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Evolutionary Progress

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ABSTRACT:

This article identifies evolutionary processes which produce progressive change, outlines the sequences of events in the evolution of life on Earth which have resulted from these processes, and predicts key future developments in the evolution of life. Progressive evolution is driven by the potential benefits of cooperation among living processes. These benefits are able to be exploited by the formation of hierarchical organizations in which managing entities with the ability to control other entities support co-operators and suppress cheaters. Examples of hierarchical organizations of this type include early cells in which RNA manages molecular processes, and modern nation states in which governments manage human organization. However, the formation of hierarchical organizations will not fully realize the potential benefits of cooperation, and will not end the progressive evolution which is driven by this potential: it is only within these organizations that cooperation can be comprehensively exploited. The widely recognized impediments to the evolution of cooperation will continue to apply to interactions between organizations. The potential benefits of cooperation between organizations will therefore drive the formation of higher level organizations. The continued repetition of this process will progressively extend cooperative organization across greater scales of space and time.

1. Introduction

In the first part of this century, there was widespread support for the view that the evolution of life is directional, that the direction is progressive, and that humans are the culmination of this process (e.g., see Blitz, 1992; Ruse, 1996).

However, in recent years this position has been vigorously criticized as being unsupported by theory or evidence, and as being driven by anthropocentrism and wishful thinking (e.g., see Williams, 1966; Hull, 1988; Gould, 1996).

More specifically, Maynard Smith (1988) argues that a fundamental problem for the progressive view is that current evolutionary theory does not predict a general increase in anything: theory has been unable to demonstrate that adaptation to local circumstances which is driven by natural selection will lead to indefinitely continuing change, let alone to progress; some directional change can be expected, but it will end as selective circumstances change or as opportunities for further adaptive improvement are exhausted.

This article develops a theoretical perspective which identifies evolutionary processes that produce progressive change, outlines the sequences of events in the evolution of life on Earth which have resulted from these processes, and predicts key progressive developments in the future evolution of life.

The article begins in Section 2 by identifying the features of evolving living processes which drive indefinitely continuing, progressive change. This is followed in Section 3 by an examination of the specific types of evolutionary change which are driven by these processes. Section 4 identifies key developments in the evolution of life on Earth which are part of this progressive change. This includes an examination of the location of humanity in this evolutionary progression. The article concludes in Section 5 by testing this new theoretical framework against various criticisms that have been directed at previous progressive approaches.

2. The Source of Continuing Progressive Change

If a theory is to convincingly demonstrate that evolution is progressive, it must identify a potential for beneficial adaptation which continues indefinitely as living processes evolve. To be indefinitely continuing, such a potential must exhibit a number of characteristics. First, the potential must be insatiable: no matter what adaptations are discovered in response to the potential, the potential must continue to favour further adaptation; the potential must never be exhausted, no matter how far adaptation proceeds. Second, the potential for adaptation must apply generally to living processes through time, and not be generated by contingencies which vary with local circumstances in space or time.

I will argue here that the potential advantages of cooperation amongst living processes across space and through time provide such a continuing potential for beneficial adaptation.

In short, this is because evolutionary processes such as natural selection are unable to exhaust the potential for beneficial cooperation by simply establishing and optimizing cooperative arrangements among living entities. Natural selection is able to comprehensively exploit the benefits of cooperation between living entities only through the formation of complex organizations of entities which are of limited scale in space and time (e.g., cooperative organizations of molecular processes forming early cells, organizations of cells forming metazoans, and organizations of humans forming human societies). However, the benefits of cooperation between these complex organizations will not be able to be exploited by natural selection except by the formation of yet higher level organizations. Indefinite repetitions of this process will extend the scale in space and time of organizations in which the benefits of cooperation are exploited, but will leave unexhausted the potential for cooperation between organizations of the largest scale.

I will now deal with these issues in greater detail.

The potential benefits of adaptations which establish cooperative arrangements among living entities are well known, whether the entities are molecular processes, cells, multicellular organisms, or human nation states. In particular, cooperation between entities can avoid the costly consequences of the pursuit by individuals of their individual interests at the expense of others, and can provide the advantages of cooperative differentiation, specialization, and division of labour (e.g., as exemplified by molecular processes within cells, cells within metazoans, and human activities within modern economies). Cooperative organization can also establish coordinated action across greater scales of space and time, enabling adaptation to external events of greater scale (e.g., metazoans can generally adapt successfully to larger scale threats than can single celled organisms).

However, the impediments to the ability of natural selection to take advantage of these benefits of cooperation among organisms is equally well known. In most circumstances, selection will favour individuals which use resources for their own benefit, rather than for the benefit of others. Individuals which use resources in cooperative activities which predominately benefit others are likely to be selected against, no matter how beneficial the cooperative effects on others may be, and irrespective of whether the resultant cooperative arrangement is more competitive as a whole. These impediments apply whether the cooperation immediately benefits others, or whether it benefits others in the future (e.g., in subsequent generations). And in most circumstances, selection will favour “free riders” or “cheats” who undermine cooperation by taking any benefits provided by co-operators, without cooperating in return. In most circumstances, beneficial cooperation will evolve only to the extent that co-operators benefit from all the beneficial effects of their cooperation on others.

A number of mechanisms have been identified which enable cooperative adaptations to capture the benefits of cooperation in some circumstances — for example, mutualism, genetical kinship theory (Hamilton, 1964), and reciprocity theory (Trivers, 1972; Axelrod & Dion, 1989). However, these operate only under restricted conditions, and have been able to produce only limited cooperation in non-human metazoans (compared with the extraordinary level of beneficial cooperation found within cells, within multicellular organisms, and within human societies).

These impediments to the evolution of cooperation between individuals also apply at all other levels of biological organization — for example, in the evolution of cooperation between molecular processes (Maynard Smith, 1979; Bresch et al., 1979; Maynard Smith & Szathmary, 1995), between cells (Buss, 1987), and in the evolution of cooperation between humans (Olson, 1965; and Williamson, 1985).

The existence of these impediments to cooperation means that evolutionary processes such as natural selection are not able to easily exhaust the potential for beneficial cooperation by simply establishing and optimizing cooperative arrangements. However, where the evolutionary process is able to establish the complex, hierarchical organizations of individuals identified by me (Stewart, 1995, 1997a), the benefits of cooperation will be able to be comprehensively exploited among individuals within the organizations. As will be considered in more detail in the next Section, the formation of these cooperative organizations relies on the evolution of entities able to manage and control the other entities in the organization, supporting beneficial cooperation and inhibiting free-riding and cheating. These controlling entities may be external to the entities they control, or internal to them. Examples of the formation of cooperative higher-level organizations which each constitute a higher-level entity include the organization of molecular processes into cells, of cells into metazoans, and of humans into human societies.

However, the formation of organizations in this way is able to establish cooperation only between individuals within each higher level entity. The impediments to the ability of natural selection and other evolutionary processes to establish cooperative arrangements between these higher level entities will apply as it does to entities at any level. Again, these impediments will drive the formation of cooperative organizations of the higher-level entities. Again, however, this will enable beneficial cooperation to be exploited only within the new organizations, but not between them. Through the progressive formation of higher- and higher-level organizations in this way, the benefits of cooperation between living processes can be extended over greater scales of space and time, but without exhausting the potential for further cooperative benefits: the potential for even further beneficial cooperation will not be exhausted until all living processes which could interact significantly are permanently organized into a single entity, and there is no possibility of life arising outside the entity which could interact significantly with it.

On this basis, the potential advantages of cooperation among living processes qualify as an indefinitely continuing potential for beneficial adaptation which will drive progressive evolution: the potential will continue indefinitely, and the potential applies generally to living processes through time. However, it should be noted here that the general application of the potential does not mean that all living processes will realize the potential by discovering cooperative arrangements or by discovering the hierarchical forms of organization which enable cooperation to be more full explored. For example, as we will consider in greater detail in Section 5, the fact that many populations of bacteria do not yet participate in cooperative hierarchical organizations is not a demonstration of the lack of general application of the potential for beneficial cooperative adaptation.

3. The Nature of Progressive Evolutionary Change

In this Section we will identify in greater detail the nature of the evolutionary changes which will be driven by the potential advantages of cooperation. In doing so, we will focus on the evolution of changes which allow cooperative possibilities to be explored, rather than on the evolution of specific cooperative adaptations such as anatomical, physiological, behavioural, or technological adaptations. This is because findings of the greatest generality are more likely to apply to the evolution of the arrangements which establish and adapt the specific cooperative adaptations; the specific cooperative adaptations themselves are more likely to be contingent and vary with local circumstances.

3.1 Management

I began the development of a theory of the evolution of organizational arrangements (Stewart, 1995 and 1997a) which are able to comprehensively overcome the initial impediments to the ability of evolutionary processes such as natural selection to discover, perpetuate, and adapt beneficial cooperative arrangements between living processes. Here we will further develop those elements of the theory which are relevant to progressive evolution, and use the theory to identify key milestones in the evolutionary expansion of cooperative organization over greater scales of space and time.

I suggested that the critical evolutionary step in overcoming the impediments to cooperation at a particular level of organization is the emergence of entities able to manage and control other entities. We will first consider the case where the managing entities are external to the entities being controlled.

3.1.1 Upper-Level Management: When they first arise, these managing entities can be expected to use their control over other entities to unilaterally appropriate resources and services from them. For example, managers may move between groups of entities, extracting as much as possible from each group and destroying the group in the process. However, in appropriate circumstances, selection would favour managers who discover ways of intervening in groups of entities to increase the availability of resources which are able to be harvested by the managers. Because of the impediments to the evolution of cooperation, a manager can do this by intervening in a group in ways which produce beneficial cooperative arrangements which would not otherwise arise within the group. The manager will be able to harvest additional benefits produced by these interventions. Such interventions could, for example, support altruistic specialists which would otherwise be out-competed within the group, and inhibit cheating which would otherwise reduce the extent of cooperation between members of the group.

Selection can be expected to favour enhancement of the management ability of managers. This will involve the discovery of management controls which are more efficient at supporting cooperation and which expand the range of cooperation which can be supported. Importantly, this will also involve improvements in the adaptability of management. The capacity of management to efficiently search the space of possible management controls will be enhanced, facilitating the adaptation of existing controls and the discovery of new controls which support better cooperative arrangements. The evolution in this way of a comprehensive ability to discover and adapt controls which support specialists and inhibit cheating will enable the emergence of the extraordinary level of cooperative differentiation and division of labour which characterizes the key evolutionary transitions to higher levels of organization.

It is worth emphasizing here that the full exploration of cooperative possibilities requires management which is capable not only of sustaining cooperation throughout the organization, but also of adapting and improving management controls. The potential benefits of cooperation can therefore be expected to drive not only the progressive formation of hierarchical organizations of wider and wider scales, but also progressive improvements in the adaptive abilities of these organizations.

Selection can also be expected to favour improvements in the capacity of managers to capture the benefits of their interventions. For example, managers might establish longer term associations with a particular group, and might use their control over the group to establish arrangements which prevent access to the group by other managers or entities which might appropriate resources from the group. The result of this evolutionary sequence will be the formation of new hierarchical organizations which each comprise a group controlled by a manager. The new organizations will constitute entities at a higher level of organization.

Importantly, the evolution of these cooperative organizations is favoured not only at the level of the group, but also at the level of the individual entities involved: the sequence will unfold if the entities do no more than follow their individual evolutionary interests. The key to this is that the inability of natural selection to exploit the benefits of cooperation among entities provides the opportunity for managing entities to increase their individual fitness by supporting and enhancing the success of the group rather than by simply exploiting it. And the control applied by the manager insures that the entities in the group act cooperatively, consistent with the manager's interests. To the extent that the interests of the manager and the organization coincide, the entities in the group will be managed so that their interests are aligned with the interests of the organization. In the absence of this management, it would not be in the interests of individual entities to cooperate.

Ideally, management will ensure that individuals are adapted so as to take into account not only the effects of their actions on themselves, but also the effects of their actions on others in the organization and on the organization as a whole, no matter how distant those effects may be in space or time. Ideally, the evolutionary interests of the manager and of the organization will fully coincide, and therefore the adaptation of management will also take into account the effects of its actions on all others in the organization. The effects of actions on others will be taken into account as if they are effects on the individual exhibiting the action. When this ideal is met, individuals will act as if they treat the other within the organization as self. Until this ideal is met continuously within an organization, the potential for beneficial cooperation will not be fully exhausted, and there will be a potential for further progressive evolution toward the ideal.

Examples of cooperative, hierarchical organizations which have evolved in this way are protein-based autocatalytic sets managed by RNA to form early cells, and human groups managed by rulers to form, for example, early kingdoms.

RNA has the ability to control protein-based autocatalytic sets through its capacity to catalyse particular proteins. For example, RNA may catalyse a protein which advances the RNA's interests by assisting the reproduction of the RNA. Because of the impediments to cooperation within autocatalytic sets (e.g., see Bresch, et al., 1979; and Maynard Smith, 1979), RNA has the potential to use its catalytic capacity to advance its interests by promoting cooperation within the set (e.g., by the catalysis of altruistic proteins, or of proteins which inhibit the reproduction of “cheats”). The resultant increased efficiency of the set can benefit the RNA directly by providing more resources for its maintenance and reproduction, and also by increasing the competitiveness of the organization as a whole.

Similarly, a human ruler has the capacity to control his/her subjects through his/her capacity to apply incentives and disincentives which motivate behaviour which may, for example, advance the ruler's interests. Again, the impediments to cooperation provide the ruler with the potential to increase the efficiency of his/her kingdom and advance his/her interests by interventions which enhance beneficial cooperation between the ruler's subjects (e.g., though the promotion of cooperative economic exchange relations between subjects by punishing individuals who cheat in exchanges, and by redistributing appropriated resources to support defence of the kingdom).

As I have demonstrated in detail (Stewart, 1997a), life itself originates through the formation of cooperative hierarchical organizations: a key step in the evolution of life is the emergence of relatively large, stable molecules (or groups of molecules, as in an autocatalytic set) which use their capacity to control and manage the activities of smaller-scale atoms and molecules to maintain themselves and to produce replicas of themselves. Again, the essence of this evolution is the discovery by managing entities of ways of controlling and coordinating other entities so as to enhance the evolutionary interests of the managing entities and the assemblage as a whole. The result is the formation of hierarchical organizations such as the autocatalytic sets which manage proto metabolisms, as described by Bagley and Farmer (1991).

3.1.2 Lower-Level Management: The discussion to this point has focused on the evolution of cooperative hierarchical organizations in which management is exercised by entities which are external to the entities being managed. In the terminology of Salthe (1985), such managers control a group of entities by providing upper-level constraints or boundary conditions for the entities. However, as detailed by Salthe (1985), control can also be exercised by lower-level constraints or initiating conditions. Typically, these lower-level constraints are established by intrinsic properties of the entities being controlled. They are lower-level entities in the nested hierarchies which constitute the entities being managed, and they “hard wire” the entities to behave in particular ways. For example, genes act as lower-level constraints on cells and metazoans, while both genes and inculcated norms of behaviour act as lower-level constraints on humans.

It is clear that the behaviour of a group of humans is able to be controlled by an upper-level manager such as a ruler who provides an appropriate pattern of incentives and disincentives to which members of the group adapt. Equally, the behaviour of the group could also be controlled by a process which constitutes the group with members who have particular intrinsic properties which constrain and predispose them to behave in particular ways. For example, cooperation could be promoted in a group either by the constitution of the group by individuals who are internally constrained genetically or culturally to behave in a trustworthy fashion in economic-exchange relations, or by an external ruler who punishes those who behave otherwise.

If a lower-level constraint is to manage a group of individuals, it must be able to exercise a degree of control over each of the individuals in the group. This can be achieved, for example, by the reproduction of the constraint in each of the individuals, thereby insuring that each individual is constrained by a replica of the constraint. For example, an insect society can be controlled by a cluster of genetic elements to the extent that the cluster is reproduced in each member of the society, and a group of human hunter-gatherers can be controlled by a cluster of inculcated behaviour patterns to the extent the cluster is reproduced in each member of the group.

Provided the lower-level manager is evolvable, selection can favour the establishment by the manager of constraints which control the group in ways which enhance the success of the manager. For example, a lower-level manager reproduced across a group may actuate individuals to behave in ways which directly enhance the reproduction of the manager (e.g., the lower-level manager may be a cluster of norms which actuate the members of the group to inculcate others with the norms).

Furthermore, because of the impediments to cooperation, lower-level managers have the same potential as upper-level managers to enhance their interests by the promotion of cooperation amongst the individuals who comprise the group. Selection can therefore favour lower-level managers who constrain the behaviour of individuals in a group in ways which promote cooperation and which ensure that the management which establishes the constraints captures the benefits of the cooperation. For example, the lower-level manager may actuate altruistic behaviour and constrain the altruists to preferentially direct their altruism to those who are more likely to include instances of the lower-level manager (e.g., genetical kin selection); and may actuate behaviour which punishes members of the group whose cheating demonstrates that they do not include instances of the manager (e.g., see Boyd & Richerson, 1992). In this way, lower-level management can sustain cooperative arrangements in a group by hard-wiring members of the group to behave in ways which may be inconsistent with their individual interests.

In summary, the potential for beneficial cooperation amongst living entities at any level of organization can be realized to an extent by the formation of hierarchical organizations in which the entities are managed by an upper or lower-level manager. However, the extent to which this will enable the benefits of cooperation to be explored across space and time will still be limited; it will comprehensively explore cooperation only amongst entities within an organization. As a consequence, the unrealized potential for beneficial cooperation across greater scales (e.g. between organizations) will drive the repeated formation of hierarchical organizations in this way, and will drive improvements in the ability of the organizations to discover and perpetuate beneficial cooperative adaptations, extending cooperation over greater scales of space and time.

4. The Evolution of Life on Earth

The application of this analysis to the history of life on Earth enables us to identify and interpret key milestones of evolution on this planet. The first three major organizational transitions in the evolution of life each involved the formation of cooperative organizations in which entities were controlled by upper-level management. The first step saw the management of a proto metabolism of atoms and molecules by a macro molecule or by an autocatalytic set of macro molecules to form a reproducing assemblage. The second step saw the management by RNA of these assemblages to form early cells, and the third saw the management of associations of prokaryotic cells by DNA to form eukaryotic cells. These steps were necessarily sequential in that the organizations formed by the first step gave rise to the entities which were managed in groups to produce the cooperative organizations formed in the second step, which in turn gave rise to the entities which were managed in groups to produce the cooperative organizations formed in the third step. The result has been organisms which are organized as nested hierarchies.

The formation of groups of entities managed by lower-level rather than upper-level managers could not emerge immediately in the evolution of life. This had to await the evolution of organisms which contained evolvable lower-level constraints which had the management ability to discover and produce complex cooperative interactions between organisms. The evolutionary sequence outlined above eventually produced organisms with lower-level constraints of this type. This occurred firstly because the progressive evolution discussed above tended to produce upper-level managers with improved management abilities to discover and perpetuate beneficial adaptation, and secondly because these upper-level managers also were lower-level constraints within the organisms which included them. They therefore had the potential to form the lower-level manager of a group of organisms by being reproduced in each member of the group (e.g., the genetic arrangements of a cell are an upper-level manager in relation to the molecular processes which are managed by the genetic arrangements within the cell, but also act as lower-level constraints in relation to the cell as a whole. The genetic arrangements can therefore act as a lower-level manager of an organization of cells if the arrangements are reproduced in each of the cells in the group). The improvement in management ability occurred not only as evolution proceeded within each level of organization, but also as new levels of organization were formed. This is because the entities which evolve at one level participate in the organizations at the next, bringing to the new organizations whatever adaptive capacities they have evolved. In this way, each new level tends to build on the management capability developed at the previous level.

The eventual result was cells containing genetic arrangements which had the management ability to produce a wide range of constraints which were able to establish complex cooperative interactions between cells. Multi-cellular organizations were able to be established by lower-level genetic managers which were reproduced across the cells in the organization and which therefore were able to appropriately constrain the reproduction and other behaviour of the group of cells. For example, a genetic manager could establish control over a group of cells by managing their reproduction to ensure that the manager was reproduced in each cell, and by insuring that any variant cells which were produced did not contribute to the next generation (e.g., see Buss, 1987). The lower-level management of multicellular organization which was established in this way enabled the comprehensive exploration of the benefits of cooperative arrangements between cells which permitted the extraordinary level of cooperative differentiation and division of labour which arose in metazoans.

The evolution in this way of organizations managed by gene-based lower-level managers could be readily repeated to form higher-level organizations. This could occur once the management ability of the lower-level management of multicellular organizations improved sufficiently to produce a wide range of constraints which could establish complex cooperative interactions between multi-cellular organizations. The result has been, for example, insect societies which are managed with varying degrees of effectiveness by gene-based lower-level managers.

In this way, the fourth and fifth major organizational transitions in the evolution of life on Earth each involved the formation of cooperative organizations in which entities were controlled by gene-based lower-level management.

4.1 The Evolution of Organizational Adaptability

The next significant organizational transitions had to await further improvements in the adaptive capacity of management. In particular, these further transitions depended on the emergence of management with the capacity to adapt the organization continually during its life. As we shall see, organizations with this capacity readily formed new, higher-level cooperative organizations.

The capacity of the organizations produced in the first five organizational transitions to adapt and improve these cooperative arrangements during their lives was initially limited. This was because the managing entities initially had little ability to adapt their management controls during their lives, and therefore little ability to ensure that cooperative arrangements were adapted during the life of the organization. The managers had no capacity to adapt heritably through processes internal to the manager (in contrast to, for example, human individuals who have the potential to discover culturally heritable adaptations during their life through processes which are internal to the individual). Instead, management adapted through natural selection operating on genetic differences in management ability between organizations — i.e., through the differential reproductive success of organizations which varied in their management capacity.

This had important consequences for the way organizations were optimally structured. It meant that management could not adapt its controls to appropriately manage new variants that might arise within the organization (e.g., by suppressing new cheats and free-rider variants which, unless controlled, might undermine cooperation in the organization). As a result, selection favoured management which suppressed the possibility of differential success among new heritable variation within the organization during its life (e.g., by preventing the production of any heritable variation within the organization, except in conjunction with the reproduction of the organization). This is achieved in cells and in multicellular organizations by gene-based management which permits the production of heritable variation in the organization only in conjunction with variation in management. And any differential success among variation within management is itself prevented within the organization, ensuring that effective management is not disrupted by competition between variants. As pointed out by Wilson and Sober (1989), the result is the suppression of differential success among heritable variation within the organization during its life, concentrating variation and selection at the between-organization level. (I deal elsewhere in greater detail with the evolution of arrangements which suppress competition within management and within the organization; see Stewart, 1997a.)

The emergence of organizations managed by entities which were limited in their ability to adapt their management during their life therefore did not exhaust the potential for beneficial cooperation even within those organizations. Consequently, the progressive evolution driven by the potential for beneficial cooperation did not end within each level of organization with the emergence of such organizations. The unexhausted potential drove a further progressive evolutionary sequence in which the management of organizations evolved the ability to continuously adapt organizations cooperatively during their life. This included the capacity to adapt cooperative arrangements to changing circumstances, the ability to improve existing management arrangements, the establishment of new forms of management (e.g., the endocrine and nervous systems are new upper-level systems of management established by the lower-level genetic management of multicellular organisms), and the ability to transmit adaptations between organizations, i.e., heritability (here heritability is used in the widest sense to include not only transmission of adaptive information from parents to progeny, but also transmission between other individuals).

I examine, below, in greater detail the key milestones in the evolution of the adaptive capacity of management.

4.1.1 Hard-Wired Adaptability: The simplest type of arrangement which would adapt management to changed circumstances during the life of an organization is one in which the adaptation is pre-programmed or hard-wired. That is, the nature of the adaptation and the circumstances under which it is invoked is determined by a fixed mechanism within the organization: there is no trial-and-error testing of alternative adaptations within the organization itself. The trial-and-error process which discovers these adaptations and hard-wires them in the organization is natural selection, which operates at the between-organization level (e.g., selection operating on genetic variation between cells or multicellular organisms).

However, pre-programmed adaptation is limited: it is unable to discover new adaptations during the life of the organization. This is particularly limiting where organizations often encounter novel circumstances in which the optimal adaptation is also novel. Where this is the case, pre-programmed adaptations favoured by selection in past circumstances will be suboptimal. As the adaptive capacities of organizations improve, the extent to which there is advantage in novel adaptation during the life of the organization is likely to increase. This is because when the environment encountered by each individual organization is considered on a scale which is fine enough, the environment will be continually novel. And, as the adaptive capacities of organizations improve, they will tend to be able to find advantage in adapting to finer and finer environmental differences (Stewart, 1993; Stewart, 1997b).

4.1.2 Internal Testing of Possible Adaptations Against Immediate Effects: Selection will therefore tend to favour the emergence within the organization of mechanisms which are able to test and discover new adaptations during the life of the organization. These mechanisms will select adaptations by testing variation against proxies for organizational success. The simplest mechanisms of this type are the ultra-stable arrangements identified by Ashby (1960). Here the proxy for organizational success is the state of an essential variable which will be changed by environmental perturbations which are detrimental to the organization. Adaptation to the perturbation is achieved by varying relevant parameters in the organization through trial and error until the essential variable is returned to its optimal range. Most homeostatic mechanisms are instances of ultra-stable arrangements.

It will be useful when examining other adaptive mechanisms to translate the terminology used by Ashby for ultra-stable adaptation into a more general form: the preferred range of the essential variable is the objective/value pursued by the adaptive mechanism; the particular pattern of trial and error changes in relevant parameters which are tested in the attempt to satisfy the objective/value is the strategy (the better the strategy, the less trial and error needed to achieve adaptation); and the value of the parameters which satisfies the objective/value by returning the essential variable to its preferred range is the adaptation. In the simplest arrangements of this type, the strategy and the objective/value are established by natural selection operating at the between-group level (they are themselves adaptations in these wider adaptive systems). In more complex arrangements, the strategy and objective/value may themselves be established by ultra-stable processes within the organization.

As organizations differentiate, ultra-stable arrangements will also differentiate, so that each functional unit will tend to be adapted by ultra-stable arrangements which maintain essential variables associated with the unit. Because these arrangements will adapt each unit only in relation to the interests of the unit, they will in turn be managed by ultra-stable arrangements which manage the units to ensure that their adaptation takes appropriate account of wider interests in the organization. A group of units managed in this way will itself form a functional unit of wider scale in the organization. Repetition of this form of organization at wider scales in the organization will result is multi-level management hierarchies which adapt the internal environment of the organization to maintain homeostasis in the interests of the organization as a whole.

It is important to note here that selection favours the establishment of hierarchical arrangements which manage smaller scale adaptive units within the organization for exactly the same reasons that selection favours the formation of organizations of organisms controlled by upper or lower-level management: both the smaller-scale adaptive units and the organisms will tend to adapt in their own direct interests, and therefore will be unable to take advantage of the benefits of cooperative adaptation between units and between organisms; management enables these impediments to be overcome.

Similar arrangements can adapt the organization in relation to its external, behavioural interactions with the environment, including interactions with other organizations. In this case, behavioural actions are tested against their capacity to result in desired internal states within the organization, e.g., an organism might move actively throughout its environment until it encounters an area rich in food, upon which it ceases movement. Again, these adaptive mechanisms can be considered within the more general framework of objectives/values, strategies, and adaptations.

Selection will favour the establishment of adaptive arrangements which reduce the extent of trial and error needed to achieve adaptation. Key milestones in this evolution are: the capacity to learn, which enables organizations to implement without trial and error an adaptation which has been discovered previously, when there is a recurrence of the conditions in which the adaptation was beneficial (e.g., the operant conditioning of Skinner, 1953); and the transmission of adaptations between organizations (e.g., through imitation, or by the parental inculcation of behaviours in their offspring), which enables an organization to adopt a successful adaptation discovered by another organization without having to discover it itself by trial and error.

However, the types of adaptive arrangements considered to this point are fundamentally limited: because they discover adaptations only by testing actions against their immediate effects within the organization, they are limited in their ability to discover adaptations which have beneficial effects only in the future. No matter how beneficial the future effects are, they will not produce beneficial effects within the organization when the possible adaptation is trialled, and therefore will not contribute to the adoption of the adaptation; as a consequence, these types of adaptive mechanisms cannot apply anticipation or foresight in their search for beneficial adaptation.

Arrangements which are hard-wired in the organization by the between-organization evolutionary process can, however, overcome this limitation to some extent. This is because the between-organization process takes into account the effects of possible adaptations on the reproductive success of organizations, irrespective of whether the effects of an adaptation accrue at a different time during the life of the organization to the implementation of the adaptation. So the between-organization process can hard-wire the internal adaptive mechanisms within the organization so that alternative adaptations are tested not only against their immediate effects, but also against hard-wired proxies for their future effects. In this way, the organization can be hard-wired so that possible adaptations are treated as if their future effects were immediately felt by the organization. This will insure that when alternative adaptions are trialled, future beneficial effects will count toward their immediate competitive ability within the organization.

For example, the organization may be hard-wired by the between-organization process so that: (a) a particular behavioural act which has no immediate detrimental effect, but which would endanger the organization in the future, will cause the organization to immediately experience fear (a proxy for future harmful effects); and (b) behaviours which result in the reproduction of the organization but which provide no immediate benefits will cause the organization to immediately experience pleasure (a proxy for future beneficial effects). In these examples, natural selection hard-wires the organization so that when possible adaptations are being trialled, the organization experiences pleasure, pain, or more complex emotional feelings which reflect the future effects of the possible adaptations. This insures that when possible adaptations are tested, their future effects are taken into account.

However, to the extent that these arrangements rely on the hard-wiring of the organization by natural selection, they share the limitation that applies to other hard-wired arrangements: they cannot be adapted and improved during the life of the organization.

4.1.3 Internal Testing of Possible Adaptations Against Future Effects: If this limitation is to be overcome, the organization must include arrangements which can test possible adaptations against their future effects and which can themselves be adapted and improved during the life of the organization. This can be achieved by arrangements within the organization which evaluate the future effects of possible adaptations by simulating or modelling their future consequences, and which insure that these consequences are taken into account when the adaptations are trialled (Popper, 1972; Holland, 1992; Stewart, 1995). The models themselves can be tested and improved during the life of the organization on the basis of their ability to accurately predict how the world unfolds. The evolution of these arrangements will be driven by the potential benefits to be achieved by more effective cooperative management of the organization.

The effectiveness of the management of an organization which is guided by internal modelling will depend on the comprehensiveness and accuracy of the models. As organizations accumulate knowledge which can underpin more and more sophisticated modelling, their ability to predict the consequences of alternative adaptations (including technological adaptations) will be enhanced. Until the unfolding of a particular phenomenon is able to be modelled by an organization, the organization cannot understand the phenomenon, nor predict its unfolding.

Once the modelling capacity is established, selection will strongly favour the establishment and enhancement of the ability to transmit knowledge between organizations, e.g., through language. This will rapidly enhance the modelling capacity by enabling the accumulation across generations of the knowledge which underpins modelling. Where a society of organizations is cooperatively managed, a high level of specialization and division of labour in the acquisition and accumulation of knowledge can be achieved (e.g., in a modern human society).

The progressive acquisition and accumulation of knowledge will enable organizations to model the consequences of possible adaptations (including technological adaptations) across greater and greater scales of space and time. As modelling improves, it is likely to identify alternative adaptations which are superior to existing adaptations when longer-term or wider-scale consequences are taken into account, or when more accurate predictions of consequences are utilized. If an organization is to take advantage of a capacity to model which improves throughout its life, it therefore must include arrangements which enable the findings of the improved models to be used to progressively modify its existing adaptations, strategies and objectives/values. This in turn will entail the modification of the operation of the adaptive processes which have established and adapted these existing arrangements, and which are relatively limited in their ability to take into account the consequences of possible adaptations. These existing adaptive processes include smaller scale modelling, hard-wired adaptive processes, learning, and ultra-stable arrangements.

As we have seen, a recurring challenge throughout the evolution of life has been to establish arrangements which modify adaptive processes or entities that adapt in relation to limited interests so that they instead adapt in relation to a wider set of interests and considerations. And, as we have seen in relation to the initial formation of organizations and in relation to the establishment of hierarchies of ultra-stable arrangements within organizations, this can be most effectively achieved by the establishment of new layers of control which can manage and modify the operation of the pre-existing adaptive processes to ensure that the wider interests and considerations are taken into account. Consequently, as the modelling capacity progressively improves in its ability to take into account the more complex consequences of possible adaptations over wider scales of space and time, new levels of management will be progressively added. Each of these will modify the operation of the previous adaptive processes (including lower-levels of management) so that these wider consequences are appropriately taken into account. This increasingly enables the organization to transcend the biological and social influences which have previously determined its actions, and instead enables the organization to adopt whatever behaviours are identified by its modelling capacity as necessary to satisfy its longer term objectives/values.

As pointed out by Wilber (1997), the executive control of the organization (which the organization experiences as the self) will tend to be associated with the highest level of management. As a new level of management develops, the self will tend to dis-embed from the level below, and increasingly develop capacities which will enable it to stand outside and manage the lower-level. Foremost among these capacities is the ability to model the processes of the previous level, so that they can be successfully modified to produce desired effects. The previous level will progressively become an object of the self which is now identified with the higher level, and the organization will experience this as becoming increasingly aware of the processes of the lower-level—i.e., the organization will develop self-consciousness of increasing scope.

Once selection at the between-organization level has established the organizational framework which underpins the modelling capacity, this evolutionary progression in which new levels of management are added will occur within organizations during their life: it is a cultural and psychological evolutionary sequence, not a gene-based one. The sequence will be driven by the potential for each step in the sequence to provide organizations with an improved ability to satisfy their objectives/values, which were initially established by the between-organization process as proxies for organizational success.

When the modelling capacity is sufficiently developed, it will make redundant the gene-based adaptive process operating at the between-organization level. This is because the modelling process will pre-empt the genetic process: organizations will generally be able to adapt to events through the modelling process before the events produce the differential reproductive success between genetically variant organizations which is necessary for the operation of the between-organization process (e.g., see Laland, 1992, for a model). The result is a new evolutionary mechanism which is able to discover new adaptations during the life of the organism, and to accumulate and improve adaptations across generations of organisms through cultural heritability.

As we shall see in greater detail in the next section, improvements in the modelling capacity of individual organizations in turn permit new and more effective ways of forming the cooperative organizations of individuals which constitute new levels of organization. In particular, individuals with a sufficiently developed modelling capacity are able to form organizations whose management is able to adapt heritably during the life of the organization from the outset, without having first to repeat the full evolutionary sequence outlined in this section. Here we will identify three distinct levels of modelling capacity which each differ significantly in the type of organization which they can found. These levels differ primarily in the complexity and scale in space and time of the events they can model: as we proceed through the levels, modelling is able to take into account the more complex consequences of possible adaptations over wider and wider scales. Each level is sufficiently distinct to necessitate a distinct level of organizational management which manages lower-levels of adaptation to insure its unique considerations are taken into account. Therefore, as well as being associated with distinct types of social organization, each level will also tend to be associated with different adaptations, strategies, and values/objectives which will result in different world views, senses of self and cultural systems:

(a) *Linear modelling*: this is limited to the modelling of the simple and direct consequences of possible actions, which are seen to be linked by linear chains of causation. This level of modelling leads to the discovery and revision of adaptations with short-term future consequences, but is very limited in its capacity to model the consequences of alternative strategies for discovering adaptations, or the consequences of alternative values/objectives, particularly in social contexts. Consequently, these adaptive needs continue to be met by arrangements which are predominately hard-wired (e.g., through the emotional system in the case of adaptations with complex, longer term consequences). Alternatives to these complex adaptations are not an object of awareness, and the organization takes adaptations founded on the hard-wired arrangements as given, and not subject to choice.

(b) *Systemic modelling*: this allows the modelling of the wider social and other systems in which the organization participates. It includes modelling of the social and other processes which have fixed many of the organization's particular adaptations, strategies, and values/ objectives, and which also determine the extent to which these adaptations are successful. These adaptations, strategies and values are therefore no longer experienced as fixed or given, and can be reviewed in the light of the modelling. An individual with this level of modelling ability is able to successfully manage a cooperative organization of individuals, using its modelling ability to discover controls which will promote beneficial cooperative organization, and adapting its management during the life of the cooperative organization.

(c) *Evolutionary modelling*: this entails the modelling of the evolutionary processes which have ultimately formed the organization and its particular adaptations, strategies and objectives/values, and which will ultimately determine the future evolutionary success of the organization and the success of the higher-level organizations in which the organization participates. The organization will therefore be aware of the progressive evolutionary sequences identified in this article, and of its place in those ongoing processes. This allows the organization to review the adaptations, strategies, and values established by earlier evolutionary mechanisms in the light of their appropriateness to the future wider-scale progressive evolutionary processes. In particular, it enables the organization to adaptively pre-empt the wider-scale evolutionary trends before they manifest as the differential reproductive success of organizations. Organizations might do this by, for example, promoting the formation of higher level organizations capable of successful cooperative adaptation on wider and wider scales.

This progressive improvement of the modelling capacity continues the trend that began with the evolution of simple ultra-stable arrangements which tested possible adaptations solely against the ability of their immediate effects to usefully deal with changes as they arise within the organization: as the new levels of management associated with these modelling capacities are progressively added, the organization will increasingly be managed so that its adaptation takes into account the effects of possible adaptations over wider and wider scales of space and time. The organization will therefore progressively move closer to the ideal of insuring that entities within the organization are adapted by appropriately taking into account the effects of their actions on others in the organization and on the organization as a whole, no matter how distant those effects may be in space or time.

4.2 The Evolution of Cooperative Human Organization

4.2.1 Lower-Level Management: We have seen that genetic arrangements which constrain the characteristics of individuals can control a group of individuals where the arrangements are reproduced in each of the members of the group. Lower level management of this kind has been responsible for the initial evolution of cooperative multicellular organization, and cooperative non-human societies.

We have also seen that the evolution of the ability of individuals to adapt during their life eventually resulted in the capacity for individuals to acquire new internal constraints and predispositions during their life (e.g., learned behaviours). Once these learned constraints could be transmitted between individuals (e.g., through the inculcation of behaviours in offspring by their parents), it became possible for a group to be controlled by lower-level management constituted not by genetic constraints, but by learned behavioural constraints. A cluster of behavioural constraints which include a predisposition to inculcate the cluster in others could reproduce throughout a group, predisposing members of the group to behave cooperatively.

These types of arrangements are seen in their most highly developed form in human organization. There is strong evidence that early human hunter/gatherer groups were cooperative and highly egalitarian within groups (e.g., see Knauft, 1991; Erdal & Whiten, 1994; Wilson & Sober, 1994). This type of organization could be achieved within a genetically disparate group by a cluster of inculcated behavioural norms which constrain individuals to behave in ways which remove any disadvantage from behaving cooperatively—e.g., by predisposing individuals to share the benefits of cooperation and to refrain from cheating. The success of such a manager within a group would be enhanced if the manager included behavioural constraints which actuated individuals to punish or expel individuals who failed to behave consistently with all the behavioural norms (e.g., individuals in whom the cluster of constraints had not been reproduced). Such a lower-level manager could successfully compete with alternatives within the group, as well as producing a group which could out-compete other groups which were unable to exploit the benefits of cooperation.

Lower-level managers are also able to arise and persist within modern, large scale human organization where the predominant form of management is upper-level: for example, an appropriate cluster of inculcated behavioural constraints can reproduce across a group to form organizations such as the Hutterite groups which are discussed in detail by Wilson and Sober (1994).

However, groups which are controlled by lower-level management constituted by inculcated behaviour patterns are fundamentally limited in their ability to adapt heritably during the life of the group. This is because lower-level management can sustain cooperation within a group only to the extent that it successfully hard-wires individuals to behave in ways which may be contrary to their individual interests, and maintains these constraints through time. Relaxation of the hard-wired constraints will result in a return to the pursuit of individual interests at the expense of the group, with the collapse of cooperation.

Management could permit variation and experimentation in the hard-wired constraints only if it had the capacity to distinguish between useful and harmful variants, and the capacity to suppress any new variants which prove to be harmful (e.g., which involve a new form of cheating, or involve any other pursuit of individual interests at the expense of group interests). The lower-level management of human groups does not have this capacity. Except in the limited circumstances where other arrangements can successfully control variation (e.g., see Stewart, 1997a), management must therefore indiscriminately suppress all variation which could possibly be harmful, including variation arising in management itself, even though this will also suppress variation which could be beneficial. Variation which could possibly be harmful can be permitted to arise only with the formation of new groups, concentrating selection and adaptation at the between-group level (Wilson & Sober, 1994). The result is the stifling of innovation and adaptive ability during the life of the group. Rigid enforcement of norms and strict adherence to traditional ways of doing things is a feature of this form of human organization. It is no accident that the technology used by Hutterite groups is greatly out of date, and that traditional human groups showed little change and innovation in their social and other practices over long periods.

4.2.2 The Emergence of Upper-Level Management: The development within humans of a capacity for systemic modelling made possible the emergence of upper-level management which overcame these limitations of lower-level management. Systemic modelling improved the ability of humans to discover actions which produce benefits that are significantly displaced in space or in time from the immediate effects of the action, and where the causal connections between the action and their benefits are complex. As a consequence, upper-level management informed by systemic modelling was no longer limited to discovering and adapting only those interventions which produced largely immediate and direct benefits. Because many of the interventions and actions needed to establish cooperative arrangements and to harvest their benefits are complex, systemic modelling greatly enhanced the ability of upper-level managers (e.g., chiefs, kings or other rulers) to produce cooperative human organization.

Upper-level managers informed by systemic modelling therefore had a much superior ability to continuously adapt the management of human organization during its life. Such a management has the ability to continually distinguish between beneficial and harmful variation arising within the group during its life. And it can continuously adapt its management to control variants as they arise. In contrast to lower-level management, upper-level management informed by well-developed systemic modelling does not have to suppress all possibly harmful variation during the life of the organization. To the extent it can distinguish harmful variation from beneficial, it can suppress only the harmful rather than having to suppress all of the variation. As a consequence, organizations which included this form of management were significantly superior in their ability to adapt heritably during their life from the outset. They did not have to evolve such a capacity by traversing the full evolutionary sequence outlined above in which the ability to adapt during the life of the organization emerged for the first time.

The result has been the forms of modern human organization which have arisen progressively since the latest Ice Age about 12,000 years ago, and which are managed largely by upper-level managers such as rulers, committees, and governments. These managers have the capacity to continuously adapt their management within the organization to improve cooperative arrangements and to adapt them to changing circumstances, and have enabled an extraordinary amount of cooperative division of labour and specialization.

Although upper-level management informed by systemic modelling has a much superior capacity to continuously adapt the management of an organization during its life, lower-level as well as upper-level management has been significant in the evolution of modern human organization to date: initially, until upper-level management accumulated sufficient knowledge to provide effective management, strong lower-level management was essential for the maintenance of cooperative organization. The lower-level management was necessary to constrain the actions of members of the organization in ways which assisted the prevention of the breakdown of the group though competition, cheating, and free riding.

Furthermore, even where the systemic modelling capacity of upper-level management was well developed, its task of managing a complex human organization could be assisted and simplified by the existence of lower-level management which promoted cooperation. For example, as economic theorists such as North (1991) and Pelikan (1995) have suggested, the reproduction across an organization of behaviour patterns which constrain individuals to be trustworthy and refrain from cheating in economic exchange relations can reduce the need for upper-level controls in which the State punishes breaches of contract. For these reasons, upper-level managers of human organizations have often fostered the reproduction of lower-level constraints which complement the interests of the managers (e.g., the promotion by the State of particular values and norms).

However, the limited ability of lower-level management to adapt as circumstances change has resulted in its progressive displacement by upper level management. Where organizational changes reduce the effectiveness of lower-level management, or impair its capacity to reproduce across the organization, the greater adaptive ability of upper-level management has meant that it is likely to take over the management functions previously performed by the lower-level management. Furthermore, improvement of the capacity in humans for systemic modelling has enabled the revision of earlier adaptations, including the revision of inculcated behaviour patterns which previously constrained behaviour. Consequently, the most recent period of human evolution has seen the weakening of lower level management, the rise of individualism in which humans use their modelling capacity to choose between alternative adaptations rather than relying on inculcated responses, and an enormous increase in the scope and differentiation of upper-level management as it has taken over more of the management burden from lower-level management.

4.2.3 The Future Evolution of Human Organization: Since their first emergence, human organizations managed by upper-level management have increased substantially in scale, exploiting the benefits of cooperative adaptation over wider and wider scales of space and time. In the future, the potential for benefits to be gained from the further expansion of cooperative organization should tend to drive the establishment of an upper-level management which manages an organization on the scale of the planet. This level of management would manage processes that arise within lower levels of organization (e.g., nation states) and that have effects which extend beyond the border of any one state—e.g., acts of aggression between states, and wide-scale environmental degradation. As for management at all other levels of organization, this would insure that processes within the planetary organization are not able to successfully pursue their own interests at the expense of others, and are able to benefit from their beneficial cooperative effects on others. The establishment of this planetary organization would be assisted by the further development among humans of a capacity for systemic modelling. This would eventually provide widespread recognition of the benefits of management on a planetary scale. The development of a capacity for evolutionary modelling would further accelerate the establishment of the planetary organization.

However, the emergence of this planetary organization would not exhaust the potential for cooperative organization on the scale of the planet. It would not fully achieve the ideal of insuring that within the organization, the adaptation of individuals (including managers) would appropriately take into account the effects of possible adaptations on others in the organization, treating effects on others as effects on self. This is because the current systems of human government (upper-level management) are fundamentally limited in their management ability. I will briefly discuss three of the main limitations:

(a) As pointed out in relation to economic systems by Hayek (1948), central governments do not have access to the information necessary to determine the ideal cooperative outcomes in particular circumstances, and to devise the management interventions to implement these. This “planning” limitation can be circumvented somewhat if governments limit their management as far as possible to establishing the governance which is necessary to underpin the operation of systems of exchange relations within the organization (e.g., horizontal economic markets). Where these systems of exchange relations are effective, the participants capture the beneficial effects of their actions on others, and have access to the information that governments lack. However, systems of exchange relations are also limited in their ability to comprehensively explore cooperative possibilities: for example, they do not allow participants to capture the benefits of their effects on others where the effects cannot be contained to those involved in the exchanges (e.g., public goods); and their effectiveness is ultimately subject to the limitations which apply to central government, because the effectiveness of systems of exchange relations in turn depends on the effectiveness of the systems of governance which underpin them, such as the institutions which enforce property rights and prevent cheating (e.g., see Hodgson, 1988).

(b) The coincidence of interests between management and the organization as a whole is not likely to be complete (the analysis of McGuire & Olson, 1996, demonstrates that the conditions under which the coincidence is complete are not met by current systems of governance). This is particularly the case where the success of a ruler or government can be influenced by individuals and groups with non-representative interests. It will be in the interests of these individuals and groups to use their influence to have the management provide them with additional benefits at the expense of the organization. However, to the extent that any individual in an organization does not capture the net effects of its actions on others, either by receiving more benefits or less, the organization will fail to optimally explore the benefits of cooperative organization. And to the extent that governance intervenes any further in the actions of individuals than is necessary to insure they experience the net effects of their actions on others, it unnecessarily restricts their freedom as well as impairing the effectiveness of the organization as a whole. Many of the features of modern governance (including the democratic process itself) can be interpreted as attempts to overcome this “conflict of interest” limitation by constraining rulers and governments to act solely within the interests of the organization. The test of the success of such measures is whether they result in government in which individuals driven solely by self-interest will always seek to govern only in the interests of the organization as a whole. Existing systems of governance clearly fail this test.

(c) Modern systems of government have limited time horizons: they do not contain processes which insure that all the future effects of actions are taken into account in determining adaptation. The effects of possible adaptations on future generations generally count little in determining which adaptations are adopted. A planetary organization managed by human government which was limited in this way would not invest the considerable resources needed to establish a comprehensive capacity to adapt in relation to possible future events which might arise outside the planetary organization. As a result, the capacity of such an organization to adapt in relation to the outside/future (including in interactions with other living systems of the same scale) would be more comparable to the ability of a plant, rather than to the ability of a mammal.

Currently, our systems of governance are devised and adapted by the same sort of processes that were so ineffective at devising and adapting economic outcomes in Soviet-style planned economies. The limitations of these processes mean that a system of planetary management implemented and adapted by humans through existing systems of governance would not exhaust the potential benefits of adaptive cooperative organization on the scale of the planet. To identify the nature of the evolutionary trends that this unexhausted potential will tend to drive, it is necessary to identify organizational arrangements which would overcome these limitations. What sort of arrangements would produce governance which would evolve optimally, searching for improvements, and adapting to new circumstances?

I outlined (Stewart, 1995) a form of adaptive organization (termed a system of competitive vertical exchange relations) which would produce an upper-level management that evolves optimally. Key features of such an adaptive system of governance are: (i) the management interventions which would be implemented would be determined by competition between alternative interventions on the basis of their ability to produce net benefits to the individuals and groups which they would affect within the organization; (ii) the extent to which an intervention would provide net benefits (and therefore its competitive ability) would be determined by the extent of the resources which those affected by the intervention were prepared to exchange for its implementation; (iii) the development and offering of alternative interventions would be open to entrepreneurial activity. Ultimately, all management interventions, including those which establish the vertical system itself, would be adaptable on this basis.

Such a system (a) involves supra-individual cognition in the sense that it discovers adaptations by trial and error processes which operate across individuals rather than within individuals; (b) operates through an invisible-hand process in that it produces its beneficial organizational effects though the pursuit by individuals (including those in management) only of their own interests; (c) tends to approach the ideal in which all individuals, including those in management, capture the net effects on others of their actions; (d) therefore will tend to approach the organizational ideal in which individuals adapt as if they treat their effects on others as effects on self; and (e) therefore also tends to approach the ideal in which the interventions of management are limited only to what is essential to insure that individuals experience the net effects of their actions on others, i.e., maximizes individual freedom.

Such a vertical system which would manage and complement systems of horizontal exchange relations such as economic markets could largely overcome the “planning” and “conflict of interest” limitations which impair the effectiveness of current forms of government. The benefits that a vertical system could deliver to the organization and to the individuals and groups that participate in the system could be recognized by individuals with a well-developed capacity for systemic modelling. A capacity for evolutionary modelling would assist this recognition. It is feasible that such a system could be adopted through the current democratic systems of government if and when sufficient numbers of humans develop the capacity for systemic modelling. However, the adoption of a vertical system would be likely to be resisted by those who, under current systems of governance, do better than merely capture the benefits of their effects on others. This resistance would include promoting loyalty and respect for current systems of government, and promoting the belief that any change would be risky.

However, an effective vertical system would not of itself overcome the restrictions on the adaptive capacity of current forms of government that result from limited time horizons. It is only where the humans who participate in the organization are informed by evolutionary modelling that these restrictions would be fully overcome. Evolutionary modellers would be aware of the future direction of the evolutionary processes in which the human system is embedded and therefore would be aware that the planetary organization must develop the capacity to adapt and act for the outside/future if it is to participate in the continued expansion in space and time of living organization which is able to adapt cooperatively on wider and wider scales. Evolutionary modellers would therefore support the establishment of arrangements which would result in the self-actualization of the planetary organization: this would mean that the planetary organization would develop its own objectives/values, plans, self-awareness, modelling capacity and projects, and it would be capable of adapting coherently as a whole. The development of evolutionary modelling would therefore enable adaptive process within humans and within human organization to pre-empt the operation of natural selection which might otherwise operate at the between-organization level, producing a self-actualized planetary organization without the operation of competition or differential reproductive success between planetary organizations.

This does not mean that evolutionary modellers would sacrifice their immediate interests to attempt to take into account the longer-term and wider-scale evolutionary consequences of their actions. Instead, evolutionary modellers would draw on their understanding of the types of organization which permit the successful formation of larger-scale cooperative organization. They would therefore support the implementation of management which insures that individuals experience the net effects on others in the organization of their actions, no matter how distant in space or time those effects may be. This management would insure that when individuals adapt to immediate circumstances, they also adapt effectively in the light of the longer-term consequences of their actions. An appropriate vertical system would enable evolutionary modellers to establish a system of management which would align the immediate interests of individuals with their longer-term interests in this way. This is because such a vertical system tends to establish whatever management arrangements are necessary to satisfy the objectives/values of the members of the organization.

The development of a capacity for evolutionary modelling could be expected to reduce resistance to the implementation of an appropriate vertical system, even among individuals and groups who are disproportionately advantaged under current systems of governance. Individuals informed by evolutionary modelling would be less driven to accumulate resources to satisfy the acquisitive objectives/values which currently motivate many humans, and which are known by evolutionary modellers to have been initially established in humans by flawed, limited, and superseded evolutionary mechanisms (e.g., natural selection operating on genetic variation). This would particularly be the case where pursuit of these objectives/values would be inconsistent with values/objectives which serve longer-term evolutionary interests. These considerations also suggest that the task of successfully managing organizations of evolutionary modellers would be less demanding.

With the full attainment of evolutionary modelling, human cooperative organization would have evolved from a form of organization in which humans were constrained by inculcated beliefs and genetic predispositions to act cooperatively, through organization in which individuals were in large part coerced to act cooperatively, to organization in which humans utilize a modelling capacity to choose to be subject to a dynamic and responsive management which aligns their interests with the organizational interest.

Of course, whether human organization will successfully evolve in this way to further exploit the potential benefits of cooperation is not certain: as we shall discuss in the next section, the fact that there are potential benefits to be gained through complex new forms of cooperative organization does not mean that these will be discovered and taken advantage of by a particular species under particular circumstances where the species discovers adaptations through the operation of limited evolutionary mechanisms. However, given sufficient time on any suitable planet, the existence of these potential benefits will drive evolutionary processes which are likely to eventually produce a species which manages a living organization on the scale of the planet.

5. Conclusion

The weight of opinion among evolutionary biologists currently appears to be strongly against a progressive view of evolution (e.g., see Nitecki, 1988).

In this section, I will briefly outline a number of the main criticisms which have been directed against previous approaches which suggest that evolution is progressive, and indicate how they are overcome by the approach presented here.

As noted earlier, a central argument raised by those who suggest that evolution cannot be progressive is that natural selection provides adaptation only to changing local environments, and that the tracking of these changes cannot produce sustained directional evolution: some directional change can be expected, but it will end as selective circumstances change or as opportunities for further adaptive improvement are exhausted (e.g. Maynard Smith, 1988; Gould, 1996).

The weakness in this argument is that adaptations which are able to improve fitness are not limited to adaptations which track local environmental changes back and forth, providing closer adaptation only to whatever local circumstances prevail at a particular time (e.g., a sequence of adaptations which produce thicker fur as mean temperatures decline, or thinner fur as temperatures increase again). Fitness can also be improved by adaptations which are general in the sense that they are capable of providing benefits across a wide range of local environmental conditions (e.g., a single adaptation that improves the physiological ability of an organism to adapt to changes in temperatures, producing benefits whether mean temperatures increase or decrease). Such general adaptations will remain beneficial despite wide changes in local conditions, and can be progressively improved by further general adaptations. Reversals in the direction of changes in local conditions will not bring these sequences of progressive evolution to an end, as it will for local adaptations.

This article has argued that there is an inexhaustible potential for general adaptations which can produce benefits irrespective of changing environmental conditions by improving the ability of living processes to exploit the advantages of cooperative organization on wider and wider scales. At any particular level of organization, these general adaptations may either improve the capacity for beneficial cooperative arrangements to be exploited between organisms (e.g., by the formation of hierarchical organizations of organisms); or may improve the capacity for cooperative arrangements within individual organisms to be optimized and adapted (e.g., by enabling the effects of possible adaptations across wider and wider scales of space and time to be taken into account in adapting the organism). Although the particular cooperative arrangements which these general adaptations make possible in any particular environment may be beneficial only locally, the general adaptations make such improved cooperative arrangements achievable across a wide range of environmental conditions.

However, the view presented here that there is a general potential for beneficial cooperation seems to raise another difficulty: why have not all lineages of organisms progressed in these ways? If improved cooperative management within and between organisms has the potential to produce benefits generally across environments, why are not all species progressively discovering improved general adaptations of this type? Bacteria are often cited as an example of organisms which show no recent progressive evolution (Ayala, 1988; Gould, 1996).

The first point to be made from the perspective developed here is that progressive evolution has been much more widespread than is generally recognized. For example, the participation by bacteria in cooperative organization is common, ranging from bacteria which are included in symbiotic assemblages, to the descendants of bacteria which participate in eukaryote cells which in turn participate in multicellular organisms, which in turn participate in social systems (e.g., see Cavalier-Smith, 1981). In this way, bacteria have been centrally involved in the progressive expansion of cooperative organization across space and time. This involvement includes progress in the ability to cooperatively adapt in relation to events of wider and wider scale: the descendants of bacteria which participate in higher-level organizations are adapted by the management of those organizations in relation to events and considerations of wider scale. For example, although bacteria have not themselves developed a capacity for internal modelling, those that participate in larger-scale organizations which have this capacity will be adapted in relation to events of wider scale as if their adaptation were itself directly guided by internal modelling.

Second, the extent to which existing lineages of organisms are participating in the progressive evolution of cooperative organization is growing rapidly. In particular, an increasingly wide range of organisms such as domestic animals, plants, pests, and disease-causing organisms are being managed as participants in cooperative organizations managed by humans. With the formation of a planetary organization, the extent of this management of other organisms would increase substantially. This would particularly be the case as management improved its ability to manage the planetary system in ways which will optimize its capacity to successfully adapt for the outside/future: management would need to take advantage of all the potential resources of the system to optimize its adaptive capacity.

This management is likely to include genetic engineering which is already being used by humans to produce new forms of organism that can contribute greater benefits to human organization. The potential benefits of cooperation between organisms are likely to encourage further management interventions along these lines to produce new cooperative organizations of organisms. For example, these could include cooperative assemblages of bacteria that provide particular benefits to the planetary organization. The potential to engineer new beneficial forms of cooperative organization which have not yet been fully exploited by natural selection should be considerable: the trial-and-error process of natural selection operating on genetic variation has a very limited capacity to explore the space of all possible gene-based organisms and organizations of organisms, and it can be expected that there will be considerable advantage in its further exploration by upper-levels of management informed by evolutionary modelling.

Increasingly as a planetary organization evolves, more and more of the living processes on the planet would be managed so that they participate cooperatively in the organization, and would be managed so that they are adapted in relation to events of wider and wider scales, including in relation to any participation in yet larger-scale living organizations.

Nevertheless, in the past, many lineages have not shared in progressive trends for long periods. However, the existence of a general potential for beneficial cooperation does not mean that all lineages will realize this potential by improving cooperative management within and between organisms. This is because the general benefits of cooperation are comprehensively accessible only with the evolution of complex hierarchical organizational arrangements, and an evolutionary mechanism such as natural selection which searches for adaptations by trial and error is limited in its ability to discover such arrangements. This is particularly the case where there is no set of simpler adaptations which are each able to provide general fitness benefits, and which are able to serve as intermediary steps in the evolution of the complex organizational arrangements. If such general intermediary adaptations were readily available, evolution could proceed toward the complex organizational adaptations across lineages and environments. However, without intermediary adaptations which are able to produce fitness benefits in a variety of environments, evolution must rely on there being particular local environmental conditions which select in favour of local adaptations which fortuitously can also serve as intermediaries to the general organizational adaptations.

Other factors will also limit the extent to which lineages participate in progressive evolution: small, simple organisms such as bacteria will be less likely to be able to successfully include within them complex hierarchical organizational arrangements, such as those necessary to establish a capacity for evolutionary modelling; and lineages which first discover progressive and intermediary adaptations are likely to exploit the circumstances which produce the greatest benefits for the adaptations, reducing the availability of circumstances which will produce sufficient selective advantages to drive similar evolution in other lineages.

These considerations suggest that it is therefore not surprising that many lineages fail to share the progressive trends, even though improved cooperative management within and between organisms have the potential to produce benefits generally across environments. However, this pattern of intermittent progressive evolution is likely to prevail only while the evolutionary mechanism is limited in its capacity to search for beneficial adaptations. Progressive evolution is likely to be more general and pronounced once evolution produces more effective evolutionary processes such as a mechanism informed by evolutionary modelling.

However, these considerations seem to raise another serious problem: if the general adaptations which exploit the benefits of cooperation within or between organisms are able to increase fitness across environments, why do lineages which discover general adaptations often appear to have failed to out-compete and replace the lineages that have not discovered general adaptations? Furthermore, if the progressive lineages fail to displace the non-progressives, and the non-progressives continue to persist, how can it be said that the progressive lineages are “better” than the non-progressive lineages in any sense which is evolutionarily meaningful? In particular, if bacteria which are not part of wider-scale cooperative organization have flourished, are not they as evolutionarily successful as, for example, humans?

If we are to adequately assess the relative evolutionary success of various lineages, it is essential to undertake the assessment over wide enough scales of space and time. This is because over narrower scales, other factors may be more important in determining the relative success of lineages, particularly where the evolutionary mechanism is natural selection operating on genetic variation. For example, a lineage which discovers a general adaptation which provides fitness benefits across environments may nonetheless fail to out-compete other lineages in other environments: this will be the case where the other lineages carry various local adaptations to their environments which, in those environments, outweigh the general benefits provided by the general adaptation. Similarly, a progressive lineage could be ousted by a non-progressive lineage if the benefits of the progressive's general adaptations were outweighed by its inferior local adaptation to its environment.

Furthermore, even though a general adaptation provides fitness benefits across environments, the fitness cost of realizing the general adaptation may vary across lineages and environments, and in some cases may not outweigh the fitness benefits provided by the adaptation. In those cases, a progressive lineage may not prevail, until a more cost/effective way of realizing the general adaptation is discovered. For example, in relation to a niche which strongly favours small size, the establishment and maintenance of a highly complex organizational arrangement will incur a relatively higher cost to fitness unless the arrangement can be achieved just as effectively on a smaller scale at proportionate cost; lineages occupying such niches would be resistant to being out-competed by progressive lineages until the progressive lineages discovered ways of cost/effectively implementing their general adaptations on smaller scales.

However, as general adaptations accumulate over time, and as their accumulated contributions to fitness become more significant, the ability of progressive lineages to adaptively radiate by outcompeting other lineages will increase. Nevertheless, for any given level of superiority in relation to general adaptations, there will be a corresponding level of disadvantage in relation to local adaptations that will not be overcome. For these reasons, progressive evolution underpinned by natural selection operating on genetic variation will proceed in fits and starts, and the extent to which progressive lineages oust non-progressives will be strongly influenced by historical contingencies.

Over much longer time scales, the probability of survival of non-progressive lineages will greatly diminish. As we have seen, the evolution of a planetary organization would result in lineages that were formerly non-progressive increasingly being managed and adapted as part of the planetary organization. And as the planetary organization develops, its human management would increasingly engineer organisms and cooperative relationships between organisms to optimize their contributions to the planetary organization. Human management would use its superior cognitive ability to adapt organisms so that they evolve progressively in ways which would overcome the historical contingencies and other limitations which restricted the evolutionary mechanism based on the more cognitively limited natural selection operating on genetic variation. Furthermore, the planetary management could be expected to further develop the practice of current human organization to utilize machines and other non-living processes instead of organisms where their contributions to the planetary organization are superior.

Increasingly, non-progressive lineages would either begin to participate in progressive evolution by being incorporated into wider-scale cooperative organization, or would be directly suppressed by the planetary organization, or would be out-competed by members of the planetary organization whose fitness is increased by participation in cooperative arrangements.

However, the evolutionary superiority of lineages which participate in cooperative organization would be most clearly seen in relation to the ability of the organization to successfully adapt to wider-scale events, particularly in relation to other living organizations of similar or greater scale. As it develops a capacity to adapt for its outside/future, the planetary organization would develop the ability to adapt to external events of abiotic or biotic origin which might otherwise threaten its continued existence on this planet. This adaptive capacity might involve relocation to other planets, and may also involve the further spread of human organization and its technological and other adaptations over greater scales of space and time.

The critical point here is that non-human organisms which are part of the human organization would be adapted to these larger scale events along with the rest of the organization, and would, for example, participate in any relocation and in any spread of the organization. In contrast, lineages which do not participate in the planetary organization would not be successfully adapted to these wider-scale events, and would not participate in any future evolutionary success which necessitates the ability to adapt coherently on larger scales. Gould (1996) acknowledges that bacteria are unlikely to survive what currently appears to be the inevitable eventual explosion of the sun. However, he fails to recognize that the likely survival of such an event by a human organization which is able to adapt on a sufficiently large scale illustrates the superiority of such a human organization in strictly evolutionary terms.

Of course, it is impossible to predict how successful a planetary organization informed by evolutionary modelling would be at adapting to the particular large scale events which actually arise in the future. However, it is possible to state with certainty that such an organization would be able to successfully adapt to a much wider range of large-scale events than would non-progressive lineages, or than would a planetary organization which does not develop the ability to adapt for the outside/future, and which is not informed by evolutionary modelling.

These considerations also suggest that the future evolutionary success of humanity will depend heavily on the acquisition of a well-developed capacity for evolutionary modelling. A comprehensive theory of evolutionary progress will be an essential component of such a capacity. In the evolution of living processes on any planet, the development of an adequate theory of evolutionary progress will therefore itself be a critical milestone in the progress of evolution.

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