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A conceptual instruction-centered model of evolutionary and developmental processes as a source of insights into the issues of group selection, multilevel selection, and the origins of order

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Abstract: This paper proposes a conceptual model of evolutionary and developmental processes as a source of insights into the old, but still controversial issues of group selection, multilevel selection, and the origins of order. Its pillars are two elementary principles of information-processing – one linking information to choices, and one pointing out the need for basic instructions – and a well-defined distinction between evolutionary selection and developmental selection. It generalizes and modifies the gene-centered view of biological evolution by centering on basic instructions, which are more than genes; and by focusing on their instructing of ontogeny, instead of replicating during phylogeny. It directly applies to socioeconomic evolution, finding the basic instructions in the genomes of individuals and the institutional rules of societies. The main insights obtained are: (1) biological evolution involves several levels of developmental selection, but only one of evolutionary selection; (2) in socioeconomic evolution, the evolutionary selection is not of groups, but of genomically compatible institutional rules for the forming, developing and operating of groups successful in developmental selection; (3) self-organization generates order at more levels than evolutionary selection, but this produces more of new information.

1 Introduction

As an economist, I must begin with an apology for trying to say something new to biologists. My alleviating circumstance is that I belong to the minority of economists who call themselves “evolutionary” and like to learn from biology. This is also what I have been doing during more than twenty years, and with so much interest that my daughter started to like it, too, and recently obtained her PhD in biotechnology. Moreover, the biologists who dislike economics (I suppose there are some, as there are plenty of economists who dislike biology) may find consolation in the fact that this paper is based more on what I had learned for my MS in electrical engineering, with specialization in automatic regulation and computer construction, than on economics proper, to which I turned for my PhD later, because I wanted to know why the economy of my country was then organized so foolishly and working so lamentably, and what could be done about it.

For a long time, my learning from biology was highly respectful. A few years ago, however, I started to see it also to suffer, even if perhaps not as much as economics, from lack of clarity on important issues. Some time after, I started immodestly to believe that I could help it make some of these issues a little clearer. The biologists reading this paper will have to judge how much, if at all, clearer.

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The issues are old, but not yet entirely settled: (1) whether or not the evolution of life also employs group selection, and possibly even multilevel selection; and (2) whether or not the order produced is due more to self-organization than to Darwinian evolutionary selection. As the source of insights into these issues, I propose a simple conceptual model of evolutionary and developmental processes, built on two elementary principles of information-processing, equally valid for computers, organisms, and societies, and on a well-defined distinction between evolutionary selection and developmental selection. My aspiration is not to explain these issues fully, but only to produce a few helpful insights.

The first information-processing principle relates information to choices, and points out the need for an experimental trial-and-error search if some of the information needed for a given choice is missing. The second makes it clear that all information-processing, however multilevel and flexible it might be, needs relatively rigid basic instructions, on which it must ultimately repose, and by which its potential is limited. Both these principles are extremely elementary, yet still far from always fully realized and consistently applied.

The model puts basic instructions is in the center between evolutionary processes, which use trial-and-error searches for producing them, and developmental processes, which are guided by them. The outcome is the forming, developing, and operating of certain acting and interacting entities, termed “agents.” [1]

Both evolutionary and developmental processes are recognized to involve selection, but of substantially different types. Evolutionary selection concerns basic instructions, whereas developmental selection concerns the according to them formed and developed agents. The agents need not be long-lived and the outcomes of developmental selection therefore need not last. But they are the key commands for evolutionary selection, whose outcomes, if successful, can last: select and retain the basic instructions of those agents that are succeeding in the developmental selection.

Intuition may be helped by thinking of agents as possibly multilayer cakes, and of basic instructions as the recipes for making them. The developmental selection may then be thought of as tasting the possibly several layers of the cakes and selecting the layers and the cakes that taste good. The evolutionary selection may then by seen as choosing and keeping the recipes for the good cakes, of which some may have only one layer and others several.

In biology, the obvious interpretation is phylogeny producing genotypes, which guide the ontogeny of possibly multilevel phenotypes. But the model is more general: it admits that both evolution and development may take place at several levels. This allows it directly to apply to socioeconomic evolution, and also to make it clear in what ways this evolution is connected to, and building upon, biological evolution.[2]

The distinction between the two types of selection appears useful by itself: biologists often seem to disagree about multilevel selection simply because some of them have in mind evolutionary selection and others the developmental one, without always realizing that they are speaking of two different things. When the distinction is properly made, it will be easy to agree that developmental selection may have many more levels that the evolutionary one.

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The model extends and refines the one presented in Pelikan (2011, 2012), whose purpose was

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[1] For reasons explained in Pelikan (2011), the term ”agent” is preferable to both ”system” and ”interactor,” by which such an entity is sometimes denoted by other authors.

[2] The evolution of human societies with their cultures and economies is usually termed ”socioeconomic” in economics, and ”sociocultural” in the other social sciences. As an economist, I will use the former term, with the understanding that ”socio-” includes ”-cultural.”

to help understand economic change by a certain generalization of Darwinism, different from, and to concrete economic problems more clearly applicable than, the generalization previously proposed by Hodgson and Knudsen (2006). As this paper aims to present this new model, and not critically survey old ones, its references are rather limited. For a good first idea of its relations with the relevant literatures, it appears that references to Dawkins (1982), Wilson and Wilson (2007), and Nowak et al. (2010) for the multilevel selection issue, and to Kauffman (1993) for the origins of order issue will suffice.

As Dawkins's gene-centered view is the model's closest kin, it is particularly important to clarify both the similarities and the differences. The main similarity is the neat distinction between possibly long-lasting entities and their possibly ephemeral companions. While Dawkins distinguishes between "replicators" and "vehicles," the model does so between "basic instructions" and "agents."[3]

One important difference is that in biological evolution, Dawkins considers "replicators" to be just genes, whereas "basic instructions" also include other instructing part of genomes, such as the non-genic DNA that codes for regulatory RNA, and possibly also the non-DNA epigenetic markers that contribute to the instructing of ontogeny. This makes the model more robust, immune against all the objections against gene-centrism aimed at the narrowness of the notion of "gene."

In socioeconomic evolution, the notion of basic instructions correspond quite precisely to the formal and informal institutional rules that guide individuals towards forming, developing and operating more or less large organizations, from small groups to complex societies. This provides, after only a slight terminological adjustment, a fruitful link to the now well-established field of new institutional economics pioneered by the Nobel laureate D.C. North (1990).[4] In contrast, genes appear to lack such a clear socioeconomic counterpart – at least none of the evolutionary social scientists searching for it has really succeeded. As to the notion of ”memes” proposed by Dawkins, it has a serious flaw on which more below.

Another important difference is the shift of focus from replicating to instructing. The model pays less attention to how basic instructions replicate during their evolution than to how they instruct the forming, developing and operating of the corresponding agents – such as

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[3] Similar distinctions are made by Hull (1980), who distinguishes between ”evolvors” and ”interactors,” and by Hodgson and Knudsen (2006), who distinguish between ”replicators” and ”interactors.” From the present point of view, however, the Dawkins version is better elaborated and more instructive to refer to.

[4] The adjustment is that what North defines as "institutions" is termed here more explicitly ”institutional rules.” The reason is that North's definition has not been generally accepted. The term "institutions" remains ambiguous, still frequently used in many other meanings, such as the one of large banks in financial economics.

phenotypes in biology, and organizations in economics. In biological evolution, of course, replicating is recognized necessary. Due to the fragile and perishable nature of their biochemical carriers, basic instruction must keep replicating as the only way to be lastingly retained. But in socioeconomic evolution replicating matters much less. Basic instructions may be there lastingly retained also by other means, such as books and computer memories. Essential in both cases is only their instructing. Intuitively, one may think of a book and a copying machine: the machine is needed if the book's paper is perishable, but it is the book's content with its impact on the real world that is always essential.[5]

This shift has two consequences. One is the need for specifying the basic agents that are instructed, and distinguishing them from the complex agents that they consequently form, develop and operate. Without this distinction, the working of basic instructions cannot be clearly grasped. Thus, instead of the couple "replicators – vehicles" used by Dawkins, the model uses the triple "basic agents – basic instructions – complex agents," and thus makes basic instruction doubly central. To deal with agents of several levels, the distinction between "basic" and "complex" is made relative: the complex agents of one level may be basic on a higher level, while the basic ones may be complex on a lower level.

The second consequence is the detection of the above-mentioned flaw in the "genes – memes" correspondence. As memes are defined only to replicate, they poorly correspond to genes, since these moreover instruct the synthesis of proteins. The shift implies a somewhat different correspondence with two branches: (i) between institutional rules and the instructing parts of genomes, which include more than genes; (ii) between memes and all the replicating parts of genomes, both instructing and "junk."

The reference to Wilson and Wilson (2007) is helpful for two reasons. One is its clear survey, with an extensive list of relevant references, of most of the group-selection controversy that preceded its publication – while, with the exception of Wilson et al. (2010) considered below, only little new appears to have been added since then. The other reason is its concise and elegant conclusion (p. 345): "Selfishness beats altruism within groups. Altruistic groups beat selfish groups. Everything else is commentary." What makes this conclusion helpful is that most of the insights obtained from the model will be possible to

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[5] When this is realized, one may wonder why the replicating of genomic messages has for such a long time been attracting so much more attention than their instructing. In Pelikan (2011) I dared to speculate on possible reasons and found two: one ideological and one cognitive. Namely, it used to be ideologically correct to emphasize the instructing by environments and minimize the one by genomes; and this instructing was too little known to be an interesting conversation piece.

understand as such a commentary. It is only that the commentary will be rather substantial, containing important qualifications and additions.

The reference to Nowak et al. (2010) is useful as an indication that the model fits rather well the current leading research on the issue: its insights fully agree with the authors that the evolution of eusociality can better and more simply be explained without the notions of kin selection and inclusive fitness. The reason is expressed in somewhat different terms, but the underlying logic appears to be the same: whatever social behaviors some basic agents will develop depend on the agents' basic instructions, which do not follow from the behaviors, but result to a large extent – in biology entirely – from uncorrelated ("random") trials. The instructions may therefore prescribe different social behaviors arbitrarily, without having to employ any kin relationship. Then, if the prescribed behaviors happen to lead to the forming, developing and operating of developmentally successful groups, even kin-ignoring instructions may be evolutionarily selected and lastingly retained.

Although after his 1993 book, Kauffman has elaborated and refined his arguments, that book remains the best reference for present purposes. The simple insights that the model will offer can best be related to the book's basic argument which the subsequent elaboration has not changed: this is, roughly, that the order produced by evolution of life is due more to spontaneous self-organization than to Darwinian evolutionary selection. The model allows the two to be clearly compared on two accounts: the number of organizational levels at which they prevail, and the total amount of new information they produce.

That the aim of the model is only to produce simple insights into elementary truths, and not settle the issues in all their fine details, deserves emphasis. My motivation for proposing the model is the strong impression I got from reading the relevant literatures that much of the remaining disagreement is in intricate discussions of fine details where some important elementary truths have not been properly taken into account. It is only such truths that the model aims to bring to light.

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The rest of the paper is organized as follows. Section 2 states the two elementary principles of information-processing. Section 3 presents the conceptual instruction-based model. Section 4 deduces insights into the issue of group selection and multilevel selection. Section 5 deduces insights into the issue of the origins of order. Section 6 concludes.

2 Two elementary principles of information-processing

The term “information” is increasingly often used, but still far from always properly understood. The first point that is not always fully realized is that information is not an objectively existing phenomenon, such as matter or energy, but may meaningfully exist only *in relation to a certain choice problem of a certain choice-making agent* – such as a cell, an organism, a society, or a technical device. For example, the red traffic light is always a physical event, but carries the information “stop” only if there are some drivers seeing it, understanding it, and having to choose between stopping and going. While all this was clearly explained longtime ago by Ashby (1956: 123-124), it is still often forgotten.

A related point is that each choice problem needs a certain amount of the information to be settled. Under certain simplifying assumptions, this amount can be precisely quantified, but this is here unimportant: the present model is only conceptual, and not quantitative.[6] Important here is to realize, as also clearly explained by Ashby, that this amount is determined by the choice problem, and not – contrary to what some biologists and social scientists trying to use information theory appear to believe – by the letters or other symbols in which the information is expressed: many letters may sometimes express little information.

Particularly important is to realize that if some of the needed information is missing, in the sense that no agent with which communication is possible has it, the only way to obtain it is a trial-and-error search, in which the trials are generated in partly or entirely uninformed (“random”) ways, the failed trials are rejected, the successful ones selected, and the information thus gained is retained (stored, memorized). Such trial-and-error searches for initially missing information may also be described by the classical Campbell’s (1965) words “variety, selection and retention,” and seen as the synthesis of “chance and necessity” in the Monod’s (1970) words. It is of such searches that evolutionary processes are made.

All this may roughly be summarized as follows.

Elementary Principle of Information-Processing I: Each choice demands information, the more of it, the relatively fewer (scarcer) are the choice alternatives with what is defined as “favorable outcome.” If some of the demanded information is missing, the

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[6] Efforts to quantify the amounts of information with precision may even be misleading. The simplifying assumptions required, especially those about the probabilities involved, may poorly represent the real choice problem, and most efforts may be spent on the question ”how much?” without realizing very well ”of what.” Quantification of information may of course be useful, but it often suffices to measure it only roughly in binary digits (”bits”) deduced from the number of choice alternatives – such as more than 4 bits for the choice among 20 amino acids, which requires at least 3 letters from a 4-letter alphabet.

> only way to obtain it is a trial-and-error search, in which trials are generated in partly or entirely uninformed ("random") ways.

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Another point – equally elementary, but perhaps even less frequently realized – is that each choice-making agent, to be able to receive, understand and effectively use any actual information, must already possess certain earlier acquired other information. This may be described as the instructions telling him/her/it how to receive, understand and use the actual information, and possibly also what else to take into account. The term "instruction" means here, as usual, an element of a possibly complex behavioral program. The expressions "instruction-based behavior" and "program-based behavior" are thus largely synonymous. But speaking of "instructions" rather than "programs" makes it easier to enter into details of how programs are made and from what different sources their parts may come.

Logically, the origins of an agent's instructions may only be of three types: (a) communicated by another agent; (b) elaborated from observed data by own learning; (c) parts of the agent's initial endowment. But origins (a) and (b) need even earlier acquired instructions, telling the agent how to communicate and how to learn.

In the above example, the drivers must have been told earlier how to interpret the red light. For that, they already had to know the language in which this was told. And for that, they must have been initially endowed with talent for learning languages.

In general, to acquire any new instructions, an agent needs some earlier acquired instructions. If the origins of these include (a) and (b), their acquiring needed some even earlier acquired instructions. Simple recursive reasoning suffices to conclude that the only logically possible stop to what would otherwise be an infinite regression is that at some ultimate stage all the needed instructions are of origins (c). These are the agent's "basic instructions." All this may roughly be summarized as follows.

> *Elementary Principle of Information-Processing II:* An agent can acquire and effectively use new information, including new instructions, only to the extent allowed by his/her/its *actual* instructions. The variety of the actual instructions that an agent can ever acquire and effectively use – be it by communication from other agents or by

own learning – is ultimately limited by his/her/its *basic* instructions.[7]

This means that there are no acquired instructions without some basic instructions, which directly or indirectly make the acquiring possible. An agent with sophisticated basic instructions may acquire – from communication with others and/or from own learning – very many new instructions, which may be highly flexible and adaptable to changing environments. Yet all this acquiring is subject to a hard constraint: it must ultimately repose on, and be limited by, the agent's initially given basic instructions. In terms of the old, but still somewhat controversial "nature vs. nurture" issue, this means that "nurture" may achieve enormously much, but only within limits determined by "nature."[8]

Note well that this principle has nothing to do with the discredited genetic determinism. An organism's genome is claimed not to *determine* what the organism will *actually* learn and do, but only to *limit* what all that might *potentially* be. This may possibly be called "genomic limitism," but not "genetic determinism."

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Intuitively at least, this principle should now be clear to all computer users. It is indeed easy to understand that each computer must have some basic instructions embedded in its inflexible hardware, and that it is they that enable it, within by them determined limits, to receive and use several levels of flexible software. Hardly any computer user may therefore believe that the human mind might be a blank slate ("tabula rasa") on which anything can be written by society: this would be like believing that one does not need any sophisticated computer, but may start programming an empty shoebox.

But in computers, the basic instructions with their possibilities and limitations are relatively easy to identify. It is more difficult to discern them in individuals and societies, especially the human ones. The reason is that there they hide deeper. In a computer, they are purely operational, embedded in the rigid organization of the logical switches that form its hardware. But neither individuals nor societies are organized so rigidly: the internal organization of both is typically flexible, changing and developing in response to both internal and external inputs. So most of the instructions embedded in it are acquired, and not basic.

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[7] This principle is discussed in slightly different words by Hofstadter (1979), who nicely concludes (p.686): "… software rules at various levels can change; hardware rules cannot – in fact, to their rigidity is due the software's flexibility."

[8] This appears to be the logical essence of the extensive argument about this issue in Pinker (2001), and also largely to agree with Ridley (2003), with the exception of the title: instead of "Nature via Nurture," more logical here appears to be "Nurture via Nature."

To find the basic ones, as shown in more detail below, it is necessary to descend to the genomes of individuals and the institutional rules of societies. Both can indeed remain relatively inflexible while guiding the corresponding organizational flexibility.

An instructive example is the brain. It may indeed be tempting to see its basic instructions embedded its actual neuronal networks, like the basic instructions of a computer are embedded in its electronic circuits. But this temptation is misleading: neuronal networks are flexible, changing and developing in function of many internal and external inputs, so that most of the instructions embedded in them are acquired. To find the relatively rigid basic ones – on which even the most flexible brain must be built – we must look inside individual neurons. These are not only operating the networks, but moreover forming, developing, and changing them. Life-long constant are only the genomic instructions within each neuron that tell it both how to form networks and how to operate within the networks formed. While both may strongly depend on many external and internal inputs, including the neuron's position within the brain, the genomic instructions guide and limit even this dependence. Logically, the brain can exploit only those inputs that its genomic instructions allow it to exploit.

That the basic instructions of both individuals and societies are rigid only relatively, during the time they guide some developmental processes, deserve emphasis. In evolutionary processes, in contrast, they both become variable, and the institutional rules of human societies even more variable than human genomes. While biological evolution is changing human genomes by drift, recombination and mutations rather slowly, socioeconomic evolution is changing institutional rules by formal reforms and informal modifications of socio-cultural norms much faster. An important point of the model is to show that, despite this great quantitative difference, the two evolutions have the same logical structure.

3 An instruction-based model of evolutionary and developmental processes

While much about the model was already said, a more systematic presentation is needed. Its intuitive idea is that the evolution of life is repeating, on higher and higher organizational levels, basically the same trick: making some relatively smaller agents self-organize into, develop, and operate what may be considered successful ("fit") larger agents, in ways that are perfectly feasible, but a priori highly unlikely. In other words, the smaller agents have very broad choice sets of feasible actions, yet keep systematically limiting their choices to the very narrow subsets leading to such apparently very unlikely successes. The only logically possible explanation is that the smaller agents possess the right instructions with all the needed information, telling them what to do, and what not to do. Much about both the evolution of life and the one of human society is then possible to learn by identifying the origins of these instructions. It is for this learning that the two elementary principles of information-processing and the sharp distinction between evolutionary selection and developmental selection prove helpful.

As noted, the model is only conceptual, aimed to clarify the overall structure of logical relationships, and not quantitative. But its terminological precision is intended to be as high as if it were mathematical.

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The model embraces two levels of agents: possibly heterogeneous basic agents (b-agents), and by them formed complex agents (C-agents). Each C-agent is a network of its b-agents, where they play possibly different roles, and thus interact with each other and with environments in possibly different ways.

Each agent is endowed with certain basic instructions (b-instructions). In a simple agent, they may identical with the actual instructions guiding its actual behaviors. In a more sophisticated agent, the actual instructions may be more complex. They may be more or less extensively developed by possibly multilevel learning in response to several internal and/or external inputs. But the b-instructions remain crucial: they determine how the learning may start and to what extent it may develop. Many b-instructions may moreover be preserved as part of the actual instructions – such as the basic instincts of otherwise civilized humans.

The model distinguishes two dimensions of b-agents' behaviors: (i) *organizing*, which make them self-organize into, and find their roles within, the network of their C-agent; and (ii) *operating*, by which they operate in the roles found, and thus make the entire C-agent operate and perform. The two need not be mutually exclusive: some operating may help organizing, and vice versa. But important is to distinguish the two and consider both.[9]

The self-organizing of b-agents may be visualized as their searching for, recognizing, and interconnecting with, the right neighbors, and thus forming the C-agent's network. To mark its dependence on the b-agents' instructions, it is labeled it as "instructed."

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[9] This appears to be the only way to clarity about the link between self-organization and selection. Limiting attention to only one dimension, as was usual to do, may give the impression that some unexplainable holistic forces are at work. Models that take into account both dimensions are relatively recent (for an excellent collection of such models, see Doursat et al., eds., 2013).

Examples are atoms that self-organize, instructed by their chemical affinities, into a certain compound; neurons that self-organize, instructed by their genomes, into a certain brain; and humans that self-organize, instructed both by their individual genomes and by their common institutional rules, into a certain society. Note that the self-organizing need not be egalitarian: some b-agents, such as catalysts in chemistry, enzymes in biology, and entrepreneurs in economics, may contribute to it more than others.

The operating of b-agents may be visualized as their responding, by a series of the operations that their b-instructions allow them to perform, to their external and internal inputs by certain external and internal outputs. Examples are logical circuits operating in a computer; neurons operating in a developed brain, and human decision-makers operating in an established organization.

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In consequence, the behaviors of a C-agent are modeled as aggregates of the behaviors of its b-agents. Emphatically, however, these aggregates are no “simple sums” – as in the naïve reductionism that advocates of holism enjoy criticizing – but possibly complex functions determined by the possibly sophisticated form of the network. The network may endow the C-agent with properties possessed by none of its b-agents, which philosophers like to call “emergent,” but of which today’s computer scientists intimately know the logical structure. They know indeed in the smallest operational detail how to construct a complex computer which may be described as goal-seeking, purposeful, innovative, creative and self-aware, while its b-agents are just simple logical switches and some sources or random impulses.[10]

Note that the network not only determines the possible complex aggregating of the b-agents’ behaviors, but is itself a possibly complex outcome of this aggregating, especially in the self-organizing dimension. In concrete cases, admittedly, this double aggregating may be far from fully understood, and much of both biology and the social sciences may be seen as trying hard to understand it. But regardless of what we actually understand, the model implies that no property of any C-agent may fall top-down from the sky. All must start bottom-up, be in only in some roundabout and over time distributed ways, from properties of its b-agents.

But the model is non-naïvely reductionist also by admitting that top-down influences of a C-agent on its b-agents may take place and be substantial. But they are strongly qualified

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[10] Such sources are needed for trial-and-error searches, which are essential ingredients of all creative problem-solving and innovating. Admitting them as b-agents moreover means that C-agents need not be deteministic Turing machines.

and limited by a hard constraint. The qualification is that each C-agent must always originate bottom-up with some b-agents forming its initial network, and only then may it begin, as a kind of feedback, to exert some top-down influences on them. The constraint is the extent to which the b-agents are adaptable (malleable, flexible), which depends on their b-instructions. The b-agents' properties are thus once more fundamental: a C-agent's top-down influences on its b-agents may work only to the extent to which their b-instructions allow it to work. For example, this is why such influences may be much stronger in a human society than in an insect society – although a hard genomic constraint must be expected also to limit the social adaptability of humans, even if this constraint is so far only little known.

The model's non-naïve reductionism thus makes it possible to demystify virtually all of the complex properties of a C-agent that might seem to emerge top-down in some mystical holistic way, and explain them logically as due to properties of its b-agents and to the network into which these have self-organized. Possible exceptions are such transcendental properties as "soul" and "free will." But this appears mainly due to the fact that these properties lack precise scientific definitions, and are therefore largely mystical themselves.

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The b-instructions of a C-agent always include the b-instructions of its b-agents, but the model distinguishes, as one of its key points, between two cases, termed "self-assembling puzzles" and "construction sets." Both are cases of instructed self-organizing, but they differ in the composition of the C-agent's b-instructions.

In a self-assembling puzzle, these b-instructions are simply those of its b-agents. These have all of the needed instructions to form, develop and operate the C-agent. The process may be influenced by environmental inputs, but only in ways allowed by the b-instructions, and without any additional instructions. In this case, the C-agent's b-instructions are just its b-agents' b-instructions.

In a construction set, the b-agents' b-instructions are also needed, but they do not suffice. To form, develop and operate the C-agent, the b-agents moreover need some additional instructions, either exogenously communicated or produced by some trial-and-error evolution. In this case, the C-agent's b-instructions therefore consist of two parts: its b-agents' b-instructions, and the additional instruction.

An example of self-assembling puzzles is an insect society, whose b-instructions are fully contained in the genomes of its individual members. An example of construction sets is the population of a human society. As human genomic b-instructions make it possible to form a great variety of societies, the forming of any specific one requires some common formal and/or informal institutional rules, produced by socioeconomic evolution. These rules are additional for individuals, but become basic for their society.

Note the elementary, but important and not always fully realized implication of the Second Elementary Principle of Information-Processing: in neither case can the b-agents be blank slates: to form, develop and operate a C-agent, they always need informationally rich b-instructions. In a self-assembling puzzle, these must fully suffice by themselves, whereas in a construction set, they must "only" enable the b-agents' to receive and effectively employ the needed additional instructions.

Considering the above examples of social insects and humans, it might appear surprising that the b-instructions of the incompletely instructed humans are informationally richer (whence the quotation marks around "only") than those of the fully instructed insects. Intuition may be helped by realizing that programmable computers with multiple uses need more sophisticated hardware instructions than fully programmed single-purpose ones.

As both the examples make it clear, the self-assembling may be a very complex process, possibly taking time, involving many feedback loops, and having to choose among several by the b-instructions predetermined alternatives, in function of some environmental influences – such as the food that determines whether a bee will be a queen or a worker. [11] But importantly, no additional instructions are either needed or admitted. It is only construction sets that both need and admit additional instructions, and that only to the extent allowed by their b-agents' b-instructions. It is therefore only in connection with a construction set that some evolutionary trial-and-error processes may take place and some evolutionarily selected additional instruction may be put to work.

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The model considers each agent to have environments of its own, including a more or less large part of nature and a more or less large number of more or less cooperating and/or more or less competing other agents. The environments impose on the agent certain performance tests, in which it may either succeed or fail. The success of an agent is also the success of its

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[11] That self-assembling puzzles may be complex and difficult to understand is demonstrated by the large number of today's biologists inquiring into the embryogenesis and ontogenesis of multicellular organisms with the help of the most advanced computer models (see, e.g., Doursat, 2008, Merks et al., 2010, Delile et al., 2013). Yet, despite the interesting results already obtained, what these real-world puzzles really do to self-assemble so well is still far from fully understood.

b-instructions. For a C-agent, to recall, these are the b-instructions of its b-agents if it is a self-assembling puzzle, or both these b-instructions and the additional ones produced by evolution, if it is formed from a construction set.

But the two successes are of different kinds, related to the difference between evolutionary selection and developmental selection: the successes of agents are developmental, whereas those of b-instructions are evolutionary. Note that the environments do not test b-instructions directly, but only through the performance of agents, which are the testing grounds for the abilities of their b-instructions. The results of the agents' performance tests are the key commands for the evolutionary selection: select and retain the b-instructions of those agents that are succeeding in the developmental selection.

An important difference is in the time perspective. Only the evolutionarily successful instructions are required to last, while the developmentally successful agents may be short-lived. Old ones may keep exiting and new ones entering, yet the b-instructions will remain evolutionarily successful if they keep enabling some of the actually present agents to be developmentally successful.

The success criteria for a C-agent usually differ from those for its b-agents. For these, the tests are often less severe than if they remained independent. This may even be seen as the main point of their forming the C-agent. But there is a necessary condition: they need sufficiently sophisticated b-instructions enabling them to do so. The C-agent that makes their performance tests easier, and their developmental success therefore more likely, also makes the evolutionary success of these b-instructions, which become part of its own b-instructions, more likely. But such sophisticated b-instructions may not be easy to come by – as illustrated by the very long time, nearly three quarters of its total length, that it took the evolution of life to find the first evolutionarily successful genome of a developmentally successful multicellular organism.

But the possibilities of a C-agent for helping its b-agents are limited. It faces performance tests of its own, in which the extent of this help may be crucial. Up to a certain limit – for instance, because of what is sometimes called "synergy" – helping its b-agents pass their tests may also help it pass its own tests. But over this limit, if it allowed too many of its b-agents to perform too poorly, it would fail itself. To avoid failing, it may then on the contrary make the tests for its b-agents more severe.

The consequences of a C-agent's developmental failure depend on whether it was a self-assembled puzzle or assembled from a construction set. The failure of the former causes the developmental failure of all of its b-agents. These are narrowly instructed to form just that C-agent, and if it fails, they cannot do anything better. In contrast, the developmental failure of a C-agent assembled from a construction set need not cause more than the evolutionary failure of the additional instructions, with which its b-agents complemented their own b-instructions for forming it. But the b-agents themselves need not fail. They may try different additional instructions to form a different, hopefully more successful C-agent.

For example, the demise of an ant society entails the demise of all of its ants. But the failure of a national economy need not mean the failure of the nation, but only the failure of its institutional rules. Most of the nation survives, be it only impoverished and hungry, only forced to try different institutional rules to form a different economy. A biological example is the extinction of a species. This means the evolutionary failure of its genomic instructions, but most of the amino and nucleic acids that were used to form its individuals stay around, ready to form, under the guidance of other genomic instructions, individuals of other species.

To make the model interesting, the environments must be neither too hostile, nor too hospitable: just so little hospitable as to allow only a small fraction of all the feasible C-agents to be successful. If the environments were more hostile, no feasible C-agents could be successful. If they were too hospitable, all the feasible C-agents would automatically be so, with no additional instructions needed. Note that the smaller the successful fraction, the informationally richer the additional instructions must be.

5 Insights into the issue of group selection and multilevel selection

The issue is usually put as follows: does the evolution of life, in addition to employing selection of individuals, also employ selection of their groups, possibly at several levels? The usual candidates for such selection are differently large and differently organized groups of distinct agents – from simple symbiotic couples, such as eukaryotic cells with their mitochondria, to complex societies.

The first thing that the model makes clear is that the answer cannot be a simple “yes” or “no,” but distinction must be made between evolutionary selection of instructions, and developmental selection of agents. In general, the model admits several levels of both, but points out that not all levels of developmental selection may have a corresponding level of evolutionary selection. While all levels of agents are submitted to some performance tests by developmental selection, evolutionary selection of additional instructions may take place only at the levels of construction sets. A self-assembling puzzle has neither the need nor the room for them. In it, the C-agent has the same b-instructions as its b-agents, which means that the two are only two different levels of testing grounds for the same level of b-instructions. All this may be expressed as the following insight.

> *Insight 1:* If the multilevel hierarchy of larger and larger b-agents forming larger and larger C-agents contains at least one level of self-assembling puzzles, it involves more levels of developmental selection than of evolutionary selection. The difference is equal to the number of levels of self-assembling puzzles.

For full clarity, note that a self-assembling puzzle may employ evolutionarily selected additional instructions, but of a lower level. Such instructions may even be what makes the puzzle's b-agents so fully instructed. But they are not directly addressed to these b-agents, but to some of the smaller b-agents of which these b-agents are formed. For instance, an ant society, to self-assemble in its species-specific way, needs certain evolutionarily selected genomic instructions, but these are not addressed to its ants, but to the chemical construction set of which the ants' proteins and consequently the ants themselves are assembled.

But this insight is only general, valid in an abstract world with imaginary agents where evolutionary processes may take place at an arbitrary number of levels. To contribute to the debate on multilevel selection and group selection, we must identify the construction sets that can employ evolutionarily selected additional instructions in the evolution of life on earth.

If we start searching for such levels bottom-up, from strings and charms through subatomic particles and atoms to molecules, it will take quite a long time before we find the first one. This is the level of certain organic molecules – in particular the amino acids for forming proteins and the nucleic acids for writing DNA or RNA genomic messages. The evolutionarily selected additional instructions are the well-known genomic messages written in DNA or RNA, which, besides the genes coding for proteins, may also contain non-genic DNA coding for regulatory RNA, and possibly even non-DNA epigenetic markers modifying their interpretation. But regardless of how these instructions are written, they all logically belong to the same molecular level, produced by evolution suitably called "biological."[12]

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[12] Note that the logic of the model may accommodate even the hypothetical origins of life in the form of self-catalyzing RNA molecules. For this, it suffices to admit that b-instructions may also be their own C-agents. It is then also easy to visualize how the two could gradually split: the RNA b-instructions increasingly backed-up and stored in the form of DNA, and the C-agents increasingly made of the proteins specified by the instructions.

Above this level, it will again take a long time before we find the next level of construction sets. We must traverse several levels of self-assembling puzzles – including organelles, cells, multicellular organisms, and instinctively formed societies – to attain the level of advanced social organisms, endowed by their sophisticated genomic b-instructions with talents to form, develop and operate a variety of different societies, but requiring, in order to know which of these actually to form, some additional instructions that only another level of evolution can provide. The complete list of such organisms is not yet entirely clear, but they definitely include as the clearest and most advanced case Homo sapiens.

What we thus find is the above-considered socioeconomic evolution, producing additional instructions in the form of institutional rules – formal, imposed by politically selected legislators, and/or informal, initiated by anonymous social innovators. Note that the institutional rules are additional for individuals, but become parts of the b-instruction of their societies – in addition to the biologically evolved genomic b-instructions of the individuals, which continue to play important roles even at that level.[13]

Socioeconomic evolution differs from biological evolution in several aspects – such as the possibility to proceed nearly as fast as development, and the absence of the Weismann barrier, which allows it to learn from past experiences and thus be partly Lamarckian. But despite all of these differences, the two levels of evolution may be shown to have a common logical structure (Pelikan, 2011).

More levels of evolution may be then found within the socioeconomic one. For instance, the institutional rules of firms and those of national economies may evolve to a certain extent separately, at two different levels. But studying different levels of socioeconomic evolution is of more interest to institutional economists than to biologists and sociobiologists. For them the most important is the great distance between the level of biological evolution and the first level of socioeconomic evolution. This is the vast no-man's land for evolutionary selection, filled with possibly many levels of developmental selection.

All this leads to two insights.

Insight 2: Biological evolution admits several levels of developmental selection, but only one of evolutionary selection.

Insight 3: The evolutionary selection in socioeconomic evolution is not of groups or

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[13] These roles were for a long time ignored or even denied, but are now increasingly recognized and studied. Cosmides and Tooby (1997) and Pinker (2001) are important pioneering studies of these roles in general, while Witt and Schwesinger (2013) study them in the specific context of organization of firms.

> other human organizations, but of genomically compatible institutional rules for their forming, developing and operating, which selects and retains those rules whose groups/organizations are succeeding in the developmental selection.

In other words, group selection and multilevel selection are admitted to exist if meant to be developmental, but not within biological evolution if meant to be evolutionary. This appears to be a nice diplomatic way to settle the issue: both sides may be satisfied, if able to content themselves with being right for only one type of selection, and not the other.

But settling this issue only raises another, bigger one: what institutional rules might possibly succeed in their evolutionary selection? More precisely: which of the genomically compatible institutional rules could guide a given a set of individuals – such as a tribe or a nation – towards forming, developing and operating a society successful in the developmental selection?

This is the central issue of modern institutional economics – even if it is there expressed in somewhat different terms and the problem of genomic compatibility has not yet been paid sufficient attention. But properties of successful institutional rules for both firms and national economies are there being carefully examined, with many interesting results already obtained. However, most of these results are unlikely to interest biologists and sociobiologists, who appear mostly concerned with the properties that relate to the issues of cooperation vs. competition and selfishness vs. altruism. It is by focusing on these properties that the model can produce a few more comments on the conclusion by Wilson and Wilson (2007) that selfishness beats altruism within groups, and altruistic groups beat selfish groups.

It was already made clear is that both these “beatings” are developmental, and not evolutionary, and that evolutionary winners must be sought among the groups’ b-instructions. What was also brought to light is that these instructions are in part genomic and in part institutional, and that the latter must be compatible with the former. But more can be learned by inquiring into this compatibility, which implies two necessary conditions. First, given the potential of human genomic instructions, the institutional rules must be comprehensible and admissible as such. Second, they must allow and encourage each individual, given his/her genomic endowment with propensities and talents, to do the best for the group, and prevent his/her from harming it.

In a first approximation, the second condition corresponds quite well to the Wilson and Wilson conclusion: to make a group successful developmentally and themselves evolutionarily, the institutional rules must allow and encourage altruistic behaviors and prevent anti-social selfishness. But a closer examination leads to several open questions and one qualification.

The open questions have to do with the lack of knowledge on what the genomically given propensities and talents of humans really are. That they substantially differ from those of the perfectly rational (although not necessarily narrowly selfish!) *homo economicus*, the hero of most of modern economic models, is now established, mainly thanks to experiments in behavioral economics. But the details of what they really are still remain largely unknown. For example, an important open question is, to what extent may efficient cooperation rely on the known genomic propensities for it, to what extent it may require additional economic incentives, and over what extent may economic incentives on the contrary work against these genomic propensities by triggering instead those for envy and distributional justice?

The qualification has to do with the unequal distribution of talents over any human population. If a group needs for its developmental success a sophisticated division of labor where certain roles require some special talents that only a few individuals possess, it will then also need to mix cooperation with some competition, in order to find at least some of these individuals and select them for such demanding roles. Its institutional rules, to be evolutionarily successful, must therefore make it sure that the needed competition will be organized. That some form of such competition is needed in national economies now appears obvious (my inquiry into what form this might be is in Pelikan, 2010). But interestingly and perhaps somewhat surprisingly, a similar competition has been found to take place even among cells of otherwise highly cooperative multicellular organisms. As described by Martín et al. (2009), the wings of Drosophila are indeed made of the cells that won the competition among many more cells trying to be part of these wings.

5 Insights into the origins of order

This issue may be understood as a contest between evolutionary selection and self-organization for the role of the origins of order. There is now a wide agreement that both play a part, but still much disagreement on how large their respective parts are. At one extreme, neo-Darwinians typically ascribe much more importance to selection while according very little merit to self-organization (if they consider it at all, which they not always do). At the other extreme, perhaps best represented by Kauffman (1993), the order of life is mostly ascribed to self-organization, with selection making only some minor final adjustments.

The key feature of the model that allows it to offer insights into this issue is its distinction between self-assembling puzzles and construction sets, and the recognition that the two may play different roles at different levels, as expressed in *Insight 1* above. This brings to light the greater number of levels of self-assembling puzzles, where order is generated by pure self-organization, than of construction sets with evolutionary selection, which, in the biological evolution on earth, is just one. But – and this is the other important side of the story – this singleness does not hinder it from producing a greater total amount of new information. All this may be summarized as follows.

> *Insight 4:* Self-organization is the source of order at a greater number of organizational levels than Darwinian trial-and-error evolution with its evolutionary selection, but the latter produces greater amounts of new information.

The model thus offers a diplomatic way to settle also this issue: both sides may again feel satisfied, if they can content themselves with one victory out of the possible two.

This insight may be refined by recalling that all self-organization must be, in one way or another, instructed. It is then interesting to distinguish the levels of self-organization below the level of evolutionary selection from those above it – which may suitably be labeled “sub-evolutionary” and “super-evolutionary,” respectively. As far as is now known, sub-evolutionary self-organization is instructed purely internally, by the inherent selective affinities of the b-agents involved, starting with the smallest subatomic particles and up to relatively simple organic molecules, including amino acids and nucleic acids. These are the key pieces of the lowest, and in biology also the highest, construction set. Above this level, instructed self-organization again takes over, possibly at several higher levels, but this is the super-evolutionary one, whose instructions include, besides the inherent selective affinities of atoms and molecules which continue to matter, the additional evolutionarily selected ones.

Two more insights may be gained into the ways in which self-organization and evolutionary selection interact with each other, which mostly consist of mutual constraints.

> *Insight 5:* Sub-evolutionary self-organization constrains evolutionary selection by supplying its construction set with only a limited variety of only limitedly capable b-agents, which limits the variety of feasible C-agents among which the selection is possible. The usual name of this constraint is “morphogenetic.”

> *Insight 6:* Evolutionary selection constrains super-evolutionary self-organization

through the selected genomic instructions. This self-organization cannot do more than what the evolutionarily selected instructions allow it to do.

5 Concluding remarks

The task of the model in this paper appears fulfilled. With its simple means – two elementary principles of information-processing and the distinction between two types of selection – some insights into the issues of group selection, multilevel selection, and the origins of order were indeed possible to gain. The model may perhaps also be accorded some merit for the diplomacy with which it recognized each of the disagreeing sides to be partly right.

An open question is whether the model might also help with other issues. In economics, I have found and discussed several of them – in particular concerning reform policies, system transformations, and economic change in general (see, e.g., Pelikan, 2011). Now I believe to see a few more at the borderline between socioeconomic evolution and biological evolution, where the model may help understand how the former builds upon, and is constrained by, the latter, and perhaps even deduce some interesting hypotheses on how the former, which is still far from any successful end of history, might continue.

In biology, however, I can see only three relatively simple issues which for most biologists are now already clear, but which the model may perhaps help make clear even for the others. The issues are: (i) Is selection the driving force of evolution? (ii) Does selection optimize? (iii) Was evolution occasionally punctuated?

As to the answer to issue (i), the model helps to say “no.” With its understanding of evolution as a trial-and-error search, in which the trials consist of different instructions for combining the pieces of a given construction set, it becomes clear that what actively drives evolution is the generation of the trials, whereas selection is only the filter through which a few of the trials succeed to pass, while many others are rejected.

For issue (ii), the model helps to say “mostly no,” with an occasional and limited “yes.” It makes it clear that selected is what works, and not necessarily what is in any sense optimal. Some convergence to some optimum may take place, but possibly only slowly. This means that any actually selected trials may still be far from any optimum, which is moreover subject to two constraints. One is the often considered path-dependence, through which the trials selected in the past constrain the variety of those that may be tried and selected in the future. Even if an optimum is attained, this may therefore only be local, possibly far from the global. The second constraint is the above-considered morphogenetic one, which the model brings to light as due to limited possibilities of the by sub-evolutionary self-organization produced pieces of the construction set.

Concerning issue (iii), the model brings additional support to the now widely accepted view that all the large jumps in the anatomy of phenotypes during phylogeny, which may induce superficial observers to believe that evolution is punctuated, are fully explainable by gradual changes of genotypes. The extra support comes from the interpretation of genotypes as b-instructions and phenotypes as C-agents. This facilitates the import into biology of a simple but crucial piece of wisdom from computer programming: a small change in one instruction, depending on where in the program it is situated, may cause an enormous jump in the outcome. Even if some jumps may require changes in several instructions, these may still change only one by one, if some of the required ones may first be neutral, and just wait for the crucial one that puts all of them to work.

Admittedly, however, many biologists may not find the model helpful at all. It is especially the molecular ones, who know so well and so concretely what they are doing that they may hardly be helped by hearing the well-known story again in generalized, less concrete terms. The model has perhaps the greatest chances to help some of the sociobiologists and philosophers of biology who still have difficulties with understanding and correctly interpreting the findings of molecular biologists. In any case, I am leaving it up to each reader to decide what biological issues, if any, the model might possibly help her or him understand.

To conclude, allow me to mention a psychological reason why the model might tend to be resisted and its helpfulness minimized. This is its instruction-centrism, which does not have the same weaknesses as gene-centrism, but shares with it the same unpopular feature: expulsing us, noble humans, from the center stage. In other words, this means to admit that, from a scientific point of view, our genomes are not here for us, but we are here for our genomes, which many of us still appear reluctant to do. But, if the model proved helpful, able to offer clear simple insights into some so far unclear apparently complicated issues, this would only be another step on the road towards more clarity about the real world paid by sacrifice of human pride, which started longtime ago with Copernicus and continued with Darwin. What remains to be seen is whether the switch from individual-and-group-centrism to instructions-centrism might lead to so much more clarity that it would be worth the sacrifice. I strongly believe it would, but expect that opinions may for a long time differ. ▪

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