Evolution : the problem solving strategy as the basic unit of adaptation?

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ABSTRACT. The theory of evolution would gain in acceptance if it were better able to banish the tautologies that continue to dominate some of its formulations. The principles of communication/problem solving might be helpful in this respect. For example, adaptation as “the evolutionary process by which an organism becomes fitted to its environment” could be replaced by : “adaptation concerns the solving of a particular (set of) problem(s) in a given environment/context, making use of preexisting problem solving strategies”. ‘Survival of the fittest’ says nothing more than that the survivors survive. An alternative could be : “If they are not prematurely eliminated by accidental death, the best problem solvers have better chances for being rewarded with a higher level of contentment, and by faster growth and reproductive advantages”. Problem solving requires adequate hardware, software, energy as well as the proper motivation.

KEY WORDS : selection, microevolution, macroevolution, megaevolution.

INTRODUCTION

Evolution is usually considered as the development of new types of living organisms from preexisting types by the accumulation of genetic differences over long periods of time (Henderson, 1995). The recent (2002) book of Stephen Jay Gould, the godfather of American evolutionary biologists, entitled “The structure of evolutionary theory”, clearly illustrates the enormous emphasis that contemporary evolutionary theory puts on genetic mechanisms. In this 1433 page book, Gould, by almost completely neglecting cultural evolution, the principles of communication and of problem solving, gives the impression that these are non-issues in (his) evolutionary theory. However, evolution can also be considered as the (evidently unconscious, non-directional) invention, application and accumulation, again and again, of novel strategies for solving problems imposed by changing living conditions, whatever their nature. A possible result is the appearance of new phenotypes and eventually new species. These two approaches will involve quite different ways of thinking for unraveling the nature of the driving forces of evolution as well as of the basic unit of adaptation/selection. The first approach almost exclusively focuses on genetics. The second approach takes into account the whole machinery that is required for problem solving, namely communication with its four pillars (Fig. 1) : hardware (the body of organisms/compartments), software (to decode incoming messages), energy and motivation (De Loof, 2002).

SOME BASIC PRINCIPLES OF COMMUNICATION

Although everybody knows that communication is very important for living organisms, its principles are seldom dealt with in common introductory textbooks of general biology. This is mainly owing to the fact that communication is experienced as being so normal and self-evident that it does not deserve an effort to get insight in its basic principles. However, communication is a much more complex activity than one usually realizes. Hence, it may not be superfluous to elaborate briefly on its principles.

Communication can be defined as transfer of information. The basic functional unit in communication is not ‘the cell’ but the ‘communicating compartment’. Such a compartment consists of a sender that releases a message that is invariably written in *coded form*. This message is then transported through what is called a transmission channel (the air, the blood stream, an axon etc.) towards a competent receiver, thus a receiver that has receptors that can somehow sense/bind the coded message. Next the receiver has to decode and amplify the message, making use of preexisting programs for decoding. Finally, to respond to the message, the receiver has to mobilize part of the energy that it had stored beforehand. Very often, feedback mechanisms are activated next. The receiver becomes a sender and the original sender, and perhaps other entities as well, becomes a receiver. There are numerous families/types of messages and they all require specific decoding mechanisms. Decoding information is not possible without a memory system. There are two types of memories, the genetic memory (in DNA, RNA) and the cognitive memory (molecular carrier not yet known), both with their specific sets of rules/dogma. It is seldom realized that any act of communication involves an act of problem solving, namely as to how the receiver should decode the incoming message(s). What we call ‘communication activity’ is in fact a synonym for ‘unconscious problem solving’ (the automaton aspect of life). Humans reserve the term ‘problem solving’ for that very tiny part of problems that they cannot automatically solve but that require conscious thinking and handling. However, both use exactly the same principles (for details, see De Loof, 2002).

From the viewpoint of possible sources of variability – essential for understanding evolution – there are many ways in which the activity of a communicating compartment can change : the structure of the sender, the transmission channel, the receiver, the storage and use of energy, the (genetic and cognitive) memory systems, the electrical phenomena that are essential to communication, the interactions with other levels of compartmentalization etc. Thus, changes in genes are only part of the causal mechanisms underlying evolutionary change. The evolution of the hardware of living systems is mainly governed by changes in gene structure/activity, according to the rules of the first central dogma (DNA→RNA→Proteins). What is called 'cultural evolution' is in fact evolution 'the software way' and happens primarily according to the rules of a second, as yet only partially defined dogma (for a sketchy outline of this second dogma, see De Loof, 2002), that deals with the processing of cognitive information. Here teaching-learning activities are of primordial importance.

EVOLUTION OF 'LIFE', THUS OF 'PROBLEM SOLVING ACTIVITY' AT DIFFERENT LEVELS OF COMPARTMENTAL ORGANIZATION

Organisms can solve problems, not because they have genes (they evidently need genes), but because they are constructed as communicating compartments. The type of problems a given compartment – or level of compartmental organization – can solve partially depends upon its architecture. A bacterium (= monomembrane compartment) can solve a given set of problems. A eukaryotic cell (= multimembrane compartment) can handle problems related to the interaction among its cell organelles. A segmented animal can handle problems on at least six successive levels of hierarchical organization : the cell organelle, the eukaryotic cell, aggregate, the syncytium, the monoepithelium, and the polyepithelium. In fact, not only metazoan organisms contain in themselves a series of layers of compartmentalization but the whole biosphere is compartmentally organized in layers of interacting communicating/problem solving compartments. My communication-based classification system comprises 16 levels arranged into three major groups (De Loof, 2002). The first group comprises levels of compartmentalization that can occur within one and the same individual. Already eight levels can be discerned, the major ones being the bacterium/ cell organelle, the eukaryotic cell, the aggregate, the syncytium, the monoepithelium, the polyepithelium, the segmented animal, and animals with their tools. The second group comprises compartments that are formed by more than one individual but still belonging to the same species. This group comprises six additional levels : the colony, the heterosexual couple, social compartments, organism-in-organism (by internal budding) compartments, the population/species compartment, and the electrosphere-compartments. The third group lists compartments consisting of more than one individual but now belonging to different species, e.g. host-parasite associations, food chains, and the highest level of all, the whole biosphere or Gaia compartment. All these levels represent key revolutions that are the heart of mega-evolution. Mega-evolution deals with evolution of life in its totality, more specifically with the revolutions underlying the coming into existence of ever higher levels of compartmental organization, all hierarchically organized. Mega-evolution crosses the borders of systematic classification. The basic principles underlying the coming into existence of the successive levels are surprisingly few in number, and simple : internalization of compartments, gluing together of compartments, utilization of tools, sexuality and development, and nutritive and protective deficiencies (De Loof, 2002).

In order to maintain itself, any organism has to solve problems on a continuous basis. When it enters a new environment, an organism will only survive and reproduce if it can instantly solve the problems that changing environmental conditions impose upon its physiology. From this point of view, a comprehensive theory of evolution should best be based upon universally valid cell biological principles that make problem solving – and hence adaptation – possible.

In my opinion, *the* question in evolution is not : "How do new species come into existence?" (= microevolution) as originally suggested by Darwin's "The Origin of species by means of natural selection or the preservation of favoured races in the struggle for life" (1859) but "How does *life* evolve?". Many biologists have as yet intuitively assumed that the known mechanisms of micro- and macroevolution should suffice to explain the evolution of life in its totality. However, the persisting impotence to provide a cell biological model by which 'cultural evolution' can be made an integral part of neo-Darwinism/the synthetic theory suggests that this is not the case. The only way to overcome this problem is to define life first. Contrary to what nearly everybody thinks, this can be done in a rather simple way as outlined in "Communication, Life, Mega-Evolution – Decrypting Life's Nature" (De Loof, 2002). Details cannot be given here. To make a long story short, life is not just a machine as so many biologists tacitly assume (Rosen, 1991), but the *activity* of a special sort of machine. In my opinion, what we call 'life' is simply an umbrella term denoting the total communication/ problem solving activity of hierarchically organized communicating compartments. This approach shifts the emphasis from 'genes make proteins' to 'genes are one of the elements in the whole problem solving machinery'.

IS PROBLEM SOLVING ACTIVITY LINKED TO SOME 'URMOTIVATION'?

As humans we know that engaging in an activity requires energy as well as the proper motivation. Motivation – an anthropomorphic term for lack of better – is different from the 'software' that is needed to solve particular problems. Because we cannot judge whether organisms other than humans make use of motivation to start mobilizing part of their stored energy to solve problems, some people may hesitate to extrapolate motivation beyond the human species. My view is that, as is also the case for feelings, motivation did not come into existence out of nothing at the moment that *Homo sapiens* became a distinct species. Most likely, we inherited the underlying mechanisms from very distant ancestors. I think that some form of 'urmotivation' must have been in place already right at the moment life started on earth.

Humans link motivation to processes in the brain, in which electrical phenomena play a crucial role. However, such phenomena (changes in transmembrane voltage gradient, transcellular currents) are not restricted to the nervous system, not even to animals but they operate in any cell type, no matter whether this cell is prokaryotic or eukaryotic. In my opinion the role of the electrical dimension (De Loof, 1986) present in all living systems has as yet been undervalued, not to say almost completely neglected, in theories of evolution.

I think that motivation is linked to the feeling of contentment (again an anthropomorphic term for lack of an appropriate alternative) that, when it turns negative into discontentment, informs – through appropriate signaling pathways – organisms/compartments that some action is required to cope with an emerging problem. Gradually biologists start to recognize that senses and feelings are more universal than generally assumed (Ford, 2000). No doubt, the unraveling of the full molecular basis of any feeling will require a lot of additional research : at present, we are only in the early exploration phase.

If the definition of life that I proposed is correct, the consequence is that life can change by alterations in the hardware (mutations), in the software needed to solve problems (mutations and learning processes), in energy or in motivation. Most of the time, all four pillars of life (Figure 1) are simultaneously subject to change.

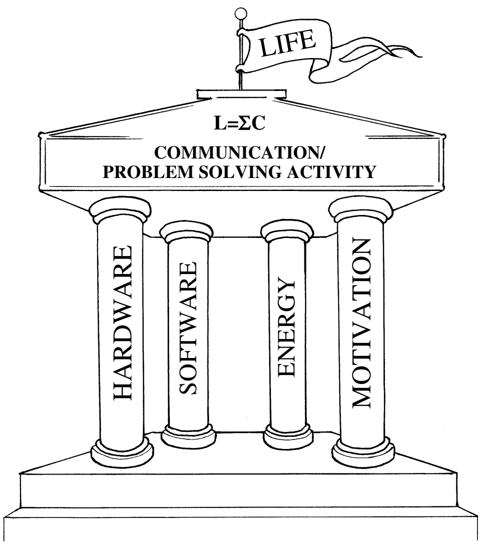

Fig. 1. – The four pillars of "life".

EVOLUTION IS FARSIGHTED BLIND

When approaching evolution from the viewpoint of problem solving, it immediately becomes clear that a given problem can only be solved if the whole machinery is in place at the moment the problem manifests itself. This requires that strategies for problem solving have to be elaborated (long) beforehand (e.g. in gametes), thus in a period when that particular problem does not yet exist. I call this "Evolution is farsighted blind". The more such problem solving strategies are accumulated in organisms/populations/compartments, the more chances their progeny will have to successfully cope with future adverse conditions. Thus, adaptive success is the *result* of the activation at the right moment of preexisting problem solving strategies.

THE PROBLEM SOLVING STRATEGY AS THE BASIC UNIT OF ADAPTATION

Adaptation is the successful solving of a particular problem in a given environment/context, making use of preexisting problem solving strategies. In my view, the basic and universal unit of adaptation is *the problem solving strategy.* As long as the second central dogma is not fully understood, the full description down to the molecular level of such strategies will not be possible.

SELECTION. WHO SURVIVES : THE 'FITTEST' OR THE BEST PROBLEM SOLVERS?

I do not favor the view that there exists something as 'a unit of selection' as put forward by Gould (2002) rather than a unit of adaptation. In my opinion, selection is itself the result of something that happened before in the context of problem solving. The view, held by some researchers, that the gene could be the basic unit of selection cannot be correct because problem solving requires more than just genes. Neither is the view justified that the organism is the universal unit (see Gould, 2002). Indeed, organisms can only solve problems at their specific level of compartmentalization, not at any other higher or lower level. The type of problem that has to be solved is usually linked to a given level of compartmentalization. I think that the two adages, namely 'struggle for life' and 'survival of the fittest' should be replaced by better ones. Indeed, because organisms are not aware of the meaning of death, they cannot 'struggle for life'. Replace this by 'Organisms solve problems or they don't'. 'Survival of the fittest' is a tautology that says that the survivors survive. Replace this by : "If not accidentally eliminated, the best problems solvers have more chances to be rewarded with better growth and possibilities for reproduction."

SUMMARY OF THE ESSENTIALS OF MICROEVOLUTION AS FORMULATED FROM THE VIEWPOINT OF PROBLEM SOLVING

The Darwinian concepts of 'struggle for life' and 'survival of the fittest' as applicable to micro-evolution can perhaps be made less harsh and more all- encompassing when viewed in the following perspective :

– Organisms live in changing environments.
– They have means for sensing changes in gradients of temperature, humidity, salinity etc.

- Organisms are comfort-lovers.
- Their basic feeling is of ‘contentment’.
- All sorts of influences can disturb this ‘state of contentment’.
- Hence all organisms must solve problems in order to regain their state of contentment and/or improve their quality of life.
- Their basic architecture as communicating compartments with their hardware, software and energy aspects allows endless variability. It generates the possibility for problem solving and it also contains the genetic and cognitive memories and mechanisms for anticipating solutions to future problems and for adaptation.
- The two types of memory are likely to involve two differential central dogmas. The genetic memory obeys the rules of the first central dogma : DNA → RNA→ Protein(s). A second central dogma, governing the cognitive memory, is likely to exist as well. Its nature is as yet only partially determined, but electrical phenomena are surely part of it – and perhaps the actin cytoskeleton as well.
- If they are not prematurely eliminated by accidental death, the best problem solvers (=the fittest) have more chances for being rewarded with a higher level of “contentment”, and by faster growth and reproductive advantages.

All levels of compartmental organization are subject to evolutionary changes. The full formulation of this concept (in 20 points) can be found in De Loof (2002).

CONCLUSION

Darwinism is a splendid theory but it deserves a better formulation, preferably in contemporary language, than is presently the case. The vocabulary of informatics/computer sciences is appropriate in this respect. An (partial) attempt in this direction has been undertaken by De Loof (2002) and is given in abbreviated form here.

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