone was supplied with a complete definition of the relevant problem-situation (perhaps including probability distributions defined over a specific set of outcomes and Bayesian rules for revising these probabilities). Rational choice equilibrium excludes unintended consequences; as a notable example, Williamson (1996, p. 46) tells us that ‘far-sighted contracting’ ensures ‘the absence of surprise, victims, and the like’. It also excludes evolution. At the other extreme, neoDarwinian theorists refuse to tolerate any trace of intentionality in evolutionary processes; it is the environment that selects, from a choice set that is generated by an unrelated process of mutation. The ancient concern of economists with the unintended consequences of intentional actions is therefore under threat from both directions.

John Hicks struggled throughout his career with ‘a supreme theoretical challenge … to find a mode of process analysis that would retain a role for equilibrium constructions without denying (or trivializing) change’ (Leijonhufvud 2000, p. 97), and he realized very early that an economics ‘in time’ must be an economics of incomplete and changing knowledge. Hayek and Lindahl, the first economists to envisage the concept of intertemporal equilibrium, quickly recognized its inadequacy as a representation of economic systems (Zappia 2001), and Hicks (1948, p. 137), having decided that the formidable assumptions about agents’ knowledge required for intertemporal equilibrium were not credible, rejected it in *Value and Capital* in favour of a succession of ‘weeks’, in each of which a temporary equilibrium was the unintended outcome of incompatible plans which were based on incompletable knowledge. But in modern microeconomics, this kind of model is not acceptable; in any theoretical crunch, equilibrium dominates process.

I believe that we should reverse this priority, and use a rather looser notion of equilibrium to support process; for all processes require some continuing, though not permanent, structure (Loasby 1991). It is precisely such a combination of structure and process that Penrose (1959, 1995, p. 149) employs in defining a firm as ‘a pool of resources the utilisation of which is organised in an administrative framework’, and we shall find that it is precisely such a combination that makes possible the growth of knowledge in any context – though it does not ensure it, and certainly does not allow us to make any specific predictions about what knowledge will be created. Structures also provide the ‘absorptive capacity’ that makes possible the diffusion of knowledge among those with compatible structures for organizing and interpreting knowledge; but because any such structure can be effective within its range only by excluding a great many possibilities, the absorptive capacity of any individual or group is always limited.

All change requires some stable structures, just as all logical operations require pre-logical premises; and institutions, like organizations, are structures which provide (relatively) stable frameworks for decisions and for the creation of new knowledge. Structure affects performance, as in old-fashioned industrial economics; different frameworks trend to produce different decisions and different knowledge. Over a longer timescale, institutions may change, with potentially significant implications for decisions and knowledge, and these changes may themselves result from deliberate attempts to induce particular kinds of improvement. However, because intentional action is the result of cognitive processes which require an established structure, any deliberate effort to secure major institutional or organisational change is likely to produce some consequences which were not intended, and which may be widely judged to be undesirable. The post-socialist transformation has provided many examples, but they are not hard to find in many other economies.

Uncertainty

Equilibrium models define the analytical structure of conventional economic analysis, and the concept of rational choice defines the decision-making structure within which economic agents are presumed to act; rational choice supports the equilibrium, and equilibrium values (sometimes filtered through probability distributions) provide the data for the algorithms of rational choice. These are the primary institutions of economic theorizing, which have had major effects on the development of economic theory. There is a correct procedure for decision-making within the model, and agents know it; there is also a correct procedure for economic analysis, and well-trained economists know that. This reliance on correct procedures clearly locates these analyses in the category that Frank Knight (1921) labelled 'risk'; the absence of procedures which are known to be correct are a mark of what Knight called uncertainty. Now, despite the propaganda of consultants and the proliferation of books offering recipes for business success, it is clear on any considered view that major business decisions (and many other kinds of major decisions) cannot be mapped onto demonstrably correct procedures; if they could, there would be no market for consultants or authors to prescribe what would already be common knowledge. That there is such a market does, however, indicate how important it is to have some kind of structure for decision-making. This paper is about structures – mental, institutional, and organizational – in an uncertain environment.

Let me briefly review three fundamental contributors to uncertainty. (For an extended treatment see Loasby 1999, pp 1-7). The first is time, which Marshall (1920, p. vii**)** noted as 'the centre of the chief difficulty in almost every economic problem'. Knight (1921, p. 313) observed that the only reason that we need to make decisions is that the future is likely to be in some respects different from the past, whereas the only reason that we can make decisions, rather than acting at random, is that the future is likely to be in many respects similar to the past. As David Hume ([1739-40] 1978) showed, continuity between past and future, even in what appear to be basic laws of nature, can never be proved; and so we can never be certain in what respects the future is likely to bring surprises. Some notable features of present-day physics and biology, for example, were beyond the imagination of physicists and biologists a century ago. Nevertheless, as will be explained, some knowledge claims may reasonably be treated as more reliable than others (Ziman 1978), and these supply some of the necessary structure.

The second contributor to uncertainty is complexity: the interaction of many variables in producing particular outcomes. Hayek (1952, p. 185) pointed out that 'any apparatus of classification must possess a structure of a higher complexity than is possessed by the objects that it classifies'; and since our mental capacities are very modest in relation to our environment we must often make do with representations which do not encompass all the features that might be important. Moreover, we cannot construct a representation by careful simplification of the full system, since that is beyond our grasp; any representation must be a conjecture. In complex situations, there is necessarily a gap between representation and reality; and there is always a danger that something crucial lies in this gap. Indeed, such gaps account for many major failures, even in apparently well-ordered systems. The time and cost incurred in turning innovative ideas into successful products is a measure of the insufficiency of the original idea as a representation of the total context of innovation; moreover, by looking only at successful innovations we underestimate the practical significance of this insufficiency, because we then fail to notice the many ideas which turn out to be unsuitable even as the starting-point for successful representations. 'Many starters and few finishers' is no less the rule in company research programmes than in the biological record.

There is an important complication. Because the representation differs from the reality, it may generate problems which are attributable to this difference, and have no equivalent in the real situation; and these artificial problems may attract attention which at best diverts resources and at worst leads into serious error. This, I suggest, has happened within economics as a consequence of representing human decision-making by a model of rational choice; the representation of human cognitive capacities and of the availability of information have been made to conform to this model at the expense of investigating the real difficulties of decision-makers in finding out what they wish to know – let alone their difficulties in recognizing what they ought to be trying to find out; the process of problem-finding (Pounds 1969) is a much-neglected issue in economics.

The representation of complexity that is embodied in the organisational structure of any business is a common source of misperception; the assignment, and limitation, of responsibilities is also a licence to ignore externalities and to post unwanted problems elsewhere; and even when conformity to the existing structure and its accompanying procedures generally works well, it may become a major obstacle when developing a new line of business which turns out not to conform to familiar patterns. The classic example of this is the struggle to cope with Du Pont's increasingly diversified activities within a functional organisation, a struggle which was protracted by the Du Pont family's knowledge of and respect for the existing wisdom on organisational design (Chandler 1962).

The third contributor to uncertainty is bounded cognition. I prefer this term (which was, I believe, first advocated by Richard Langlois) to Simon's 'bounded rationality', because the latter is too easily converted into information cost or optimally simplified calculation. This misrepresentation emphasises the importance of human logical powers which, as psychologists have demonstrated, are not particularly great, and diverts attention from the remarkable human capacity to create and use patterns, which is responsible for many features of human behaviour and human society, especially the generation of novelty (Ziman 2000, p. 120). Since, as we have just noticed, representations of complex phenomena cannot be deduced from the 'correct model' but must be created by some non-logical process, pattern-creation is essential to the development of knowledge about complex systems. In contrast to rational choice models in which the problem-definition is supplied by the analyst, the first task in making most important decisions, as Simon insisted, is to identify the problem and to define the decision space; and this is not a logical procedure but a process of applying or even making patterns.

Any structure is a pattern of selected relationships, and knowledge is not simply a collection of elements but is constituted by the particular connections, for example of similarity and causality, between them. Potts (2000) has identified the essential background to rational choice equilibrium analysis as the assumption of integral space, or a complete set of connections. Because the set is complete, 'there is no explanatory content in the connective structure' (Potts 2000, p. 182); outcomes are deduced directly from the elements. It is not surprising that such features as agent heterogeneity, firms, and institutions, all of which imply highly selective connections, are difficult to fit into the system, nor that many attempts to incorporate them are designed to explain them as responses to some kind of failure at the margins of an otherwise fully-connected system, responses which restore the direct derivation of outcomes from the system elements. Explanations of the firm, for example, preserve the standard theory of production, which assumes integral space: there is no asymmetric information about production sets or consumer preferences.

Potts (2000, p. 182) argues that incompleteness is 'the crucial fact' in the study of systems: the dependence of both analyst and actors on selective connections is central to understanding and to intelligent decision-making. To construct a tractable analytical representation of a complex system requires the omission of a great many conceivable connections in order to display a discernable pattern, and the choice of pattern may have a major influence on the relevance of the subsequent analysis; to construct a large organisation which is capable of performing complex tasks similarly requires drastic restrictions on the number of working relationships and regular communications between members of that organisation, and the particular set of restrictions is likely to have significant effects on performance, not just in quality but also in the orientation of effort. Without investigating the implications of these selective connections, conventional economics is inevitably restricted to a very 'thin' theory of the firm (Potts 2000, p. 135). Formal organisations and informal institutions are both consequences of the human dependence on patterns to guide understanding and action, and they have their own consequences for understanding and action.

That the fundamental difficulty with rational choice theory is its untenable assumption about human knowledge was pointed out by Frank Knight (1921) 80 years ago; by excluding uncertainty it excludes some of the basic determinants of human behaviour. We will focus on two of these, each of which has an individual and social aspect. On the individual level, an important defensive reaction is to stick to the familiar, as long as it seems to work. Co-ordination is first of all a problem for each individual – an insight which is the core of Kelly's (1963) *Theory of Personality*; and uncertainty favours rules and routines which constitute an 'interpretative framework'. Heiner (1983) produced a parallel argument for routines as a response to uncertainty. If the familiar no longer seems to work people look for some other pattern, often by observing how other people behave in apparently similar situations; and the diffusion of satisfactory rules and routines creates shared regularities, even if interpersonal co-ordination is not an issue. That this human characteristic often provides a basis for interpersonal co-ordination is then easy to understand.

Nevertheless, any such institution, however effective in the past, may be found wanting in changed circumstances. Therefore a good defensive strategy (conscious or unconscious) at the social level may be to develop a variety of institutions as buffers against unpredictable change, not least because they can be modified in different ways and adapted by others; the accompanying inefficiencies (as they would appear in standard theory) are the cost of survival. In the guise of the proliferation of species with very differentiated behaviour patterns, this has been the 'grand strategy' of natural evolution, which has enabled life to survive a series of catastrophes, as well as localised disasters, which have extinguished the great majority of life-forms that have ever existed.

However, as Knight recognised, uncertainty is double-edged; as well as difficulties, it creates opportunities. Without uncertainty, there is no scope for entrepreneurship, for if there is a known best procedure no improvement is possible; more fundamentally, as Shackle (1972, 1979) insisted, without uncertainty there is no hope, no novelty, no room for imagination. Individuals need a measure of uncertainty to make life worth living. But since any particular new idea is likely to be wrong, the generation of alternative hypotheses (some of which may be embodied in artefacts and institutions) and selection among these hypotheses, which may lead to the generation of further hypotheses, is likely to be an effective means of social progress, though not always of improvement in terms of human happiness, particularly of those whose ideas appear to fail. Thus diversity, as well as offering some protection against uncertainty, may exploit some of the opportunities for improvement that it offers, and its short-run inefficiencies may be a cost of growth as well as a cost of survival. The homogeneity within each industry which appears to be so desirable a feature of both perfect competition and an ideal planned economy (and which has appealed to governments impressed with both the economic potential and the administrative convenience of supporting 'national champions') fails on both counts.

Uncertainty seems to be pervasive enough to justify an evolutionary approach to the growth of academic, technological and everyday knowledge, but an approach which is significantly different from the biological model; in particular, though rational choice models are inadequate, evolutionary processes in human societies need not, and I suggest should not, exclude rationality in the broad sense of acting for good reasons. 'Good reasons' depend on a structure of appropriate connections, the underlying source of which we shall find in the reliance on selected connections, or patterns, in human cognition.

Cognition

Human cognition is the product of biological evolution, to which the biological model may be presumed to apply. (This presumption is itself an example of the application of established patterns, which is a standard, and non-logical, cognitive operation.) Evolutionary fitness depends on the recognition of threats and opportunities, of many kinds, and on appropriate reaction to them, and this must occur at all stages of the sequence which eventually produced modern humans. It seems clear that brains could not have developed as logical processors under these conditions, for they are conditions which impose Knightian uncertainty on all forms of life. What appears to have happened was the gradual supplementation of genetically-programmed behaviour by some capability of adapting behaviour to classes of situations through the development of environmentally-stimulated neural connections within the individual brain. This evolutionary pathway does not require the inheritance of adaptations, but only inheritance of the capability of adaptation, supplemented by the capability of imitating the adaptations of others; imitation would presumably be facilitated by the similarity between brains.

The effectiveness of this capability would be reinforced by a general motivation to invent patterns, even without much attention to the likelihood of success, on which Popper (1972, pp. 23-4) remarked. This powerful preconscious orientation to patterns, as Schlicht (2000) has suggested, may be the origin of our widely shared aesthetic sensitivity. We need not assume that fitness-enhancing patterns are error-free, because in many circumstances the balance of risks is asymmetric: in identifying prey or predators, for example, false positives are less costly than false negatives.

Among modern humans, genetic selection continues to provide both the basic architecture of the brain and the neural structures which control automatic activities; but the process of making sense of the world which begins at birth and, significantly, accompanies a substantial part of the development of the brain's architecture, creates for every individual a particular network of connections that imposes order on events and allows these ordered perceptions to be linked to actions, or at least to premises for action. It is this imposed order, not the events themselves, that constitutes experience, as Kelly (1963, p. 73) emphasises, and a shared belief in orderliness does not imply a shared belief in a particular kind of order: it is not uncommon to find that a particular series of events is construed in different ways by those who witnessed or participated in them. Like other evolutionary biological processes, the development of neural networks and the classification systems that they represent is path-dependent, although not path-determined, and relies substantially on exaptation, the extension or modification of existing structures for new purposes.

This organised system of connections we might think of as the evolved institutional structure which guides the thoughts and actions of each individual, and provides the basis for co-operation with others who rely on compatible structures. It strives to preserve its own coherence, even by denying the validity of information. This self-preserving structure is necessary in order to keep the energy demands of the brain within acceptable bounds; but it also has positive value, for without firm anchors, no intelligent variation is possible. What novelties are possible for any person at any point of time depends on the pre-existing structure and the history of past adaptations; but these constraints are rarely sufficient to be of much help in predicting novelty, except in a negative sense, because the potential range even of relatively small modifications to a reasonably complex set is very large. Thus these rules and routines make a double contribution to cognitive efficiency.

It seems clear that there is no point at which a switch to a logical processing system could have been successfully introduced into this evolutionary sequence, since this would entail a major restructuring of connections. The ability to construct logical inferences is a relatively recent and relatively weak development, almost an ‘artificial’ form of intelligence, and its effectiveness depends on the prior creation of appropriate categories, as has been repeatedly – and sometimes spectacularly – demonstrated. Logical skills are not easily transferred between domains, suggesting that piecemeal logic is a manifestation of particular localised connections. The argument from anticipated consequences, that is construed as rational choice may even be thought of as an extension of pattern-making.

Since the creation of neural networks preceded the emergence of conscious thought, which did not displace these networks of unarticulated ‘knowledge how’, it is necessarily true that we know more than we can tell, and that codification must always rest ultimately on tacit knowledge. That is not to deny the value of codification; but it reminds us of the fundamental importance of neural coding – which may not correspond to later attempts at codification. Hayek's (1952) account of the formation of our sensory order, formulated at the outset of his career, is a remarkable anticipation of this model of evolutionary psychology, which Hayek uses to explain why the connections of science often fail to match the evidence of our senses. A similar evolutionary sequence, from connections between impressions and actions to connections between ideas of impressions and actions, including the imagination and anticipatory (though fallible) selection of possible connections, was conjectured in Alfred Marshall's (1994) early paper 'Ye Machine', which predates his interest in economics.

With the emergence of consciousness, the growth of knowledge and skill becomes increasingly subject to deliberate control, though this control is necessarily highly selective – the equivalent of 'management by exception' – and not always effective. Human purpose appears, as a genetically-induced alternative to genetic programming which extends the range of options by the equivalent of 'management by objectives'; and human action, though still conditioned by our biological heritage, is now often the result of human design – though rarely accomplishing precisely what was intended. Penrose (1952) rightly pointed out that the absence of purpose from the biological model of evolution disqualified that model from any simple application to social systems; but she explicitly distanced herself from rational choice theory in seeking to explain the growth of the firm (Penrose 1959, 1995). Her explanation is set in the context of Knightian uncertainty with its twin features of incompletable knowledge and the scope for imaginative conjecture, and it turns on the emergence of new knowledge and skills in the process of running the business and the selection of uses to which some of these new resources may be applied. There is purpose and pattern, but nothing approaching omniscience; human design is inherently fallible, because it relies on knowledge which is incomplete and sometimes erroneous. Thus there is ample room, even within an industry, for the generation of different actions and different patterns of knowledge, to be subjected to selection which may lead to modification of actions and patterns.

The consequences of cognition

Our reliance on patterns of neural connections which generate a range of distinct associations and procedures makes possible the evolution of human knowledge and of activities and organisations which produce and use that knowledge. Our shared mental architecture leads us to expect other people also to rely on such procedures; this is a necessary condition of all social life, and of especial interest for the functioning of any large organisation, or network of organizations. In addition we are often able to benefit from the 'vicarious experiments' offered by variations within groups (Choi 1993); thus skills and knowledge may be selectively transmitted between members of a community by non-genetic means (although the capability for transmission must itself be genetically transmitted). This non-genetic means of transmission transforms the rate of diffusion, and it is the real-world process that underlies the grossly over-simplified concept of public knowledge as a free good.

This sharing of patterns and procedures, which may be thought of as supplementing our internal mental organisation by external organisation, greatly improves human efficiency, even when actions do not need to be co-ordinated; by simple exaptation it supplies a basis for co-ordination, and may suggest the desirability of agreeing on new patterns for further co-ordination. As Choi notes, Adam Smith's ([1759] 1976a) *Theory of Moral Sentiments* provides a model for this argument. The perceived benefits of conforming to other people's procedures also encourage the acceptance of authority, in Chester Barnard's (1938) sense of 'taking someone's word for it' in very many situations. As Claude Ménard (1994) has pointed out, hierarchical relationships, though important, generate a relatively small proportion of authoritative communications; the development of non-hierarchical authority relationships is a major contributor to organisational coherence, and a major force in preserving the organisational coalition. (Sometimes the acceptance of authority is a means of saving mental energy for life outside work, as organizational psychologists have noted; this is perhaps a more common form of opportunism than that invoked to explain why firms exist.)

Institutional clusters not only provide an important basis for choosing our own actions; they also facilitate improvement by providing the margins at which such improvement may most conveniently be sought and a baseline against which experiments may be evaluated. This was an essential part of Marshall's explanation of incremental growth, and a dynamic aspect of his principle of substitution. Because the cognitive capacity of every person is much less than the potential range provided by the architecture of the brain, different individuals use this capability of pattern-creation in different ways in different circumstances, and according to the particular history of the groups that are using them – even within an industry. Individuals and organisations engaged in similar activities therefore have somewhat different margins at which experimentation is likely to occur, as Marshall (1920, p. 355) noted, thus encouraging the 'tendency to variation' that he identified as a chief cause of progress.. The connection between Marshall's account of economic progress and his early sketch of cognitive development, which is broadly compatible with that outlined in this paper, has been argued by Raffaelli (2001).

The growth of knowledge

If the natural differentiation of circumstances is accentuated by the division of labour, then the possibilities are enormously expanded. The recognition of the power of the division of labour between trades to generate knowledge was Adam Smith's ([1776] 1976b) great contribution to the understanding of economic progress; and it seems to have resulted from his interest in the problem of human knowledge, stimulated by his close friendship with David Hume. The sequence appears to have been from his cognitive theory of science as the invention of connecting principles (Smith [1795] 1980), by way of the rhetorical appeal of such principles (Smith 1983) and his analysis of the importance of widely-shared moral sentiments as adopted rules of behaviour (Smith [1759] 1976a), to his theory of economic development (Smith [1776] 1976b), thus illustrating in his own mental processes the connectionist character of human thought that he began by emphasising, and providing an outstanding example of exaptation.

Smith's ([1795] 1980) exploration of 'the principles which lead and direct philosophical enquiries' is an evolutionary theory of the growth of human knowledge, which Hume had shown could not be a logical process. It is founded on the desire to escape the discomfort of being unable to make sense of phenomena by inventing patterns that appealed to the imagination; as he shows by his examples, this is not a random process, but is powerfully influenced by aesthetic considerations. Though directly influenced by particular environments, the creation of knowledge by the formation of connecting principles is a process of trial and error, in which Newtonian cosmology, however deserving of approbation, is the product of Newton's imagination and therefore subject to possible falsification at some future date through its failure to encompass new observations, just like its predecessors; but because the failure of a hitherto successful pattern creates a powerful incentive to find a replacement, the growth of knowledge is self-sustaining through the interaction between human motivation and human capability. Smith's link between the growth of scientific knowledge and economic development through the division of labour was provided by his observation that increasing specialisation between emerging scientific fields leads to greater attention to detail and therefore an increased likelihood of discovering inadequacies in the patterns currently being applied in each of those fields. We might think of this account of scientific differentiation as a pre-Darwinian theory of speciation.

John Ziman likewise treats the growth of scientific knowledge as an easily recognisable exemplar of the growth of all human knowledge. 'Human beings owe much of their success as organisms to the further evolution of more complex cognitive capabilities, such as recognising patterns, defining similarity classes, constructing "maps" and mental models, and transforming these socially, through communication, into intersubjective representations' (Ziman 2000, p. 300), and 'the *epistemology* of science is inseparable from our natural faculty of *cognition*' (Ziman 2000, p. 289). Uncertainty is pervasive, and explanation depends on 'the linkage of a known empirical phenomenon into a wider network of accepted – or at least potentially acceptable – "facts" and concepts' (p. 291). A theory is a mental structure which must be capable of being shared with other members of the relevant community, and the effectiveness of the process of variety generation and selection within that community depends on its members' adherence to a particular set of norms, which are the equivalent of Smith's moral sentiments. Science depends on what Simon called procedural rationality, embodied in the general institutions of science and the particular institutions of each discipline.

Data alone do not constitute knowledge; for knowledge lies in the particular connections between elements, rather than the elements themselves. Knight (1921, p. 206) argues that 'in order to live intelligently in our world … we must use the principle that things similar in some respects will behave similarly in certain other respects even when they are very different in still other respects'. In Smith's words, we rely on 'connecting principles' of association and causation in developing our own ideas and in adapting other people's, applying different contexts of similarity to situations that we judge to be different. As Popper (1963, p. 44) has pointed out, similarity is always relative to a point of view, and points of view may differ. Some differences may threaten the cohesion of an organisation, but when there is no correct procedure differences in ways of thinking between organisations generate the variety which drives the growth of knowledge. The recognition of such differences within a firm is often the stimulus for an individual or group to leave in order to create a new business, founded on new connections and therefore with new margins at which to experiment. Uncertainty is the precondition of knowledge, and human cognition provides the means by which knowledge can be grown from uncertainty. 'The supply conditions for new knowledge depend on the present state of knowledge' (Metcalfe 2001, p. 148); the sequence matters because connections matter.

In this process, institutions supply a number of indispensable functions. By simplifying the performance of many activities, including the making of many decisions, they economise on the energy demands of the brain, and also provide, in Shackle's (1967, p. 286) words, '[a] sense of order and consistency' which is a psychological necessity. They set bounds to uncertainty; and '[t]he boundedness of uncertainty is essential to the possibility of decision' (Shackle 1969, p. 224). The combined effects of energy saving and reassurance permit imagination and experiment, while institutions provide both the necessary baseline and the boundaries across which one may move to an adjacent state of knowledge. Institutions cannot protect against all uncertainties, but they may be adapted to give better protection against new uncertainties.

We all operate within our own contexts of similarity, and when we encounter new problems we look for a partial match (Potts 2000, p. 121) and experiment with exaptation: that is how the division of labour leads to differentiated knowledge. If we think of the knowledge on which we can rely as particular patterns of connections, and potential new knowledge (which, of course, is often false) as new connections that extend or modify some of those patterns, we find it easy to accept that standard procedures and true novelty are both products of our mental architecture. They are interdependent: without our reliance on standard procedures it would be hard to identify situations in which new knowledge seemed to be needed and without some rules of procedure and premises for thinking it would hardly be possible to reduce the search space to manageable proportions. (This is the foundation of Simon's theory of organisation, in which effective performance requires agreement on a set of facts and a set of decision premises.) New connections that provide us with new rules and routines which improve our understanding and our actions release cognitive capacity for new applications, as in Penrose's (1959, 1995) conception and use of 'the receding managerial limit'.

Innovation may require the breaking of some established connections, but if the innovation is to be successful the new connections must be adequate substitutes for the old in forming complementary relationships with some established patterns. The new ideas and the old may be incommensurable in the straightforward sense of not being partitions of a single structure of knowledge (and therefore not susceptible to standard economic analysis in terms of information sets), but successful novelty is carried by what Schlicht (2000) calls 'good continuity'. Unless carefully thought out and skilfully managed, major transformations may fracture this continuity and subvert the established basis for creating and using knowledge. It is no accident that Schumpeter (1934) saw major innovations as the work of outsiders, and their impact as destructive of established order: when the familiar basis for decision-making is overthrown, people do not know what to do, and the result is idle plant and unemployment; but Schumpeter insisted that the emergence of a new institutional framework could not be hurried.

Attempts to recast an economic system have similar effects: in Spring 1990 Ludwig Lachmann drew on his deep understanding of the significance of institutions to warn that 'getting market economies started in Eastern Europe, after half a century, will give rise to a host of problems hardly as yet appreciated. … The more I think about Russia the more pessimistic I become. How can this turn out well? Of course, market institutions cannot be introduced by political fiat' (Loasby,1998, pp 13-14). Having failed to recognize the need for an institutional basis for planning, it is unfortunately not surprising that economists advising the governments of transition economies neglected the importance of 'good continuity' in the institutional changes towards a very different system; it is consequently not surprising that much of the institutional adaptation that occurred has had unwelcome consequences, many resulting from exaptation of long-established informal institutions. Schumpeter's (1942) own prediction of a transition from capitalism to socialism assumed the gradualness of the process – and, not coincidentally, increasing success in directing the growth of knowledge.

Conclusion

Evolutionary processes combine the generation of variety and selection from this variety. As we have seen, the genetic capability of developing a set of behaviours, out of a very large potential, by selecting connections in response to perceptions of phenomena, together with the emotional impulse to develop particular parts of this potential, is the biological precondition of modern economic systems. However, although neoDarwinian evolution explains this precondition, and encourages us to postulate stable genetic characteristics in modern human populations, it is not a good model for the development of human knowledge. Because both practical and formal knowledge is incompletable there is always the possibility of improvement through the imagination of new categories and new connections; neither the capacity nor the motivation to imagine has any parallel in the processes of genetic mutation and recombination, and the effective selection criteria for new knowledge, both theoretical and practical, include emotional and aesthetic as well as 'rational' elements. The processes of variety generation and selection are often deeply intertwined: the incubation of a new artefact, a new method of production, a new form of organisation, or a new way of thinking involves frequent rejection of candidate variants which leads directly to new variants, all within an institutional setting which may itself be modified during these interchanges. The organisation of knowledge is supported by the organisation of the process of generating, testing, and modifying knowledge; and the reliability of knowledge – and not only scientific knowledge – depends on these processes (Ziman 1978).

The specific characteristics of human cognition underlie Smith's recognition of the crucial importance of the division of labour as a non-biological evolutionary process that has operated much faster than biological evolution and encompassed unprecedented categories of applications. The combination of uncertainty – the unlistability of possibilities and the absence of any procedure, known to be correct, for assessing and evaluating those possibilities which are listed – and the evolved characteristics of human cognition warns us of the likelihood of failure and at the same time creates the alluring prospect of extraordinary success, as well as explaining our reliance on institutions. The growth of knowledge depends on the diversity of individual initiative, but also on the relationships, formal and informal, between individuals. For every one of us, as well as for the communities to which we belong, knowledge depends on the organisation of categories and the relationships between them; and the organisation of people into categories and relationships, if appropriately managed, aids the development and use of knowledge in society.

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