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Metaevolution

John E Stewart

Department of Industrial Relations, Labour Relations Policy Branch, GPO BOX 9879 Canberra, ACT 2601 Australia

Abstract: This article presents a general theory of the evolution of the evolutionary mechanisms that discover and perpetuate adaptations in living systems. I propose that new evolutionary mechanisms arise because they overcome the limitation in the ability of evolutionary mechanisms that operate at the level of individual entities to systematically discover beneficial cooperative arrangements between the individuals. Evolutionary mechanisms that arise to overcome this limitation are hierarchical in structure. This is because the limitation can be comprehensively overcome by a form of organization in which arrangements intervene across a dynamic of individuals to sustain beneficial cooperative adaptations. These intervening arrangements must be in hierarchical relationship with the dynamic of interacting individuals if they are to escape the limitations of the evolutionary processes that operate at the level of individuals in the dynamic. Variation in these interventions, and sorting of this variation on the basis of its benefit to the organization, will allow beneficial cooperative adaptations to be discovered and sustained. The repeated arising of evolutionary mechanisms in this way produces the familiar nested hierarchies of living processes, and, as each new level of organization is formed, extends the scope in space and time of cooperation among living processes. The paper identifies other key metaevolutionary trends within and across levels of organization of living processes, and considers the evolution of human organization from this metaevolutionary perspective.

1. Introduction

Dobzhansky's well known statement "Nothing makes sense in biology except in the light of evolution" applies equally to evolutionary mechanisms themselves-the processes that discover and perpetuate adaptations in living systems. Any theory of evolution which fails to deal with the evolution of evolutionary mechanisms obviously cannot provide an understanding of the present nature and pattern of these processes in living systems, and will thus be incomplete. It will also fail to explore the attractive possibility that biological laws of greatest generality may be found to apply to the evolution of the processes which discover adaptations, rather than to the adaptations themselves.

Biology is yet to provide a unified theory and account of the evolution of evolutionary mechanisms which is applicable across the various levels of biological organization. The objective here is to present an outline of such a theory which applies at a high level of generality. The outline is intended to provide a broad account of the arising of new evolutionary mechanisms, examine the circumstances and processes that produce them, and apply this understanding to identify and explain the regularities and trends that

characterize the main existing evolutionary mechanisms, separating the contingent from the general. This account focuses on three evolutionary mechanisms that each appear to have arisen when a new level of biological organization evolved through the formation of organizations of individual living systems from the level below:

1) the genetic system, which arose with the organization of individual molecular processes into cellular systems;
2) the neural mind, which arose with the organization of individual cells into multicellular systems; and
3) government and related hierarchical arrangements, which have arisen with the organization of humans into multi-human systems.

The article commences by demonstrating that the arising of each of these evolutionary mechanisms is driven by similar circumstances, and each mechanism is necessarily hierarchical in structure. The arising of a new mechanism is favored where there is benefit in cooperative arrangements between individual living entities, such as between individual molecular processes, cells or, multicellular organisms. This is because the "old" evolutionary mechanism which operates at the level of the individual entity is limited in its ability to systematically discover beneficial cooperative arrangements: at the level of individuals, adaptations compete primarily on the basis of their effects on the individual; any beneficial cooperative effects of adaptations on others will generally not contribute to the success of the adaptation, except where the effects in turn result in benefit to the individual, or where the others also exhibit the adaptation. Ideally, the new evolutionary mechanism would be able to overcome this limitation by systematically searching for and perpetuating any cooperative organization of individuals which is more adaptive as a whole. This article proceeds to demonstrate that this can be achieved in a general way by arrangements which are in hierarchical relationship with the dynamic of interacting individuals in an organization, and which intervene in the dynamic to sustain cooperative arrangements that would otherwise be "outcompeted." The hierarchical relationship provides the intervening arrangements with sufficient functional independence from the dynamic to escape the limitations of the evolutionary processes which operate at the level of individuals in the dynamic. This enables the intervening arrangements to produce outcomes which would not otherwise arise in the dynamic (e.g., by sustaining individuals that provide benefits to others).

New cooperative adaptations can be discovered by the testing of variation (possible adaptations) in the interventions. In simple organizations such as early cells and early metazoans, the variation is tested by competition and selection between organizations (i.e., by natural selection operating on genetic variation between organisms). However, strong advantage can accrue to organizations which are themselves able to anticipate selection at the between-group level by continually discovering adaptations within the organization itself. This can be achieved by the introduction within the organization of variation which is tested by the organization itself in interaction with its environment. This article examines the evolution of these new evolutionary mechanisms in the three levels of organization under consideration.

2. Evolution's Collective Cognitive Problem

Evolutionary theory has long recognized that natural selection operating on individual organisms will favor the evolution of cooperative arrangements in only limited circumstances: an adaptation will be selected only where its net contribution to the fitness of the individual is greater than the contribution of alternative adaptations; the fitness effects of the adaptation on other individuals are not relevant to its success, except insofar as these in turn affect the fitness of the individual, or benefit others that also exhibit the adaptation (e.g., kin selection). Consequently, an adaptation which involves the provision by the individual of fitness benefits to others through cooperation will generally be selected against where it reduces the fitness of the individual. This is true even where the net fitness effects measured across all individuals affected by the adaptation are positive, and greater than for alternative adaptations. In fact, in most circumstances, selection will favor "free rider" adaptations which involve the individual taking any fitness benefits provided by others, and not cooperating in return.

From the metaevolutionary perspective, this is a limitation in cognitive ability (meaning, in this article, the ability to discover and perpetuate beneficial adaptations): the evolutionary mechanism is limited in its ability to discover and perpetuate adaptations in individuals that would result in cooperative organizations, even where the organizations would be more lit as a whole than their competitors. This does not appear to be an insignificant limitation: the benefits of cooperative organization at least in some domains is evidenced by the extensive division of labor and cooperative interdependence which has evolved amongst the constituents of cells, metazoans, and human social systems. This "collective cognitive limitation" also applies to evolutionary mechanisms which operate in relation to individuals at other levels of organization: it will manifest in any evolutionary mechanism where the success of an adaptation is dependent only on its effect on the individual that exhibits the adaptation. So it will arise where alternative adaptations compete only on the basis of their effect on whatever factor(s) the evolutionary mechanism maximizes in the individual, e.g., reproductive success, or the efficient maintenance of particular psychological states or of physiological or other variables. Again, the success of adaptations will generally be independent of their effect on other individuals, except insofar as these effects in turn affect the individual exhibiting the adaptation, or benefit others also exhibiting the adaptation.

The literature contains many examples of where the evolution of organizations of individuals at various levels is constrained by what is described here as the collective cognitive limitation. For example, at the molecular level, selection operating on individual RNA molecules within an RNA hypercycle is limited in its ability to evolve hypercycles that are more competitive as a whole, because the individual will not necessarily achieve any selective benefit from contributing to the effectiveness of the hypercycle (Bresch, Niesert, & Hamasch, 1979; Maynard Smith, 1979); in an autocatalytic set, protein or RNA molecules that contribute nothing to the catalysis of other members of the set may outcompete those that do, which may limit the ability of the set to discover cooperative arrangements more beneficial to the set (Bagley & Farmer, 1991). At the level of cells, selection operating solely at the level of individual cells is unable to evolve a cooperative division of labor among cells through the formation of organizations of differentiated cells (Buss, 1987). At the social level, Williamson (1985) points out that in regulatory environments where enforcement of contractual arrangements is not cost effective, the interests of a participant in an economic market may be served by reneging on cooperative

agreements with other participants. In such circumstances, markets may fail to discover and perpetuate the most efficient economic arrangements; the behavior needed to give rise to efficient arrangements may be non-adaptive for individual participants. The formation of a lobby organization which is assured of achieving a net benefit for an industry as a whole may be impeded because individual firms may be able to successfully "free ride" (Olson, 1965)-economic markets will not allocate an optimal level of resources to functions which provide benefits which cannot be sold in the marketplace, even where the overall benefits of the function outweigh its costs. In fact, most market failures are examples of the cognitive limitation.

Evolutionary theory has sought to identify the particular circumstances where natural selection operating at the level of individual organisms will allow at least some cooperative arrangements to be discovered and perpetuated. Genetic kinship theory (Hamilton, 1964) and reciprocity theory (Trivers, 1972; Axelrod & Dion, 1989) have gained widest acceptance. Kinship theory observes that an adaptation which involves an individual giving fitness benefits to others may be selected even where the net effect is to reduce the fitness of the individual, provided that a sufficient amount of the benefits are received by others who also exhibit the adaptation (e.g., due to kinship); in appropriate circumstances, when all fitness effects are taken into account, the fitness of the genetic basis of cooperation may exceed that of alternatives. Reciprocity theory suggests that cooperation can be selected where individuals reciprocate in the provision of benefits to each other, provided that these cooperative interactions between pairs of individuals occur repeatedly through time, and provided that free riders are excluded from the on-going benefits of the repeated interactions once they decline to reciprocate.

Furthermore, theorists widely accept now that the mere formation of groups of individuals which are subject to group selection will not, in the absence of additional arrangements, account for the evolution of complex cooperative organizations (Maynard Smith, 1987). This is because within the competing groups, the collective cognitive limitation will continue to apply: within a group, cooperative arrangements between individuals will tend to be discovered and perpetuated only where they result in success for each of the individuals involved, even if the arrangements benefit the group as a whole. And where cooperative arrangements arise, they are continually at risk of being eroded by the emergence of free riders who may be able to outcompete the co-operators. Nor are these difficulties overcome by arrangements which ensure that organizations themselves are targets of selection, rather than their component parts, and which thereby enable organizations to evolve as individuals in their own right (e.g., the arrangements discussed by Buss, 1987, and Wilson & Sober, 1989, and reviewed by Jablonka, 1994, which suppress competition amongst heritable variation within organizations, thereby concentrating competition and natural selection at the between-group level). Even with such arrangements, the fundamental difficulty remains: the organizations will be cognitively limited to the extent that many cooperative relationships among constituent individuals will not be sustainable within the organization, and therefore will not be available for selection at the between-group level.

In general, those mechanisms that allow the evolution of cooperative arrangements in some circumstances are of limited application, and do not disturb the general conclusion: any evolutionary mechanism which is responsible for the evolution of individuals at a particular level is seriously limited in its ability to systematically explore the various possible cooperative organizations of those individuals. Such mechanisms are unable to

account for the evolution of individuals into complex organizations such as cells, organisms, and societies of organisms, which display an extraordinary level of division of labor and other cooperative relationships.

3. Overcoming the Collective Cognitive Problem-The Evolution of a New Evolutionary Mechanism

Kin selection and reciprocity are able to overcome the cognitive limitation only to the extent that they ensure the effects of an adaptation on others are taken into account in determining the success of the adaptation: kin selection achieves this to the extent that it ensures the effects of a cooperative adaptation benefit other individuals that also exhibit the adaptation, and reciprocity achieves this to the extent that it ensures beneficial effects on others are returned to the individual exhibiting the cooperative adaptation. To the extent that the effects of an adaptation on others are not captured by the adaptation, the cognitive limitation will remain.

This analysis suggests that a comprehensive solution to the cognitive limitation could be achieved by arrangements which intervene in an organization to ensure that the effects of adaptations on others in the organization (and ultimately their effects on the organization as a whole) are appropriately taken into account in determining their success. This could be achieved, for example, by interventions which have the effect of feeding back to individuals the effects of their adaptations on others. This could ensure that adaptations are sustained or inhibited to the extent that their net effect on others benefits or harms the organization. Ideal arrangements of this kind could cause individuals to adapt as if their effects on others are effects on self, comprehensively overcoming the cognitive limitation within the organization.

For example, an intervention could support an adaptation that provides benefits to others in the organization but which fails to directly benefit the individual exhibiting the adaptation (interventions of this kind could underpin the evolution of division of labor between individuals, allowing extensive specialization); and interventions could inhibit adaptations involving free riding that might otherwise undermine cooperation arising among individuals. More concretely: in the evolution of cells from molecular processes, a protein that catalyzes other beneficial processes might itself be catalyzed by an appropriate intervention; in the evolution of multicellular organisms from individual cells, cells which specialize to provide useful functions for other cells in the organization may themselves be provided with resources for their reproduction by suitable interventions; and in the evolution of human groups, individuals who undermine cooperation by stealing the products of cooperative arrangements may themselves be punished by an appropriate intervention.

On this basis, the collective cognitive limitation could be comprehensively corrected most simply by arrangements which comprise:

a) interventions in the dynamic of individuals within the organization which are able to sustain cooperative arrangements that would otherwise be outcompeted, and which are able to modify the dynamic in any other way that is beneficial;
b) variation in the interventions, which enables alternative interventions to be tested; and
c) sorting of the variation on the basis of its benefit to the organization.

These arrangements would constitute a “universal constructor” to the extent that they have the potential to produce all possible adaptations of the organization, including those that could not be discovered and perpetuated by the “old” evolutionary process operating at the level of individuals. These outcomes are not capable of being produced by intervening arrangements that themselves participate in the dynamic of individuals in such a way that they share its cognitive limitations: an intervener that participates as a member of the interacting dynamic and which uses resources to sustain or inhibit other members of the dynamic without any benefit to itself is itself likely to be outcompeted in the dynamic (the “second-order” problem of Axelrod, 1986). An intervener that fully participates in the dynamic will no more be able to serve the needs of the organization at its own expense than any other member of the dynamic.

This difficulty can be overcome if the intervening arrangements are to some extent functionally separate from the dynamic of individuals: what is needed are intervening arrangements which can influence and modify the dynamic of constituent individuals without themselves being modified and determined by the processes of the dynamic. This last point is critical: the interveners must be able to evolve and adapt in accordance with criteria different from those imposed by the evolutionary processes operating at the level of individuals in the dynamic. The ability of the intervening arrangements to reproduce through time must be independent of the detailed interactions within the dynamic, and ultimately dependent instead on the contribution of the arrangements to the success of the organization as a whole; the arrangements need to be able to stand functionally outside the processes of the dynamic and act across them to modify the dynamic. But such considerations beg the question: what sort of organizational arrangements would provide this type of functional relationship between the dynamic and the interveners? We need to turn to hierarchy theory to provide an answer.

Salthe (1985) identifies the functional relationships that obtain between different levels of hierarchy in living systems. He suggests that three levels of hierarchical organization need to be described in order to provide a minimal description of a natural system: the focal level, which is the level of a hierarchical system examined by an outside observer, and which typically comprises a dynamic of interacting entities; the lower level, which gives rise to the focal level and provides initiating conditions as lower level constraints on the focal level processes (initiating conditions represent the intrinsic properties of the entities interacting at the focal level); and the higher level, which regulates or calls for the focal level, providing boundary conditions as higher level constraints on the focal level processes. Salthe gives as a paradigmatic example a population of organisms subject to natural selection: the genes are lower level constraints and, as such, are perceived as intrinsic properties of the organisms; the focal level dynamic is constituted by the interacting members of the population; and the upper level constraints are the environment that regulates the dynamic by determining which possible adaptations of organisms are fittest and will persist.

Salthe points out that constraints do not participate in the focal level processes dynamically: they can inform and influence the dynamic, but are not changed by interactions within the dynamic; the constraints stand outside and act across the dynamic. This capacity to modify without in turn being modified constitutes the essence of the ability of one set of processes to regulate another, by, for example, causing the other set of processes to adapt in ways it would not in the absence of the regulation. The functional

separateness between levels in the hierarchy is related to differences in scale between levels. Higher levels are of larger scale. Scale is a relative ranking based on size and scope of influence, which is often reflected in the duration of time of phenomenon (longer for higher scale entities) or of periods between events (longer for events coming out of processes of higher scale). Thus, from the perspective of an individual participating in the focal level dynamic, higher level constraints are typically relatively unchanging features to which the individual adapts.

Clearly the cognitive limitation of the dynamic of an organization would be able to be comprehensively corrected by appropriate arrangements that are, in the sense developed by Salthe, lower level or higher level constraints in hierarchical relationship with the dynamic of the organization. In effect, the functional separation provided by the hierarchical relationship enables the intervening arrangements to influence the dynamic yet escape its limitations, and thus answer to the concerns of the organization as a whole rather than to those of the dynamic. A concrete illustration of this type of functional separation which is readily accessible to human experience is government regulation of economic or social activity: the resources needed to sustain and reproduce government and its activities do not have to be obtained through the participation of government agents in the exchange relations and other interactions of the economic dynamic; the government takes the resources (by force if necessary) from across the dynamic as taxation; this enables the government to act in accordance with different concerns to participants in the dynamic. Government is therefore able to use such resources to intervene in the economic or social dynamic to produce different outcomes than would otherwise be produced in the dynamic. In principle, these interventions could correct for the cognitive limitations of an unorganized economic or social dynamic by sustaining cooperative behavior or suppressing free riding where a net benefit to the social or economic organization as a whole will result.

This example is readily generalizable to the case of any dynamic of individuals (i.e., molecular processes, cells, or organisms): the dynamic can be systematically modified by appropriate interveners in hierarchical relationship with the dynamic that are able to take the resources needed for their reproduction and for their interventions from across the dynamic without having to participate in the detailed interactions of the dynamic (examples of such interveners include RNA in early cells, the genome in multicellular organisms, and rulers in human organizations). The success of the modifications produced by the interventions will depend not on the fate of the modifications in the dynamic, but on the success of the interveners which produce them.

In order for different interventions to be explored, the interveners must be evolvable in their own right: heritable variation must be able to arise in the interveners in a way that can give rise to different forms of intervention which can in turn sustain different cooperative arrangements. The variation (possible adaptations) must be sorted in a way which generally ensures that only variation which benefits the organization as a whole can persist. This can be achieved most simply by an effective group selection process which selects variation on the basis of differential reproductive success between organizations. For group selection to be fully effective, it must ensure that the only way in which heritable variation can gain an advantage relative to other variation is solely through its contribution to the differential success of organizations; within an organization, there must be no heritable differential success. This can be achieved by the restriction of heritable information to the interveners which become the hereditary components at the level of

the organization, and by the arrangements discussed above which suppress competition between these hereditary components within the organization, thereby concentrating competition and natural selection at the between-group level. Examples of such arrangements which suppress competition include: the organization of genes on a single chromosome, which reduces competition amongst genes (Cavalier-Smith, 198 I); meiosis, which limits competition amongst genes and chromosomes (Ettinger, 1986); and sequestration of the germ line together with reproduction through a single cell, which reduces competition within organizations of cells (Buss, 1987). (Jablonka, 1994, provides a review.) From a different perspective, these types of arrangements prevent the interveners from interacting to form a new dynamic which would be at a different hierarchical level to the original dynamic, and which would have its own collective cognitive limitation. Selection at the level of the organization will favor the discovery and perpetuation of such arrangements (Wilson & Sober, 1989).

More complex arrangements are necessary if variation is to be sorted for-the-organization within the organization itself, thereby allowing the discovery of adaptations during the life of the organization (e.g., behavioral adaptation in later metazoans, and adaptation of the economic system in human societies). Section 4 of this article considers how this capacity may secondarily evolve in organizations that initially are adapted by an evolutionary mechanism which sorts variation at the between-group level (i.e., in organizations that are initially adapted by natural selection operating on genetic variation between organizations), and Section 5 demonstrates that where constituent individuals themselves have sufficient internal cognitive ability, organizations of individuals can readily form which effectively sort heritable variation within the organization (e.g., human organizations).

We now turn to consider the issue of how suitable interveners which are in hierarchical relationship with the dynamic might plausibly arise with the evolution of each of the three levels of organization under analysis here. In relation to the formation of organizations of molecular processes, Dyson (1985) has already suggested the possibility that the relationship currently found in cells between the genetic material and protein-based processes may have originated with RNA parasitizing an autocatalytic set of proteins which directed a metabolism; he envisions that the relationship began with the parasitic RNA unilaterally taking resources off the protein-based dynamic, and then evolved progressively via symbiosis into the current arrangements. This is consistent with the account given here of the way in which new evolutionary mechanisms evolve in conjunction with the formation of higher levels of organization: the RNA constitutes the intervener (in this case producing higher level constraints) which achieves a hierarchical relationship to the protein-based dynamic through its ability to take resources from across the dynamic without having to participate in the detailed interactions of the dynamic, and through the functional separation it achieves due to the relatively longer time scale over which it reproduces (associated with its relatively greater stability). This enables the RNA to correct cognitive limitations in the protein-based dynamic (by, for example, promoting the production of a beneficial protein that otherwise would not be sustained in the dynamic), opening the way for the discovery of fitter organizations, which can also provide more resources for the intervener. This article adds to Dyson's suggestion by identifying a powerful selective advantage that could drive the proposed evolutionary sequence, by recognizing the essential hierarchical relationship between the RNA and the dynamic, and by providing a general theoretical framework for what would otherwise remain an ad hoc suggestion. In relation to the formation of human organizations, a system of interventions

comprising higher level constraints could be established by a chieftain, king, parliament, or committee able to obtain resources from across the dynamic of individuals without having to participate in the dynamic. The resources could be obtained by familiar human activities such as coercion, manipulation, or majority consent. The intervener could create further levels of interveners, forming multi-level hierarchies. In principle, the intervener could modify the dynamic to overcome cognitive limitations, enabling the discovery and perpetuation of the forms of cooperative organization which characterize complex human societies, including division of labor and specialization. For example, rulers who use coercion where necessary to extract resources from across their subjects could use these resources to sustain activities that are beneficial to the group but which would not be sustained in the dynamic in the absence of hierarchical intervention, e.g., the ruler could sustain an army for defence against other groups, or sustain a workforce to build a large scale irrigation system and sustain an administration to, among other things, prevent theft of the benefits of the irrigation system.

Of course, these forms of hierarchical organization do not provide the only conditions under which cooperative human organizations or cooperative organizations at other levels can evolve: as has been discussed above, there are other circumstances in which cooperative arrangements can arise. However, these circumstances and processes are generally significantly limited in their ability to systematically explore cooperative possibilities, and hierarchical arrangements have been necessary to achieve the comprehensive and complex cooperative arrangements evident in large scale human organizations-including, as we shall see, economic markets.

In relation to the formation of organizations of cells, the dynamic of cells can be most simply modified by lower level constraints (the initiating conditions constituted primarily by the genetic arrangements), rather than by higher level constraints: a particular genetic arrangement can act across and control cells within a dynamic to the extent that the cells each contain the particular genetic arrangement (e.g., due to asexual descent from a single ancestral cell). Thus, in principle, the genetic arrangement is capable of modifying any of these cells, acting across them to achieve beneficial cooperative arrangements. This could involve, for example, modification of some cells so that they provide resources to other cells whose activities benefit the organization but at net cost to themselves. However, if genetic constraints vary between groups of cells in the organization, competition can arise, with constraints achieving differential success within the organization. This variation may exist due to initial heterogeneity in the formation of the organization, immigration, or mutation. As discussed above, additional arrangements are needed to prevent differential success of this kind in the dynamic. To the extent that such arrangements fail to concentrate selection and differential success at the between-group level, the ability of the lower level genetic constraints to fully correct for cognitive limitations of the dynamic will be impaired: for example, some cooperative arrangements that would otherwise benefit the organization as a whole may be outcompeted. Kin selection involving sexually reproducing metazoans can be reinterpreted within this more general framework: kin selection can be seen as an instance of hierarchical intervention in a dynamic through lower level constraints in which the ability to correct for cognitive limitations is restricted by the failure to fully preclude differential success among lower level constraints within the dynamic (i.e., because even where individuals are related, they are unlikely to have identical genomes). Kin selection also illustrates the ease with which an arrangement such as the genetic system which can readily provide lower level constraint of a dynamic can be used repeatedly to constrain dynamics at higher and higher levels to form organizations of individuals from each dynamic

(e.g., lower level genetic constraint underpinned the emergence of multicellular organisms, and then provided the basis for the evolution of organizations of related organisms such as insect societies). However, as we shall see in the next section, arrangements that rely solely on lower level constraints are fundamentally limited in their ability to provide some cognitive functions. The main developments in cognitive capacity since the initial evolution of multicellular organisms have been based on hierarchical arrangements comprising higher level constraints, such as the neural mind and human societies.

At each of the levels of organization under consideration, the existence of the collective cognitive limitation has provided selection favoring the discovery and evolution of evolvable constraints that can intervene in and manage a dynamic from a hierarchical relationship with the dynamic. As indicated above, the evolution of these arrangements at each level represents the evolution of a new and distinct evolutionary mechanism that discovers adaptations which benefit the organizations as a whole and which cannot be discovered and perpetuated by the evolutionary mechanisms operating at the level of individual members of the organization.

4. Evolution of Cognition within Organizations

Organizations such as early cells and early multicellular organisms which comprise individuals with limited internal cognitive ability must initially rely on selection operating at the between-group level to sort heritable variation for-the-organization. This between-group process can sort variation between organizations to produce adapted organizations (e.g., by natural selection operating on genetic variation between multicellular organizations). However, the process will not discover adaptations within the organizations themselves, during their life. For example, it will not discover the heritable behavioral adaptations which are discovered by some later individual metazoans during their life. This is because once differential success of heritable variation is precluded within the organization, in order to concentrate selection at the between-group level there can be no trial and error testing of heritable variation within the organization during its life. Initially, organizations will also be limited in their ability to discover non-heritable adaptation (e.g., physiological adaptation): their ability will be limited to the capacity of the individuals that have formed the organization to themselves discover adaptations proximately. Significantly, this cognitive ability based on the proximate adaptation of individuals through time will also suffer the collective cognitive limitation that has driven the evolution of hierarchy: as discussed above, the limitation will manifest in any process where the success of an adaptation is dependent only on its effect on the individual that exhibits the adaptation; thus, proximate adaptation operating at the level of the constituent individual will adapt the individual only for the individual's benefit, and will not necessarily discover cooperative patterns of adaptation among individuals which are optimal for the organization. For example, in an early multicellular organization, optimal adaptation of the organization as-a-whole in particular circumstances may require that certain individuals adopt non-optimal states (e.g., so that resources can be freed to be used elsewhere in the organization where this will provide greater overall benefit). Without additional arrangements, the proximate adaptive capacity of the individuals will not produce these non-optimal states.

We should emphasize that these limitations apply only to the cognitive ability of individual organizations-to the ability of an organization to discover adaptations during its life. This therefore does not mean that these organizations will not be able to adapt

as organizations in response to, for example, environmental perturbations that arise during their life: the between-group process (i.e, natural selection operating on genetic variation between organizations) can come upon adaptations which, in effect, pre-program organizations to either endogenously change in ways that may be usefully correlated with environmental change, or beneficially change in ways that are triggered by environmental events. But this does not involve the discovery of these adaptations by processes operating within the organization itself.

This section will consider how these limitations in the cognitive ability of individual organizations might be overcome. It will identify what sort of arrangements need to be discovered and perpetuated by the between-group evolutionary process to provide for continuous cognition within organizations. This Section will demonstrate that the most simple and easily discovered form of internal cognition involves the discovery of adaptations that deal with circumstances which directly influence the organization. This is because possible adaptations can be tested and "trialled" against their ability to directly correct the actual impact of the circumstances on the organization (e.g., adaptations which restore the temperature of the organization to an appropriate level). Further metaevolution will favor the emergence of more complex arrangements within the organization which can discover adaptations that have no immediate effects on the organization, but which produce benefits only in the future (e.g., farming). This capacity requires more complex arrangements because possible adaptations cannot be directly tested against their (future) effects on the organization, and instead must be tested against internal representations or models which allow the future effects of adaptations to be assessed within the organization.

Other critical improvements in organizational cognition include learning, which enables the past experience of the organization to be used to better target the possible adaptations that are trialled, and the transmission of learning between organizations, which enables the accumulated experience of many organizations to be used in this way. As cognition improves, organizations arise that are able to discover adaptations during their life that previously could be discovered only by the between-group process. Eventually, the ability of the internal cognition may surpass the ability of the between-group process, with the internal cognition reassessing and revising adaptations discovered by both the previous internal cognition and the between-group cognition. This trend is experienced by humans as the progressive bringing into consciousness of various domains of human activity, and the use of this consciousness to test and revise existing actions, strategies, values, and cognitive processes against their future consequences-including, eventually, their longer term evolutionary consequences.

4.1 *Ultrastability*

As discussed above, the ability of an organization such as an early cell or an early multicellular organism to discover adaptations during its life will initially not extend beyond the ability of its constituent individuals to discover adaptations proximately. And the collective cognitive limitation will apply to this proximate adaptation: the constituent individuals will adapt for-themselves, not for-the-organization. As we have seen, appropriate interventions which are in hierarchical relationship with the dynamic of constituent individuals can cause the individuals to adapt and act for-the-organization. However, if different adaptations are to be tested and discovered during the life of the organization so that it can adapt to changing conditions, variation (possible adaptations)

must arise in the interventions and be sorted within the organization itself, rather than solely through the between-group process.

This variation could be sorted for-the-organization via testing of possible adaptations against their effects on variables within the organization that are proxies for organizational success. This could be achieved most simply in relation to environmental perturbations that have direct impact on the organization and that move critical variables (e.g., temperature) outside their preferred range (i.e., the range within which a variable is kept for the most efficient operation of the organization). For such perturbations, possible interventions could be tested directly and immediately against their ability to return the variable to its preferred range. In this way, particular interventions could be discovered during the life of the organization which cause individuals within the organization to adapt and act in ways which benefit the organization. Ideally, the interventions would cause individuals to adapt as if the effects of their adaptations on others in the organization were effects on self, at least in relation to events which immediately influence the organization.

Such an arrangement is an example of what Ashby (1952/ 1960) referred to as an ultrastable process. He suggested that living systems could discover adaptations by maintenance of certain of the systems' internal variables (termed "essential" variables by Ashby) through trial-and-error variation of relevant parameters within the system. As organizations become differentiated, there is likely to be advantage in the complementary differentiation of these ultrastable processes within the organization: this would enable specialized ultrastable processes or units to become associated with functionally specialized groups of individuals within the organization (e.g., a biochemical cycle in a cell, or a particular organ or component of an organ in a multicellular organism). Such an ultrastable unit would adapt its functionally specialized group by maintaining essential variables that are proxies for the effective functioning of the specialized group (this contrasts with an unspecialized ultrastable unit that would maintain an essential variable which is a generalized proxy for the effective functioning of the organization as a whole, not for a differentiated component of the organization).

Again, however, without additional arrangements each differentiated ultrastable unit associated with each specialized group would adapt for-itself rather than for-the-organization, and would suffer the collective cognitive limitation that has driven the evolution of intervention hierarchies: each unit discovers adaptations solely on the basis of the effect of possible adaptations on the essential variable maintained by the unit and fails to take account of the effect of its adaptation on other ultrastable units within the organization. Consequently, where the maintenance of a number of essential variables has impact on each and interacts dynamically (e.g., because there are trade-offs between variables in the use of resources to maintain the variables), the individual units will not necessarily discover cooperative patterns of adaptation among variables that are best for the organization as a whole (i.e., that optimally use resources across the dynamic of variables). Once again, there will be advantage in the establishment of interveners in hierarchical relationship with the dynamic of its units that stand outside and act across it, modifying the dynamic through time to achieve beneficial patterns of adaptation of units that would not have been discovered and perpetuated otherwise. Such an intervener, together with the essential variable it maintains and the dynamic of ultrastable units that it manages, forms a higher level ultrastable unit of greater functional scope in the organization.

Where a number of these higher level ultrastable units interact across the organization to form a dynamic, further interveners might arise to manage this new dynamic. In this way, multi-level interpenetrating hierarchies of ultrastable units are formed. In effect, each new level in a hierarchy will adapt the level below to a new set of concerns for the organization, generally of wider scope, that are not taken into consideration in the adaptation of the level below. The net result is that variation is sorted within the organization by proxies for organizational success that are established and tuned by the between-group selection process.

This hierarchical structure of cognition presents an organization with a number of possible options when a particular adaptive problem is encountered: in principle, the organization could seek to restore the relevant essential variables by trialling changes at any level in the applicable hierarchy, or at any combination of levels. However, due to the particular nature of the functional relationship between levels in the hierarchy, lower levels will tend to trial changes in their adaptations before changes are trialled at higher levels. This is because, as discussed earlier, the interveners do not participate dynamically in the dynamic they influence. This functional separation is achieved in part because the interveners are generally constituted by processes operating on a longer time scale. Thus, on the time scale in which the ultrastable units in the dynamic adapt and test alternative adaptations, the upper level constraints which intervene in the dynamic will tend to be relatively unchanging and given. Hence adaptation of the dynamic will occur in the context of the relatively fixed environment of the higher level. On a longer time scale, the intervening upper level constraints will themselves vary, trialling possible adaptations at the higher level.

Thus levels in ultrastable hierarchies will tend to be ordered on the basis of the time scale in which the adaptations applicable to each level are trialled. Efficiency of cognition will favor the allocation of ultrastable units to a level in the hierarchy which reflects the appropriate relative time scale in which the adaptation dealt with by the unit is best varied or tested. The higher an adaptation in the hierarchy, the less frequently will it be likely to require variation. The ordering of adaptations in a hierarchy thus can be viewed as a hypothesis about how frequently adaptations can be changed with benefit. For example, adaptations that would be dealt with by higher, slower changing levels might include: adaptations that are relatively costly to change (e.g., because the adaptation is of wide scope in the organization, and any change would require many consequential changes), or where the adaptations represent strategic positions (e.g., default conditions, “wisdom”) that have stood the test of time. Rather than abandon these positions at the first sign of maladaptation, a more beneficial strategy might be to first attempt to adapt them to current circumstances by lower-level tactical changes (although this carries the danger of protecting inappropriate traditions from testing). In this way, the strategic knowledge accumulated by the organization can be preserved.

This analysis provides a basis for understanding the evolution of the behavioral, physiological, and other adaptation hierarchies (ordered on the basis of the time scale in which adaptations are trialled) which have been described by Bateson (1963), Slobodkin and Rapoport (1974), and Holland, Holyoak, Nisbett, and Thagard (1986), as well as the belief hierarchies of New Guinea tribes described by Rappaport (1979), where the slower changing strategic beliefs at higher levels in the hierarchy were perceived by the tribal members as “sacred”. This analysis also provides an explanation for the relative stability

over long evolutionary time scales of the fundamental body plans of the main lineages of animals (Gould, 1977). The fundamental body plans represent strategic adaptations of wide scope in the organization which are trialled for change on a longer time scale; in most circumstances, adaptation at lower levels of the default hierarchy will change to meet changing conditions, preserving the strategic adaptations of the fundamental body plans. We should note, however, that the higher level adaptations do not have to be optimal to persist. In effect, the lower levels adapt the higher levels to changing circumstances so that the upper levels do not fail their relatively infrequent testing, in the same way that the addition of ad hoc hypotheses can adapt a general scientific theory to almost any new evidence.

This analysis also suggests that the adaptive system based on the between-group evolutionary mechanism will also be organized into a hierarchy ordered on the basis of the time scale in which adaptations are trialled. For example, we can expect that the testing of genetic alternatives in a genetic system will be organized in a hierarchy with changes in "sacred" and strategic genetic arrangements trialled on a relatively much longer time scale than changes in genetic arrangements which deal with more "tactical" adaptations. The arrangements discussed by Brooks (1988) which produce variation in the rate of recombination throughout the genome provide ample basis for the arising of different rates of testing among genetic arrangements. The pattern of mutation and variation of genetic arrangements within a population will therefore not be random, and can be viewed as a set of hypotheses generated from past experience about how frequently beneficial changes can obtain in adaptations. This genetic hierarchy will integrate with and coevolve with the adaptation hierarchy associated with the internal cognition of the organization, with the genetic hierarchy trialling adaptations on longer time scales than the internal cognition. As we shall see, as the internal cognition improves, it progressively takes over from the genetic system, trialling adaptations on longer and longer time scales.

We now turn to the issue of whether both upper and lower level constraints are equally capable of providing the system of interventions needed for internal cognition. In organizations in which the cognitive limitation is being dealt with by upper level constraints (e.g., RNA in early cells), the resultant system of interventions provides a ready-made basis for the evolution of ultrastable arrangements: the effect of interventions would be varied during the life of the organization, and the variation would be sorted on the basis of its effect on maintaining essential variables. The well-known example of cellular adaptation elucidated by Jacob and Monod (1961) reflects this type of ultrastable organization. However, there is a fundamental asymmetry between interventions arising from upper level constraints and those arising from lower level constraints in relation to the organization of ultrastable arrangements: consider a dynamic comprised of interacting ultrastable units (for example, a dynamic of individual cells which are constituents of a multicellular organization, and each individual cell is ultrastably organized, enabling it to discover beneficial adaptations to different environmental conditions). The object is to modify the dynamic as is necessary through time in order to maintain an essential variable within a particular range in the face of environmental changes. An upper level intervener modifies the dynamic by appropriately changing the environment encountered by individuals in the dynamic. The individuals are modified by their ultrastable adaptation to the new environmental conditions. Significantly, the modification is achieved without limiting the internal cognitive capacity of the individuals; the changed outcome is achieved not by overriding the individual's cognitive arrangements, but by establishing boundary conditions which will evoke the desired changes as an adaptive response from the

individual.

By contrast, a lower level intervention (e.g. a particular genetic arrangement in the case of a cell which is part of a multicellular organism) modifies the dynamic by appropriately changing the initiating conditions of individuals-the individuals are constrained to change irrespective of whether the change is an appropriate ultrastable response to the environmental conditions being experienced. Modification by lower level constraint therefore generally must override and ultimately impair the effective operation of the existing ultrastable arrangements of the individuals in a dynamic. A human example is a person who has been inculcated with the need to put duty and virtue above all else, irrespective of the consequences-the person is not free to adapt in an ultrastable fashion to circumstances as they arise. Where the retention of the proximate cognitive ability of individuals and other ultrastable units in an organization is advantageous, the use of initiating conditions as interveners to achieve ultrastable arrangements is not likely to be favored. Hence in multicellular organisms with well-developed adaptive arrangements, the ultrastable arrangements have been established primarily with hierarchies of upper level constraints (e.g., the nervous and endocrine systems), even though the original cognitive limitations of the dynamic of cells were initially dealt with by the genetic system of lower level constraints. Similarly, the most highly developed cognition in organizations comprised of metazoans has been achieved by human social systems which utilize higher level constraints (e.g., government), rather than by insect societies which are based on lower level constraints (e.g., genetic arrangements).

4.2 *Limitations of Ultrastability*

These basic ultrastable arrangements can provide continual cognition within an organization, but this cognition is limited in a number of ways:

1. Basic ultrastable arrangements have no capacity to learn: adaptations must be continually rediscovered by trial and error as relevant environmental conditions change, and are not heritable.
2. Ultrastability can discover only adaptations that affect the current values of essential variables-if an adaptation produces beneficial changes in an essential variable that are experienced at a time different from the trial of the adaptation, basic ultrastable arrangements have no way of identifying the adaptation as the cause of the change. Ultrastability is therefore unable to discover adaptations which benefit the organization in the future, and cannot discover adaptations whose benefits are not captured at all by the organization during its life, but which are necessary for the reproduction of the organization (e.g., courtship behavior). In organizations limited to basic ultrastable cognition, at very least the framework of these adaptations thus must continue to be discovered and provided by the between-group process (e.g., by natural selection operating on genetic variation between organisms).
3. The basic ultrastable arrangements are blind to the causes of changes to the essential variables; the arrangements respond only to changes in the essential variables, and do not themselves distinguish different causes of the same change. They are therefore not effective in targeting adaptations to the particular cause of a change that may have many causes. Beer (1972) distinguishes between arrangements which manage an organization in relation to the inside/now, and those that manage the organization in relation to the outside/future. This is a useful distinction here: operating alone, the basic ultrastable arrangements are largely restricted by the limitations outlined above to discovering

adaptations for the inside/now (e.g., adapting the internal processes of an organization, such as the metabolic systems of cells and the physiology of metazoans, in relation to perturbations that directly and immediately affect the efficient operation of these processes). Of course, this does not mean that organizations are unable to adapt for the outside/future if their internal cognition is limited to basic ultrastable arrangements: the between-group process can in effect pre-program such adaptations, and can also combine ultrastable arrangements with pre-programmed adaptations to achieve some flexibility.

4.3 *Learning, and Transmission of Learning*

The acquisition of the ability to learn is a major cognitive advance which allows ultrastable arrangements to return without trial and error to an adaptation which was discovered in relation to particular circumstances, whenever similar circumstances recur. The capacity to learn can also assist in overcoming the ineffectiveness of basic ultrastable arrangements in targeting adaptations to the particular cause of a change in an essential variable, where the change may be caused by any of a number of different environmental perturbations. Provided the organization can discriminate states of its outside environment associated with each of the perturbations, it can learn to adopt adaptations so that each appropriately responds to a particular perturbation-dealing with causes, not just effects. The ability to reuse adaptations also increases the payoff for trial and error exploration of adaptive possibilities, increasing the circumstances in which trial and error is beneficial. Learning within organizations would be particularly favored over learning through the between-group process where there are differences between organizations in what is to be learned (e.g., where each organization needs to learn the characteristics of the particular physical environment in which it lives).

Learning acquired by a particular organization could also be of benefit to other organizations. As a result, cooperative arrangements involving learning and the transmission of learning between organizations can provide overall net benefits to participants: for example, the cost of discovering a particular adaptation need apply only once, learning can be accumulated and developed across the population of organizations (parallel processing) and across generations, and eventually division of labor and specialization can arise in relation to the acquisition of adaptations. The evolution of cooperative arrangements involving the acquisition and transmission of learned adaptations would be subject to the same cognitive limitation that applies to the evolution of other cooperative arrangements between living processes (e.g., involving the generation and transmission of other resources). Consequently, the potential for cooperative acquisition and transmission of learning can be extensively explored only where the collective cognitive limitation is being significantly corrected by hierarchy (e.g., in human societies where the transmission and use of innovations is regulated by appropriate hierarchical interventions to prevent free riders and to enable specialist innovators to be sustained). Where the correction is limited, only much more restricted forms of cooperative transmission between organizations are possible (e.g., heritability and sex).

The cognitive significance of the ability to transmit learning is that it transforms a cognition which is limited to individual organizations into an evolutionary mechanism that potentially can discover, accumulate, and build upon adaptations indefinitely, across organizations. In effect, it also reinstates the situation where transmittable (i.e., heritable) variation can arise and can achieve differential success within the organization. The transmittable variation need no longer be suppressed within the organization, with sorting

concentrated at the between-group level; instead it is sorted within the organization in interaction with its environment. This sorting will tend to ensure that the transmittable variation can achieve differential success only where it benefits the organization as a whole.

4.4 *Modelling for the Outside/ Future*

Basic ultrastable processes use the immediate impact of possible adaptations on the organization to test and sort alternatives. Additional arrangements are necessary if cognition within the organization is to be able to readily discover adaptations which provide only future benefits and which do not provide an immediate beneficial impact on essential variables. The discovery of adaptations of this sort would appear to require the testing of possible adaptations within the organization against some internal assessment of their future impact. To make such assessments, the organization needs to acquire rules, generalizations, and other knowledge about how its world unfolds through time, particularly in response to the actions of the organization. For example, this could enable the discovery of an adaptation which produces an environmental state that itself has no beneficial effect on the organization, but which is known to unfold to a state that does; or enable the discovery of adaptations which beneficially anticipate future events, but which have no beneficial effect when first implemented. When fully developed, this capacity to assess possible adaptations against their future consequences involves the generation within the organization of representations or models of its environment which incorporate the relationships, generalizations, orders, and useful abstractions that the organization has discovered. These can be used in conjunction with the system of essential variables to sort variation by assessing the benefits (and costs) that are likely to flow from possible adaptations over time.

As the organization develops models not only of its immediate external environment but also of itself and of its evolution, the internal cognition would be able to take account of effects that are more distant in time and space, directly adapting the organization in relation to social, historical, and longer term evolutionary consequences of competing adaptations. The progressive development and extension of this capacity to generate models would progressively extend the ability of the organizational cognition to discover and modify adaptations that previously could be dealt with effectively only by the between group evolutionary mechanism, and to eventually surpass the cognitive ability of the between-group process (as we shall see below, the between-group process is itself limited in its ability to discover adaptations with future benefits). As modelling is extended to additional domains, adaptations which were previously established by the between-group mechanism or earlier internal cognition would be treated as contingent and variable within the extended models, and could be reassessed within the new framework. For example, the organization could become aware of the wider evolutionary processes that have formed the organization and the systems with which it interacts, and which will ultimately determine the longer-term effects and outcomes of any actions and projects initiated by the organization. The role of the organization in future evolution would then be accessible to consciousness, no longer taken as given, and subject to revision using its models; the organization would be able to consider possible evolutionary futures for itself and for the other systems of which it is part.

The enhanced cognitive ability which is provided by the capacity to model can be applied recursively to the cognition of the organization itself. In other words, the modelling capacity could be used to model the cognitive processes of the organization and their

application in the world, enabling the processes to be revised, modified, and improved in the light of their longer-term effectiveness, including over long evolutionary time scales. This extension of the use of modelling is being experienced by humans as the progressive bringing into consciousness of more and more aspects of the world which are of relevance to humans, including features of the physical and social environment, the strategies used by humans to discover knowledge and other adaptations, the processes which determine human values and objectives, human cognition (including aspects that were initially unconscious), and the wider evolutionary processes that have formed humans and the human condition and that will continue to do so in the future. (This article itself can be seen as a modest contribution to the process of bringing into human consciousness the wider metaevolutionary processes which have formed and will continue to form cognition including human cognition. This is part of the process of the evolutionary mechanism becoming conscious of itself and of its evolution as an evolutionary mechanism.) Such modelling and bringing into consciousness of these aspects of the world is enabling humans to revise previous adaptations (including values and objectives) and discover new ones by using the modelling to test competing adaptations against their longer-term consequences.

Because the capacity to be applied recursively is fundamental to the ability to model, we can usefully consider the evolution of the modelling capacity in relation to the following four broad domains:

External Modelling: Here the organization models the external environment and possible adaptations of the organization in relation to the environment. Thus adaptations do not have to be actually implemented to be assessed: the benefits of potential adaptations can be tested internally within the model, and models can be developed on the basis of knowledge acquired through relatively safe interactions with the environment (e.g., research). As stressed by Popper (1972), this effectively internalizes natural selection, substantially reducing the costs and risks of discovering adaptations by trial and error. As discussed above, this modelling enables the discovery of adaptations that have only future effects on the organization. It enables the organization to make plans and projects, and to invent machines. However, modelling on this level does not model the possible strategies which can be used by the organization to discover new adaptations, as these strategies are taken as given and are not accessible to consciousness.

Strategic Modelling: Here the organization also models the possible strategies and other arrangements it can use for discovering adaptations. The organization will become aware of, for example, the strategies it uses to build models, to make inferences from evidence, undertake experimentation, generate and test hypotheses, identify regularities, and establish theories. The organization can use its modelling of these strategies to assess and discover alternatives, taking into account the longer-term effects of the alternatives. For example, the tendency for the organization to become increasingly mechanistic as trial and error processes are progressively replaced with fixed adaptations (Salthe, 1985) can also be overcome where the organization utilizes strategic modelling to discover longer-term benefits in retaining flexibility and adaptability. Modelling in this domain is related to Bateson's (1973) category "Learning 2," which includes learning to learn.

Intentional *Modelling:* This goes beyond strategic modelling by also modelling the criteria used by the organization to sort adaptations, i.e., the objectives and values pursued by the organization. These will no longer be treated as given by the organization; they

will be accessible to consciousness, and subject to revision using its models. Living systems that extensively model in this domain are likely to experience crises of meaning and purpose. The organization will become aware of the social and other environmental circumstances that have formed its objectives and values, and use its models to reassess these and other alternatives in the light of their longer-term social, historical, and evolutionary consequences. It may continue this reassessment throughout its life as its knowledge and models develop further, in a continuing process of self-actualization (Maslow, 1970). The implementation of changed values is likely to necessitate modifications to the organization's pre-existing cognitive system, which is likely to comprise a combination of more or less specialized cognitive processes that may utilize ultrastable, pre-programmed, and other arrangements. Initially, such pre-existing cognitive processes may each discover and perpetuate adaptations according to their own criteria, rather than to satisfy the revised values of the organization as a whole. New levels of intelligent hierarchy are necessary to provide boundary conditions to adapt these pre-existing cognitive processes to the new concerns and values of the organization. This process of establishing new levels of management to implement changed values is likely to be accelerated when changed demands are placed on organizations-by, for example, the rapid evolution of social arrangements. The establishment of these new levels of hierarchy is experienced by individual humans as movement from a mode of being where the individual identifies with the pre-existing cognitive processes and their concerns to a mode where the individual no longer "is" the pre-existing cognition, but stands outside it, and can act somewhat independently of its concerns.

Cognitive Modelling: Here the organization becomes explicitly aware of its overall cognition and of the cognitive processes that have formed the organization and its cognition. The cognitive processes of the organization and of any higher level organization in which it participates will no longer be taken as given, will be accessible to consciousness, and will be subject to revision using its models. In particular, the organization would be able to evaluate the ability of its cognitive processes to take into account the longer-term effects of possible adaptations, including their longer-term evolutionary consequences, and make appropriate cognitive adjustments. The organization would become aware that the successful future evolution of a new level of organization which is comprised of organizations like itself would necessitate the establishment of new hierarchical cognitive processes that overcome the cognitive limitation at the level of the organization. Cognitive modelling would also provide awareness that the successful evolution of cognition at the next level of organization is critical if individual organizations (like the organization now aware of its cognition) that comprise the new level are to benefit from participation in cooperative arrangements that can be discovered and perpetuated only by the cognition at the higher level (including arrangements that prevent free-riding and harmful conflict). Organizations may act on this awareness to contribute to the evolution of cognitive processes at the next level (e.g., humans with this awareness are likely to support the establishment of hierarchical arrangements that operate across humanity, overcoming the collective cognitive limitation for humanity-as-a-whole, and enhancing the discovery and perpetuation of cooperative arrangements across the human system, such as greater international cooperation).

4.5 *Pre-Emption of the Between-Group Evolutionary Mechanism by Internal Cognition*

A sufficient level of cognitive ability within organizations will result in the pre-emption through time of the between-group evolutionary mechanism, essentially making it

redundant. To pre-empt the between-group process in response to a particular environmental threat, the internal cognition must discover adaptations which remove the ability of variation at the between-group level to achieve differential success; in effect, the internal cognition must solve the adaptive challenge first, leaving no advantage to be exploited by the between-group mechanism (Laland, 1992, models this process). This does not mean that adaptations discovered by the internal process will be selected to maximize differential reproductive success: provided the minimum condition that has been identified continues to be met, the between-group process will be anticipated, and the internal cognitive process will select adaptations on the basis of the values and objectives of the organization's internal sorting processes irrespective of whether these maximize reproductive success. Where the internal cognitive process is sufficiently developed, these values would be able to be revised within the organization through the process that has been described as intentional modelling. This would enable the internal cognition to finally overcome a significant cognitive limitation of the between-group process discussed above: the between-group cognition is essentially a basic ultrastable process; it is therefore limited in its ability to discover adaptations which have benefits that are not experienced in the time scale in which adaptations are trialled at the between-group level; it is therefore limited in its ability to discover adaptations which, for example, are beneficial only on a longer-term evolutionary time scale, and which anticipate longer term evolutionary and metaevolutionary developments.

There is likely to be a coevolution between the between-group and the internal cognitive processes as organizations evolve: initially, the between-group process dominates; as internal cognition evolves, it can pre-empt between-group cognition more and more, particularly as the internal process accumulates adaptations and models which it uses to generate new adaptations. The between-group process is progressively relegated to the role of a reserve power which is invoked only when internal cognition and adaptations which are pre-programmed in the organization fail to adequately deal with a challenge (e.g., for sexual organisms, the growth of a clone; see Stewart, 1993). As the organizational cognition improves, it may also exceed the cognitive ability of the individuals that comprise the organization. Where this is the case, the system of hierarchical interventions associated with the organizational cognition will cause the constituent individuals to adapt and to act as if the individual had the improved cognition of the organization.

As we have seen, the constituent individuals initially adapt for-themselves. In an important sense, an ideal system of hierarchical interventions that establishes an internal cognition would feed back to these individuals the effects of their adaptations on others in the organization, and ultimately on the organization as a whole, causing the individuals to adapt as if they treated effects on others as effects on themselves. Where this internal cognition is limited to basic ultrastable arrangements, the hierarchical arrangements would be able to feed back to individuals only the immediate effects of possible adaptations on the organization. Progressively as the internal cognition improves, it would be able to feed back to constituent individuals the effects of possible adaptations that are more and more distant in time and space.

5. Evolution of Cognition within Organizations, Based on the Cognition of Individuals within the Organization

Where there is no process within an organization of individuals to sort transmittable variation for-the-organization, differential success of transmittable variation within the

organization must be initially precluded, thereby concentrating selection at the between group level. As we have seen, transmittable variation can be reintroduced when the between-group process discovers arrangements which will sort the variation within the organization. However, if at least some variation could be sorted for-the-organization without the evolution of additional arrangements, this would render the initial suppression of all transmittable variation unnecessary: the organization would be able to discover adaptations during its life, and the between-group process could be pre-empted and avoided somewhat from the outset. This might also avoid the other severe organizational constraints necessary to underpin an evolutionary mechanism based solely on a between group process (e.g., the formation of populations of separate, near identical, temporary organizations which compete against each other). In what circumstances might this be achieved, with variation that arises in hierarchical interventions sorted internally for-the-organization from the outset?

Consider an organization comprising an intervening individual in hierarchical relationship with a dynamic of individuals (e.g., RNA managing a protein-based dynamic, or a human chieftain ruling a tribe). The intervener obtains resources from across the dynamic, and is potentially able to correct collective cognitive limitations of the dynamic by appropriate interventions. There is an area of common interest between the intervening individual and the organization as a whole: for example, there is a common interest in interventions which assist the perpetuation of the group by preventing damaging conflict within the organization, and in interventions which correct cognitive limitations in the dynamic in a way that increases the efficiency of the dynamic, making more resources available to the intervener.

But clearly the ability of the intervener to fully explore areas of common interest by establishing and adapting appropriate interventions would depend on its cognitive ability: consider the case where individual interveners have no internal cognition, and interveners must discover adaptations (i.e., interventions) by a cognitive process which relies on the differential reproductive success of individual interveners (e.g., by natural selection operating on variation between RNA interveners). Here, evolution of the interventions would necessitate reproduction of the intervener within the organization, and competition among the variants that are produced. But clearly the success of the individual variants that are competing within the organization would not depend only on the success of the organization as a whole; sorting would therefore not necessarily be for-the-organization. As we have seen, in these circumstances sorting for-the-organization would be achieved most simply by arrangements that suppress this competition within the organization, concentrating competition and selection at the between-group level.

This difficulty would in part be overcome if possible adaptations could be sorted within the intervening individual by cognition which is internal to the individual, rather than by cognition which relies on differential reproductive success between individual interveners. However, if this internal cognition were arranged solely through ultrastability, the intervener would discover interventions that benefited the organization only where the benefit of the intervention is also immediately experienced by the intervener. This particular limitation could be overcome if, as in many humans, the intervener's internal cognition includes the capacity for what has been described above as external modelling, enabling the intervener to discover any intervention that its models indicate would eventually benefit the intervener, whether or not the effects were felt immediately. As the models available to the externally conscious intervener improve, the common interest could

be more fully explored, and the between-group process pre-empted to a greater extent.

Transmittable variation arising in individuals in the dynamic would not need to be suppressed, provided that the interventions could establish boundary conditions for the individuals that ensure that adaptation of the individual would be for-the-organization. Interveners could evolve multi-level hierarchies structured similarly to the ultrastable hierarchies that have been discussed, enabling a diversity of specialized individuals and groups of individuals to arise and adapt for-the-organization. These hierarchies could also intervene in the dynamic to create the conditions under which economic markets and other systems of exchange relations could be discovered and perpetuated. This would involve, for example, establishing boundary conditions that make cheating in exchanges maladaptive.

Organizations of humans structured on the basis outlined above (e.g., where the intervener is a chieftain, ruler, king, committee, board, or government) are therefore readily able to establish an internal organizational cognition which overcomes the collective cognitive limitation at least in part, without having first to establish and rely solely on a between-group process. However, from a cognitive perspective there are a number of limitations inherent in this form of organization in which interventions are devised by an intervener operating largely as a central planner. These limitations fundamentally restrict the ability of the organizational cognition to explore, discover, and perpetuate adaptations that are beneficial to the organization as-a-whole. Two such limitations will be discussed.

1. Although the internal cognition will tend to discover adaptations that are beneficial for the organization wherever they are also beneficial for the intervener, the interests of the intervener and the organization are not always likely to coincide. For example, the intervener may better serve its essential variables (and those of its agents) by taking more resources from across the dynamic than is optimum for the effective operation of the organization. The effects of this may be increased by competition between organizations: a group which is impaired because the intervener takes a non-optimal share may be outcompeted by others that do. This will result in inter-group selection, unless the intervener pre-empts the selection by, for example, reducing its taxation of the dynamic. However, a comprehensive solution to this cognitive limitation would require additional arrangements that increase the extent to which the interests of the intervener and the organization coincide, irrespective of the organization's external competitive environment. Competition between organizations may limit the circumstances in which an intervener can successfully adapt ways which are contrary to the interests of the organization: for example, laws binding the intervener and the hierarchy which are enforced independently of them; performance contracts; and democratic controls.

This raises a related issue: what cognitive mechanism within the organization would discover and perpetuate these constraining adaptations that clearly may not be in the interests of the intervener? We find that not only in the intervener does external modelling open up new cognitive possibilities for organizations: individuals in the dynamic with the capacity to externally model may recognize that they could benefit from arrangements that appropriately constrain the intervener. However, if the intervener is to accept these constraints, individuals in the dynamic will generally be obliged to make such acceptance manifestly in the intervener's interest. To achieve this, individuals will need to act collectively: the nature of the hierarchical relationship between the intervener and the dynamic means that the normal individual interactions of the dynamic will not strongly

influence the intervener; collective action overcomes this limitation by operating at the same hierarchical scale as the intervener. Individuals will generally need to form organizations in order to act collectively, and to solve the collective cognitive limitations of the organizations. These organizations obviously will suffer the same difficulties in overcoming the cognitive limitations as are being discussed here (e.g., they may be unrepresentative).

Of course, instead of attempting to constrain the intervener, collective organizations can attempt to oust the intervener, and institute a new organization. However, to the extent that the new organization does not contain internal arrangements to overcome the various cognitive limitations, it will be similarly limited in its ability to adapt for-the-organization. And the intervener can respond to these types of developments in a number of ways other than accepting constraints on its behavior, or being ousted: for example, it can attempt to persuade individuals that the organization will be more efficient and productive if more of the organization's resources are possessed by the intervener (i.e., the intervener can attempt to influence the content of the models used by individuals in the dynamic), or it can make formation of effective collective organizations of individuals difficult, and so on. A history of move and countermove is likely as these fundamental conflicts in interests are worked out through time.

An intervener able to use the power associated with its hierarchical position in ways that are not for-the-organization is also likely to be the target of influence from other individuals in the organization. Individuals that are best able to use and influence the intervener for their ends are those who are able to operate at a similar hierarchical level to the intervener; for example, those who have accumulated sufficient resources to enable them to operate apart from and act across the dynamic, and who can intervene in the dynamic in their own right. These individuals may use their influence and their hierarchical position to impede beneficial adaptations for-the-organization that might reduce their resources or their ability to continue to accumulate them. In general, to the extent that individuals within the organization do not encounter boundary conditions which cause them to adapt for-the-organization, the cognitive ability of the organization will be impaired.

2. The second cognitive limitation that will be discussed arises because the ability of the organization to discover beneficial interventions in the dynamic is limited to what can be discovered by the internal cognition of the intervener and of any other hierarchical arrangements it establishes. The ability of the hierarchy in this respect will be fundamentally limited: this can be seen by considering what the hierarchy must assess to identify the system of interventions that need to be established and adapted through time to comprehensively overcome the collective cognitive limitation. Ideally, the interventions must ensure that each individual in the dynamic experiences through time the consequences of its actions on others, so that when the individual adapts within these boundary conditions established by the interventions, it adapts for-the-organization. However, except in simple situations, the hierarchy will not have the information to enable it to design and implement the interventions necessary to directly provide this feedback to all individuals in relation to all possible adaptations.

A special case of this general problem is where the adaptations involve economic activities, such as the production and transfer between individuals of goods and services. In relation to this special case, Hayek (1948) demonstrated that a central authority would

not have the information to determine and cause the optimum production and distribution of goods and services. Much of this information is private to the individuals actually involved in the economic interactions of the dynamic, and is actually created by those interactions: only the interacting individuals are in a position to experience and evaluate the effects of alternative economic adaptations, or to model them effectively; and competition among alternative providers of goods is necessary to establish an appropriate value for goods, and to inform consumers of this value (through the pricing mechanism). These difficulties are compounded in a rapidly evolving dynamic which comprises innovatively adaptive individuals: effective modelling of the consequences of implementing the various alternative interventions through time may not be possible due to the complexity of the circumstances. Hayek's arguments in relation to the special case of economic activity are equally applicable to the general problem of the identification by a hierarchy of optimal interventions in a complex dynamic.

To the extent that this limitation restricts the ability of the hierarchy to discover interventions that correct collective cognitive limitations, the organization will be unable to discover beneficial cooperative arrangements between individuals. For example, if a level in the hierarchy is unable to provide appropriate boundary conditions for the individuals in the level below, the individuals will be able to adapt in ways that benefit the individual at the expense of the organization (e.g., corruption, theft, or avoidance of responsibility) in lieu of adapting in ways that create additional net benefits for the organization. In organizations where the hierarchy is limited in its ability to provide individuals in the dynamic with appropriate boundary conditions, variation may need to be suppressed in the individuals to preserve the organization against damaging internal competition. The hierarchy would be able to successfully manage only organizations which are relatively simple, predictable, and mechanistic-e.g., where behavior is stereotyped and creativity is suppressed. As the cognitive ability of the intervener evolves, more variation could be permitted within the organization and sorted effectively for-the-organization (e.g., this process has contributed to the recent trend away from "Tayloristic" work organization, and the rise of individualism in society more generally). However, the potential for improvement in the ability of the "central planning" hierarchy to discover optimal interventions is fundamentally limited for the reasons outlined above.

6. Improving Organizational Cognition-Vertical Exchange Relations

What arrangements might overcome these cognitive limitations of organizations in which a central authority establishes and adapts the interventions needed to sustain cooperative arrangements? What system of establishing and adapting interventions could move closer to the ideal of causing individuals in the organization to broadly experience the effects of their adaptations on others in the organization so that they adapt cooperatively, as if they treated effects on others as effects on self?

Hayek (1948) argued that the economic market overcomes the limitations of central planning in relation to the special case of economic activity. We do well to examine the extent to which the processes which constitute economic markets could be extended to other domains to overcome the collective cognitive limitation more effectively than forms of organization in which the hierarchy itself establishes interventions. The ideal economic market can be characterized as a system of reciprocal exchange relations between individuals which overcomes the collective limitation in relation to certain economic interactions in the following way: an individual takes account of the effects of its economic

activities on others because, through exchange, the individual gains benefits from providing market goods or services to other individuals. In this sense, individuals adapt in relation to these economic activities as if effects on others were effects on the self. The exchange value of goods is determined by competition between providers of goods, thereby tending to ensure that benefits received by providers are sufficient to sustain only the most efficient way of providing an optimal level of goods.

Viewed as a whole, these arrangements go a considerable way towards overcoming the cognitive limitations of hierarchy that adapts by central planning, at least in relation to certain economic activities. First, provided individuals pursue their interests only through activities sanctioned within the market system, the boundary conditions established for them by the system will cause them to adapt for-the-organization. To this extent, the immediate interests of all individuals in the ideal system will coincide with those of the organization. Second, possible adaptations are not generated and sorted by the hierarchy or by individuals who otherwise do not have access to the necessary information. Instead, the system utilizes multiple perspectives among individuals to provide intelligent trial and error (any individual may test an adaptation that it considers will be beneficial to others); sorts these possibilities by competition; and ensures that this competition occurs solely on the basis of the extent to which the cooperative adaptations would benefit the individuals affected by the adaptations, assessed solely by these individuals (rather than by the hierarchy).

However, observers generally accept that market systems are limited in their ability to replace hierarchy and therefore to circumvent the cognitive limitations of hierarchy which adapts by central planning. Two difficulties will be discussed here:

First, exchange relations between individuals in the dynamic can operate effectively only in relation to those interactions between individuals in which the benefits provided to others are discrete and tradeable, and can be limited to the individuals involved in the exchange. Where benefits cannot be limited in this way, the individual will have difficulty exacting appropriate benefits in exchange for the benefits it provides to others. For example, this will often be the case where possible cooperative adaptations have collective effects (e.g., in relation to adaptations that provide many of the conditions of social existence, that establish public goods, and that affect environmental conditions). In these circumstances, the market system will fail to ensure that individuals gain the full benefit of adaptations that benefit others, and will therefore fail to discover beneficial cooperative arrangements. For effective cognition, the market would have to be supplemented by a system of hierarchical interventions which ideally would ensure that individuals obtained all the beneficial effects of their adaptations on others, including those that the market failed to provide to them.

Second, economic market systems cannot persist without a complementary system of hierarchical interventions, and the prior evolution of adaptive hierarchical arrangements is what makes possible the evolution of a market system in the first place. Observers have long recognized that markets can exist on a large scale only where interventions establish particular conditions in the economic dynamic (e.g., Arrow, 1974; Hodgson, 1988). For example, hierarchical interventions are necessary to preclude behavior that would otherwise undermine the successful operation of exchange relations. These interventions would generally include a system of regulation and enforcement to prevent cheating in exchanges, and arrangements which require market participants to behave in ways that

facilitate detection and punishment of inappropriate behavior.

Within the framework developed in this article, market relations can be viewed as a form of reciprocal relation where the collective cognitive limitation which arises because of free riding is prevented by a system of hierarchical interventions. In effect, these interventions provide participants with boundary conditions which ensure that their interests can be satisfied only through the pursuit of activities sanctioned within the market system. To the extent that hierarchy fails to provide these boundary conditions, the interests of participants and the organization may not coincide (e.g., cheating may be in their interests), and the system will be cognitively limited (in fact, Williamson, 1985, has demonstrated that where the regulatory framework is not sufficiently effective to prevent cheating, hierarchical organization may be competitively superior to market organization).

Market efficiency and effectiveness depends on adapting these hierarchical interventions through time as circumstances change, and integrating externalities into the market wherever possible as they arise with the evolution of the system. The cognitive effectiveness of the market therefore depends critically on the cognitive ability of hierarchy, and this dependence limits the ability of the market system to circumvent any cognitive limitations of hierarchy.

The central issue therefore remains: what arrangements would provide an organizational cognition that would discover and adapt the necessary hierarchical interventions and that is not inherently cognitively limited due to the way in which the cognition is organized? Although the extent to which systems of exchange relations within the dynamic can provide a comprehensive organizational cognition is strictly limited (even in relation to economic activity), we might well consider whether a new form of organization could be envisaged which takes the key cognitive features of the ideal economic market, and utilizes them for the establishment and adaptation of hierarchical interventions. Such an organization would need to contain processes similar to those which enable the market system to avoid the cognitive limitations associated with the central planning of interventions: that is, alternative interventions would need to be sorted as far as possible by the individuals in the dynamic affected by the interventions, rather than by the hierarchy; and the arrangements would need to continually provide all participants, including individuals in the hierarchy, with boundary conditions that cause them to adapt for-the-organization, thereby ensuring that the interests of all (or at least most) individuals coincide with those of the organization. In essence, this would necessitate a system where possible hierarchical interventions would compete for resources from the dynamic in exchange for the benefits they can provide to the dynamic. This would constitute a system of vertical exchange relations. As is the case for horizontal economic exchange relations, the values of individuals in the dynamic would effectively determine what is called into existence, and competition would tend to ensure that it is provided efficiently. In more detail, this would mean: multiple perspectives would be utilized for the generation and exploration of possible interventions. This could be achieved through the activities of "entrepreneurs" who would develop possible interventions for exchange with the dynamic.

In principle, this role could be filled by any member (individual or group) of the organization. The variation provided by the multiple perspectives would be sorted by competition. Ideally, this competition would occur solely on the basis of the extent to which the competing interventions would provide net benefits to the individuals affected by the interventions, as assessed solely by these individuals, and as recognized by the

amount of benefits which the individuals were willing to provide in exchange for the interventions. Ideally, any adverse impacts of the interventions would be taken into account and dealt with by these exchanges, ensuring that no individuals were disadvantaged by the interventions.

An evolvable regulatory framework would be necessary to establish and adapt the conditions necessary for the effective operation of this system of competitive vertical exchange relations. This regulatory framework is the counterpart of the system of hierarchical interventions that create the conditions essential for the operation of horizontal exchange relations such as economic markets. For example, the regulatory framework would deal with the prevention of cheating in exchanges, and the establishment of collectives of individuals in the dynamic, so that collectives could engage in exchange relations as a unit (hierarchical interventions act across the dynamic, affecting many individuals, so vertical exchange relations necessarily involve collectives in the dynamic). The collectives might be defined so that, as far as possible, they comprise similarly affected individuals-internalizing the costs and benefits of particular classes of interventions, correcting the collective cognitive limitations within the collective by, for example, preventing free riding, and regulating the way in which decisions are made within collectives.

In large part, the extent to which competing interventions would be sorted by the dynamic on the ideal basis identified above would depend on the effectiveness of the regulatory framework. This in turn would depend on contingent circumstances such as the types of regulatory processes that had been discovered up until that time within the organization, and their cost/effectiveness. The regulatory "technology" which was available within the organization would itself evolve. The vertical system would sort competing regulatory interventions and reassess them through time, and the cognitive ability of the organization would improve as the regulatory framework evolved and as the ideal was approached more closely.

This natural inclusion of regulatory interventions along with all other hierarchical interventions in the system of vertical exchange relations means that all elements of the system could evolve and adapt in a way not open to systems of horizontal exchange relations. In effect, the vertical system would include markets in different forms of markets, vertical and horizontal. This would enable, for example, implementation of a vertical system to begin with the existing arrangements that are currently used to establish hierarchical interventions (e.g., the normal processes of democratic government), and allow alternative frameworks to be proposed and to compete with the pre-existing arrangements. The particular regulatory interventions needed to establish a specialized segment of the vertical system specifically adapted to deal with a particular class of interventions would not be implemented unless the potential beneficiaries were willing to "purchase" the regulatory interventions. Thus the extent to which the pre-existing arrangements would differentiate into more complex and responsive vertical exchange arrangements would depend on the outcome of these types of metamarket processes.

The ultimate control of the entire system of hierarchical interventions by collectives in the dynamic does not mean that all decisions about the establishment and adaptation of interventions would be made by the dynamic, overwhelming individuals with a necessity to make many technical and specialized decisions. Instead, a vertical system could be expected to respond to demand from the dynamic for assistance in deciding appropriate

interventions by, for example, offering interventions which establish organizations that in turn implement and adapt interventions in the dynamic. In the early stage of the implementation of a vertical system, considerable entrepreneurial activity likely would be directed at establishing organizations that are both cognitively adept at discovering and adapting relevant interventions, and that are constrained by boundary conditions which ensure they pursue only the goals and objectives demanded by the dynamic. Thus the organizations which are established may themselves incorporate specialized vertical or horizontal systems of exchange relations and other forms of organization that produce an organizational cognition which would economically and effectively discover and adapt appropriate interventions. And the arrangements proposed by entrepreneurs might include higher-level hierarchical interventions which would constrain the proposed organizations to pursue only the objectives supported by the dynamic. As these arrangements are developed and improved, the dynamic would progressively become a consumer of general goals and objectives and of cognitive systems adept at achieving these, rather than a consumer of specific adaptations and specific interventions. As the vertical system evolves and as its cognition improves, less and less would need to be directly specified and decided by the dynamic in order to ensure its interests are met.

A system of competitive vertical exchange relations would comprise an invisible-hand process in the sense that adaptations beneficial to the organization would be achieved through arrangements in which constituent individuals and organizations pursue only their own direct interests. For example, a vertical system would provide the hierarchy with boundary conditions that ensure the hierarchy adapts only for-the-organization: the individuals and organizations involved in developing and establishing hierarchical interventions would be able to satisfy their interests only by the provision of interventions which are accepted by the dynamic in exchange relations. An effective vertical system would also move closer to the ideal of discovering and adapting interventions which provide individuals in the dynamic with boundary conditions that cause the individuals to adapt as if they had taken into account the effects of their adaptations on others in the organization. To the extent this is achieved, individuals would broadly act as if they took effects on others to be effects on themselves, as indicated above.

Viewed in its entirety, the vertical system (together with any horizontal arrangements it sustains) would provide supra-individual cognitive processes that operate across individuals in the sense that individuals would be components in higher level trial and error processes (in the same way, for example, that neural cognition in metazoans includes processes that involve cells, but operate across them). Although it operates across individuals, the supra-individual cognition would nonetheless make full use of the pre-existing cognitive ability of the individuals that participate in the supra-individual processes: individual cognition would play a major part in the generation of alternative interventions, which are then trialled supra-individually.

A system of vertical exchange relations organized in this way would also have the potential to share the ability of horizontal economic markets to coordinate supply and demand, ensure that the level of resources allocated to particular functions maximizes overall interests, and facilitate trade-offs between competing interests; individuals in the dynamic would be able to call into existence through the vertical system many of the things of value to them that presently cannot be obtained in the horizontal economic system, such as conditions which produce more satisfying social and cultural relations, and valued environmental circumstances. The invention, implementation, and adaptation of these

interventions could be as much the subject of entrepreneurial activity and as responsive to demand as the provision of goods and services in an effective economic market: because the effectiveness of the vertical market system is dependent to some extent on the cognitive ability of individuals in the dynamic, the evolution of the vertical market would be likely to drive further evolution of the cognition of individuals. There would be a collective interest in the improvement in this cognition; hierarchical interventions would interact together to form new, higher level dynamics. These dynamics could use the vertical system to obtain beneficial interventions, and horizontal exchange systems could be established within these dynamics. In this way, multi-level hierarchies would be likely to evolve. In certain circumstances, cognitively limited forms of determining interventions, such as those discussed above that rely on the cognition of the hierarchy, might outcompete forms that involve high levels of trial and error-for example, where there is little uncertainty as to what interventions are best (this may be more common as knowledge accumulates), or where a segment of the market is thin because there are a small number of individuals involved. However, in contrast to current arrangements, the possibility of competition would always exist. The vertical system would sort the possibilities, and the mix of arrangements in the system would be likely to evolve as knowledge accumulates and circumstances change; and interventions could be established to ensure individual interests would not be sacrificed for the interests of organizations in the establishment and adaptation of interventions.

A system of competitive vertical exchange relations could provide the human system with a very general cognitive capacity to not only discover new adaptations, but evolve new cognitive arrangements. This would enable the cognition of the human system to attain the cognitive milestones identified earlier, without the need for cognition at the between-group level-i.e., the development of the ability to adapt for the inside/now through ultrastability (e.g., the adaptation of economic and social arrangements within the human system); and the development of the ability to adapt for the outside/future through a capacity to model (e.g., the adaptation of the human system as-a-whole in relation to interactions with living processes elsewhere, or in relation to larger scale external physical events). The evolution of these cognitive capacities would necessitate the further evolution of supra-individual cognitive processes that operate across individuals within the human system. The evolution of a supra-individual cognition which comprises a system of vertical exchange relations would free the future evolution of the human system from dependence on what is capable of being conceived, planned, and implemented by the cognition of individuals within the organization. For example, this supra-individual cognition would free the human system to discover cognitive arrangements (e.g., that store information, learn, operate models, and utilize categories and meanings) that no individual human is able to effectively model, or is even necessarily aware of (individuals would generally have even less capacity to predict outcomes than they now have in relation to the horizontal economic system). Eventually, the human system or some higher level organization might self-actualize in its own right.

In principle, the evolution of a vertical system would enable the human system to pursue any set of values and objectives (including cognitive objectives), unimpeded by the collective cognitive limitation. In an effective vertical system, the goals and objectives of the organization are determined primarily by the goals and objectives of the individuals of the dynamic, which ultimately sort variation within the organization. A fundamental issue is whether the goals and values of individuals within the human system are likely to drive the pursuit of the cognitive milestones identified above. This is particularly an

issue where costly adaptations are likely to have only future benefits that are unlikely to accrue within the life span of individuals (as in adaptation for the outside/future). Effective cognition within the human system for the inside/now is likely to be experienced as immediately useful to the current values of individual humans. The benefits of effective cognition for the outside/future may be equally as clearly demonstrated by interactions between the human system and its environment, particularly with other living systems (that originate from humanity, or otherwise). However, such interactions may be fatal if the human system has not previously invested in some cognitive capacity to adapt for the outside/future so that it can anticipate the interactions. The issue is whether values are nonetheless likely to arise in individual humans that will support the evolution within the human system of a highly developed cognition for the outside/future.

The need for this cognition is more likely to be accepted and acted upon in advance by a dynamic that includes a high proportion of individuals that have the capacity for what was referred to in Section 4 as cognitive modelling. This capacity is likely to produce the understanding that an attempt to live a life in isolation from and without regard to the ongoing cognitive processes in which the individual is embedded is inconsistent with the processes that have formed the individual, and renders the individual irrelevant to them. In this context, values and objectives focused solely on the individual render the individual existence absurd and without meaning, and are as much a denial of life as suicide. A well developed capacity for cognitive modelling is conducive to the individual instead identifying with the on-going collective cognitive processes, rather than as a temporary individual, alone. More specifically, this capacity is likely to produce awareness that the ability of the human system to adapt for the outside/future is essential if the human system is to eventually form complex relationships as an equal with other living systems at the same level of organization, if the human system is to positively contribute to the further evolution of living processes, and if the human system is to live forever.

7. Conclusion

New evolutionary mechanisms arise because they are necessary for the systematic discovery of beneficial cooperative arrangements between living processes: within each level of organization of living systems, the evolutionary mechanism operating at the level of individuals is limited in its ability to discover and perpetuate adaptations that produce beneficial cooperative arrangements. This limitation can be overcome by arrangements that are in hierarchical relationship with the dynamic of individuals and that are therefore able to intervene in the dynamic without sharing its limitations. Selection favors enhancement of the ability of the system of hierarchical interventions to sustain any arrangement in the dynamic that may be beneficial for the organization as a whole. To discover adaptations that give advantage to the organization, variation in these arrangements has to be sorted for-the-organization.

At the cellular and the multicellular level of organization, this is initially achieved by the suppression of competition among heritable variation within the organization, thereby concentrating competition and selection at the between-group level. A consequence is that these organizations are unable to adapt heritably during the life of the organization until the evolution of additional arrangements that can appropriately sort heritable variation within the organization. The progressive evolution and improvement of arrangements which sort variation internally allows the progressive introduction of variation of greater variety and scope in the organization. At any stage in this coevolution,

variation that cannot be sorted effectively for-the-organization is generally suppressed, resulting in arrangements that are mechanistic and inflexible within the organization, but subject to trial and error at the between-group level.

Variation can be sorted most simply within the organization via testing of possible adaptations against their ability to correct the effects of events which directly affect the organization. Further metaevolution will favor the arising of more complex arrangements within the organization which can discover adaptations that have no immediate effects on the organization, but which produce benefits only in the future. This capacity requires more complex arrangements because possible adaptations cannot be directly tested against their (future) effects on the organization, and instead must be tested against internal representations or models which allow the future effects of adaptations to be assessed within the organization. Other critical improvements in organizational cognition include learning, which enables the past experience of the organization to be used to better target the possible adaptations that are trialled, and the transmission of learning between organizations, which enables the accumulated experience of many organizations to be used in this way.

A sufficiently developed modelling capacity can be used recursively by the organization to reassess its strategies, its values and objectives, and its cognition, in the light of their longer-term effects on social, historical, and evolutionary outcomes. This reassessment provides the basis for the establishment of new levels of hierarchy within the organization to manage pre-existing cognitive processes to ensure they adapt to the concerns of these new domains of consciousness. With the full development of the modelling capacity, the organizational cognition will be able to directly adapt the strategies, values, and cognition of the organization to anticipate the wider evolutionary and metaevolutionary developments which affect the organization and the living processes with which it interacts. Once this capacity arises in the evolution of successive levels of biological organization, the cognition will manage lower levels of organization consistent with its concerns, and ensure that higher levels of organization that are formed subsequently will incorporate similar cognitive capacities from the outset.

Once the evolution of living processes has produced individuals with sufficient internal cognitive ability, organizations can be readily formed which are able to internally sort at least some variation for-the-organization from the outset: individuals in the hierarchy of the organization who are themselves able to sort heritable variation internally will sort variation for-the-organization where their interests and those of the organization coincide. The ability of these individuals to discover mutually beneficial adaptations will be greater if the individuals are also able to adapt for the outside/future by modelling their environment, including the organization itself. The coincidence of interests will be more extensive where the interests of the hierarchy are influenced by the interests of members of the dynamic.

However, the cognition of organizations in which interventions are discovered and adapted by the cognition of the hierarchy will be inherently limited even where there is a coincidence of interests, because the hierarchy itself will generally not have access to the information needed to accurately evaluate the impact of alternative interventions on the dynamic and on the organization. These limitations can be overcome by supra-individual cognitive processes in which possible interventions are sorted on the basis of their ability to compete to obtain resources from the dynamic in exchange for the net benefits they can provide to the dynamic by sustaining beneficial cooperative arrangements.

On this basis, once the evolution of living processes achieves organizations with a sufficiently developed internal cognition, further levels of organization should be able to be formed more readily, and without a return to a cognition based on between-group processes: the severely constrained forms of organization which are necessary to underpin a between-group cognitive process are not likely to be general features of living processes; populations comprised of near identical, competing, temporary organizations should be a feature only of the levels of organization of living processes which arise before the development of sufficiently competent internal cognition.

New levels of organization of living systems will arise as new evolutionary mechanisms evolve through the establishment of hierarchical arrangements. These hierarchical arrangements manage across dynamics of individuals from the level below, forming organizations at the new level. The repeated emergence of evolutionary mechanisms in this way produces the familiar nested hierarchies of living processes. The hierarchical arrangements for each successive level of organization will necessarily be of greater scope than those of the level below, progressively extending the management of living processes across space and time. Thus, molecular processes have come to be managed by RNA and DNA to constitute cells, cells in turn are managed by the neural mind to constitute later metazoans, and humans are managed by governmental and related processes to form the human system on a global scale. Increasingly across space and time, living processes will be managed by hierarchical arrangements which tend to ensure that each process adapts as if it takes into consideration its effects on others, by adapting as if it treats effects on others as effects on self. These hierarchical arrangements create the conditions necessary for the differentiation and specialization of the living processes that they manage, while also ensuring that the differentiated processes adapt in a unified way for-the-organization.

The processes managed by the hierarchical arrangements can include material processes, and are not limited to any particular class of living systems (e.g., hierarchical processes will act across species: hierarchy is necessary to comprehensively overcome the collective cognitive limitations of multi-species assemblages, and to enable the benefits of symbiosis to be fully explored). New supra-individual evolutionary mechanisms will evolve in association with the development of each new level of hierarchy, ensuring that the management undertaken by the hierarchy is cognitively adept.

The human system can be located within these metaevolutionary developments and trends: the cognitive ability of the human system is currently limited to the extent that hierarchical interventions are primarily established and adapted by the cognition of the hierarchy. Arrangements such as democracy and consultative mechanisms provide the hierarchy with some additional information about the effects of possible interventions on individuals in the dynamic, but the fundamental limitations remain. An ideal cognition in the human system would provide boundary conditions for individuals that cause them to adapt as if they take account of the effects of their adaptations on others in the organization-by acting, as emphasized above, as if consequences for others were consequences for self. A supra-individual cognition comprising a system of vertical exchange relations would move closer to this ideal: it would involve the systematic sorting of possible hierarchical interventions on the basis of their ability to compete for resources from the dynamic in exchange for the benefits they can provide to the dynamic by sustaining beneficial cooperative arrangements.

Of course, this is not to say that the human system as it is presently constituted will

necessarily evolve the superior cognitive arrangements identified here: the general metaevolutionary trends and developments that have been described are not inevitable for any particular instance of living processes; what has been identified is rather a series of cognitive developments where each is likely to overcome some of the limitations of the arrangements that precede it. However, there is no guarantee that any particular trial and error process associated with particular living systems will discover each development before the demise of the systems, or before some other living process discovers the development and exploits it in a way that removes the circumstances which would otherwise provide advantage to others in the discovery.

Significantly, the broad direction and nature of these metaevolutionary trends and developments is largely independent of both the details of the environment in which the living systems evolve, and the specific chemical and physical basis of the living processes themselves. As Hegel (1807) pointed out in his theory of the evolution of consciousness in humanity, the specific nature of the environment is unimportant; all that consciousness requires is something to react against to stimulate its evolution. These observations add weight to the possibility that the metaevolutionary perspective may identify biological laws of the greatest generality.

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About the Author

John Stewart is a senior labor relations policy adviser with the Australian government. Prior to that, he was with the Australian Fisheries Service, and before that, he was a trade union negotiator and arbitration advocate. He is interested in cognition in the broadest sense-especially those forms of human organization whose “cognition" attempts to satisfy societal objectives.