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Information Processing in Evolutionary Systems

An Outline Conceptual Framework for a Unified Information Theory

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CONTENT:

A common information-concept would turn the sciences dealing with certain aspects of real-world information-processing manifestations into a single, though transdisciplinary information science. The philosophical interpretation of the self-organisation theories is a proper background theory capable of restoring information theory as a theory of evolutionary systems which process information. A multi-stage (spiral) model of information may be derived from it.

Key words: information science, evolutionary systems, semiosis, cognition, reflection, representation, anticipation

1. The information theory debate

Even today, Information Theory" is largely taken to mean something closely related to Shannon and Weaver's channel model of communication. This interpretation rests on the misunderstanding that a hypothesis which has not been mathematically formalised, and whose object cannot be measured, has not reached the status of a theory and remains mere conjecture. It is on the grounds of the same misunderstanding that Heinz Zemanek, the Austrian computer pioneer, opposes the name Information Theory". As he believes that the relevant content of the term Information" cannot be formalised, there cannot, in his opinion, be such a thing as Information Theory".

In this paper we would like to express a different opinion. We do agree with Zemanek that important aspects of Information" are not covered by Shannon-type formalism, and perhaps not even by any other mathematical tool (at least in the foreseeable future), but we see such formalism as being of merely secondary importance. Information is not only the subject of technical, physical, so-called exact" sciences, in which precise measuring plays an exceptionally import role. Information is also very much a part of softer" scientific considerations such as semiotics, cognitive science, psychology, communications science, sociology and so forth. In these disciplines, qualitative methods are more important than quantitative ones, but it cannot be denied that these areas of science have made meaningful contributions to research into the concept of information. These contributions are dedicated to aspects of information processes which are different from, but no less important than, those which lend themselves to precise calculation (such as a simple technical exchange of messages).

Whilst at the end of the last war the concept of information was still seen largely from a limited and one-sided military viewpoint, scientific debate on the topic has since then been dominated by attempts to move away from these limitations and see the subject in a different way. Shannon's sysntactic definition was thus followed by attempts to formulate a semantically-based term (most notably by Carnap and Bar-Hillel) and a pragmatically-based term (of which Weizsäcker is seen as the most prominent proponent).

Since then, there has been a search for a concept which can integrate the various aspects of information processes, include the useful findings of the old term as a special case, and extend the old information theory into a new, universal theory. We still need a term which is flexible enough to perform two functions. It must relate to the most various manifestations of information, thus enabling all scientific disciplines to use a common concept; at the same time, it must be precise enough to fit the unique requirements of each individual branch of science. A term is needed which combines both the general and the specific; the general as the governing laws of each form of information, the specific as those characteristics which make different types of information distinct from each other. The position of the boundary between general and specific will vary according to the level being considered.

The possibility of forming such a concept has increased with research into self-organisation" which has recently fired up the debate.

2. Theorising evolutionary systems

There are those, who interpret the phenomena of self-organisation of matter, and the results of their own research, against a background of the old mechanistical world view. There is no room in their view for objective uncertainty, open developments, or freedom of choice; everything that happens here must be due to the unambiguous principle of cause and effect. And yet we are sure that if their blinkered vision could be opened up, we would experience a paradigm shift that would affect all sciences and even our world view.

With the transition from System Theory I to System Theory II, as with the change from Cybernetics I to Cybernetics II and the increased slope of the Theory of Evolution, we can see a theory of open, non-linear, complex, dynamic, self-organising (in short: evolutionary) systems approaching. This theory no longer deals merely with mechanisms, strategies and controls for achieving/maintaining homeostasis and the development of species; it also concerns the birth, growth and decline (i.e. development) of all systems, from the formation of the earliest known particle, through the arrival of terrestrial life forms, to the shaping of specific human socio-technical systems. This theory breaks the short-circuiting cause-and-effect theory by recognising the spontaneous appearance of individual activity from independent entities; the behaviour of these entities cannot be entirely put down to external causes and internal mechanisms, because options and freedom to decide" exist, each of which (albeit perhaps with varying probability) could happen, although only one actually will. We can see necessity in having to choose one of several possible paths, as opposed to the old situation in which there was only one way to go.

The theory of evolutionary systems which is to be elaborated is pre-destined to use emergence theory as its philosophical base, upon which we can build methodologically. This new theory will thus avoid the extremes of reductionism and holism. Reductionism reduces the whole to a mere collection of parts, and novelty to a mere collection of the old. Holism overstresses the value of the whole as opposed to the parts, and the value of the new as opposed to the old. Emergentism, however, declares the parts and the old to be essential pre-conditions for, but not the entirety of, the whole and the new respectively. It allows the whole to be more than the parts and the new to be more than the old, without invalidating the individual contributions of the parts or the origins in the old. It combines continuity and discontinuity.

In this context, self-organisation means that the development path of systems which are far from thermodynamical/chemical equilibrium will encounter bifurcation points, where the systems are forced to take one of several possible ways (which may exhibit different levels of probability).

This positioning between the world view of Laplace's omniscient being and the blinkered vision of unrelated world parts would enable the theory of evolutionary systems tofurther the integration of science and the unification of disciplines, without producing a bland, uniform science as a result.

We believe that such an emergentist theory of evolutionary systems forms an ideal foundation for unifying information concepts.

3. Steps towards an evolutionary-systems model of information

In this section we shall firstly distinguish three levels of a system. Each of these will then be related to the appropriate aspect of semiosis. The next step is to identify the current state of the evolution of information processing systems and, after that, the stages which led to this. Finally we shall integrate the layer and phase perspectives into a single multi-stage (spiral) model.

3.1. Identifying system levels

In identifying a system, three different levels of the system's dynamics can be distinguished (see fig. 1):

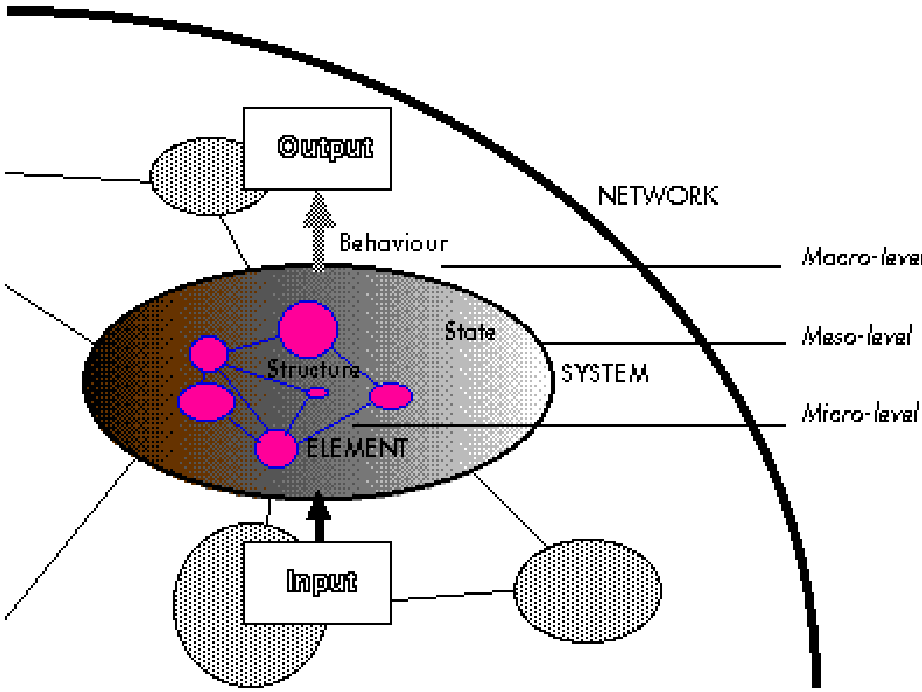

Fig. 1

1. The level on which the elements of the system in question are interconnected. This is the level of the internal structure of the system (the micro-level).

2. The level on which the system itself is in one state or in another (the meso-level).

3. The level on which the system exhibits its external behaviour vis-a-vis its environment. The way the system interacts with its co-systems in the net is examined here (macro-level).

Each level is the base on which the next level is built; each level has progressively less space for possibilities than the one below. From one level to the next there is a leap of qualitative difference. This leap can (but need not) be bridged by a self-organisation cycle. Thus these levels give the prerequisites for understanding the emergence of new system structures, system states, or system behaviour, or even the emergence of new systems.

3.2. Assigning semiotic aspects to the system levels

According to semiotics, information can be conceived as something having syntactical, semantical and pragmatic aspects. It seems sensible to relate each of the three semiotic aspects to an appropriate system level, as follows (see fig. 2):

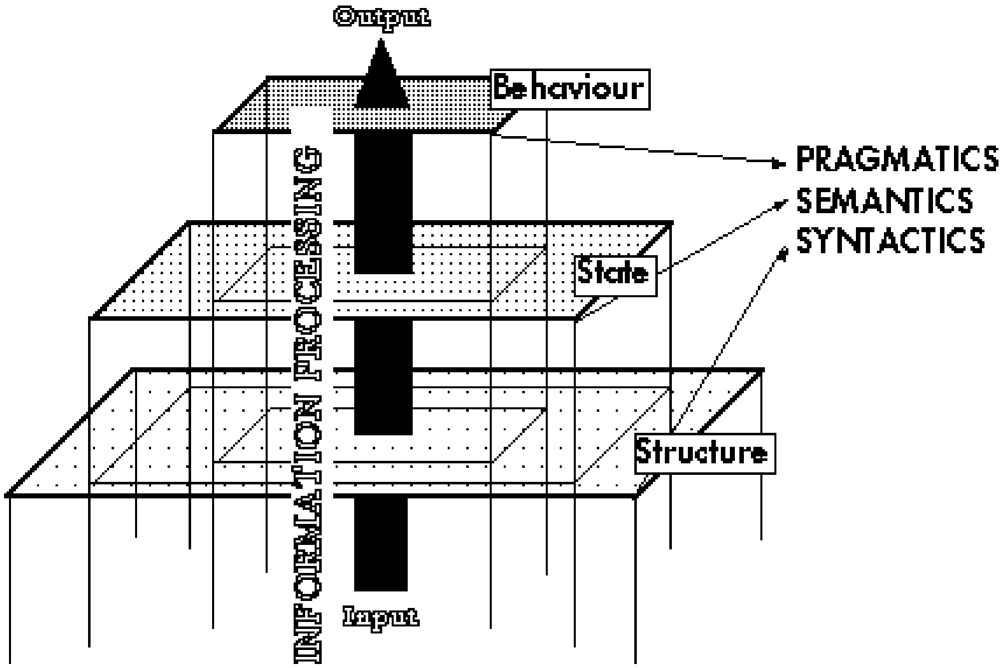

Fig. 2

1. syntactics refers to the micro-level;
2. semantics refers to the meso-level;
3. pragmatics refers to the macro-level of a system.

The three semiotic aspects thus relate to one another in the same way that the system levels relate to each other. This means that (contrary to the view of the founding fathers of semiotics) they are not merely placed side by side, without having anything to do with each other; each initial aspect is essential for the following one, and each following aspect is a sufficient condition for the preceding one.

Together they mark the varying qualities of information. That is to say, in any particular system, information occurs when as a result of a self-organisation process there is a qualitative change on any one of the three levels. The underlying information process may result in structural changes to the interior of a system (on the micro-level), it may result in changes to the actual state of the system (on the meso-level), or it may result in altered external behaviour (on the macro-level). We must note that changes in the interior structure need not lead to changes in the system's state, and that changed states need not necessarily entail changes in the behaviour. But a difference in the output of a system must be based upon a different state, and a different state must take as a basis elements and relations that differ from previous structures.

Information thus has two characteristics: on the one hand it is static (ssen by many people as its only quality); on the other hand it is also dynamic, i.e. the process itself by which qualitative changes are produced and from which the static entity results.

3.3. Identifying the most advanced information-processing system known

Certainly human cognition and communication are the most highly developed appearance of information processing which is known to us at present. Thus social systems form the peak, and temporary end point, of a branch of the evolution of information-processing systems. In social information-processing systems, cognition (the case of informational relations between cultural subjects and some objects as opposed to the case of informational relations amongst cultural subjects which forms communication) can be imagined as a process of self-organisation cycles, leading from one to another, as follows (see fig. 3):

The first, perceiving, makes data from signals;

the second, interpreting (the assignment of meaning), makes knowledge out of data;

the third, decision-making, makes practical applications from knowledge, and forms wisdom.

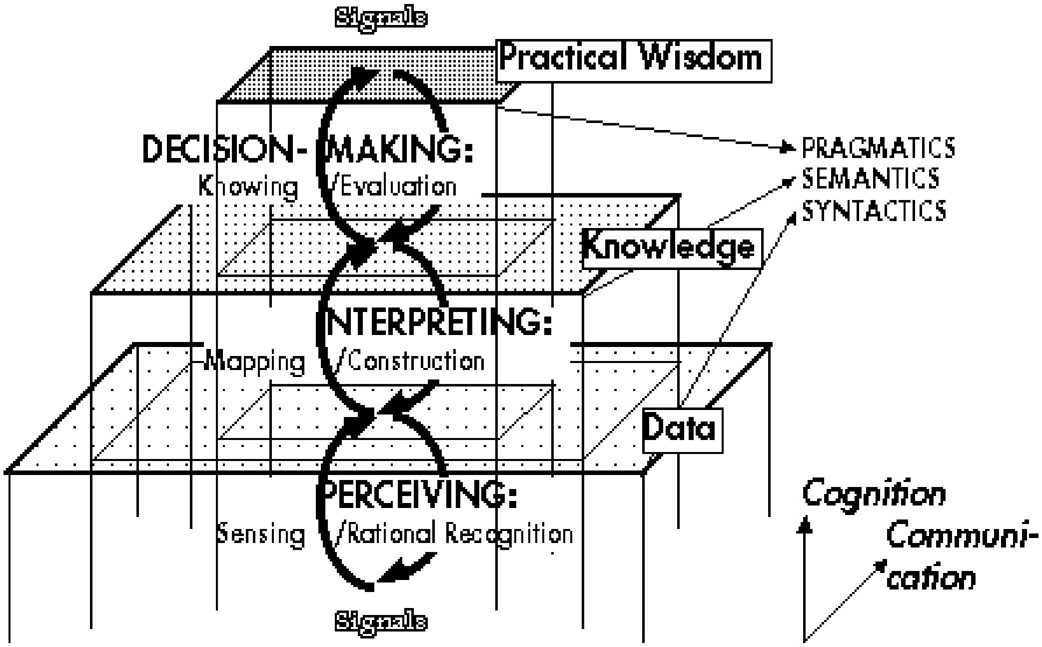

Fig. 3

Between signals and data, between data and knowledge, and between knowledge and decision, there are stages of information processing which represent not merely algorithmic transformations (as suggested by the term information processing" and the practice of computerisation), but rather a metamorphosis in which the quality of information perpetually changes as one moves up from one level to the next. On the data level, we refer to the syntactic dimension, which concerns rules for the linking of signs, regardless of the fact that these signs are only representative of other objects. On the knowledge level we find the previously omitted semantic dimension, which gives the meaning of the signs for the system's goal. On the decision level there is the pragmatic dimension, which concerns the role of the signs (which already carry meaning) in controlling and regulating the functioning of the system.

What then exists as information on a particular level is the result of a specific process of information generation which is made up of two opposite motions: data is the result of the interaction of sensual" with rational" experience; knowledge is the product of confirmation and refutation of conjectures which are constructed to map reality; decisions are instructions to act which are selected in the evaluation of possible options. These processes are cycles of self-organisation.

There is a certain feedback between layers. The process of information generationflows in the direction of the higher levels, but these exert a certain degree of macrodetermination on the lower levels.

3.4. Distinguishing intermediate stages

Looking back in evolution we can recognise phases, in whichless-highly-developed systems serve as preliminary stages of human cognition and communication systems.

Analogously to the Eco-threshold we want to define a limit on the far side of which we cannot find even the most rudimentary form of information processing. This is the threshold of self-organisation. Systems which are unable to organise themselves exhibit no information processes; systems which can organise themselves, but at a particular time do not do so, show no information processes at this time (see fig. 4).

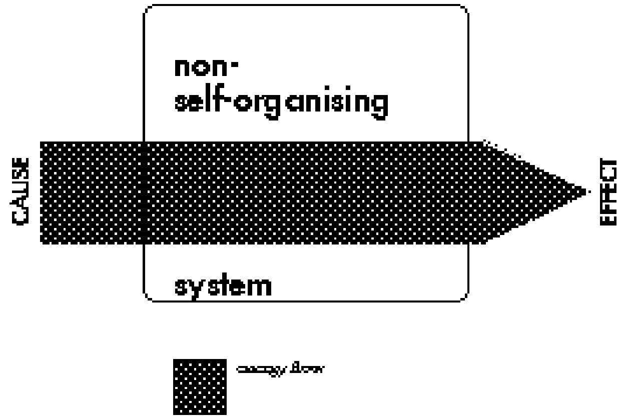

Fig. 4

Though we are talking about an open system in that there is exchange of energy with the environment, the effect is however clearly due to the cause, i.e. here are only quantitative, not qualitative, changes; small causes have small effects, large causes have large effects. So a mechanistic explanation is quite sufficient.

3.4.1. The genesis of reflection:

When a system, through which energy is flowing, shows spontaneous pattern formation, the first stage of information processing has taken place. It builds order, in that it makes use of energy for performing work, depreciates it and removes the resulting entropy (see fig. 5). This is done by the selection of a particular option from the various structuring possibilities which the system has. This selection results in a rudimentary self, and in the self-determined restructuring the system reflects its environment in its own way. The reflex as structural change thus represents a change in the environment, and so may be seen as an informational relation.

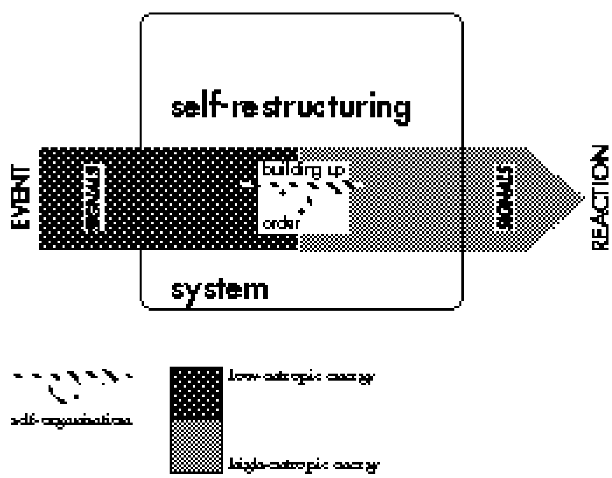

Fig. 5

This reflex is the precondition for the existence of a sphere of influence" in which the behaviour of the system triggers the behaviour of systems in the surroundings so that this produces conditions beneficial to the maintenance and improvement of the system. Simple dissipative systems are, however, not in a position to perpetuate the flow of energy.

3.4.2. The genesis of representation

So-called autopoietic systems (we use the term autopoiesis" without solipsistic consequences which can be drawn from Maturana and Varela's concept) are a special category of dissipative systems which arose from the first simple non-biotic dissipative systems (see fig. 6). They exhibit division into a sensorium and an effectorium, which involves two cycles of self-organisation, one on the top of the other. Structural change splits into structural and state/behaviour change. The self-organised structure, which represents a change in the outer world of living systems, then undergoes a further step and becomes understandable and behaviourally relevant to the system. Representations appear as new informational relations. The sphere of influece shows (due to the presence of representations) better adaptability of the systems to their environment. They are in a position to take advantage of the environment to such an extent that they can reproduce themselves.

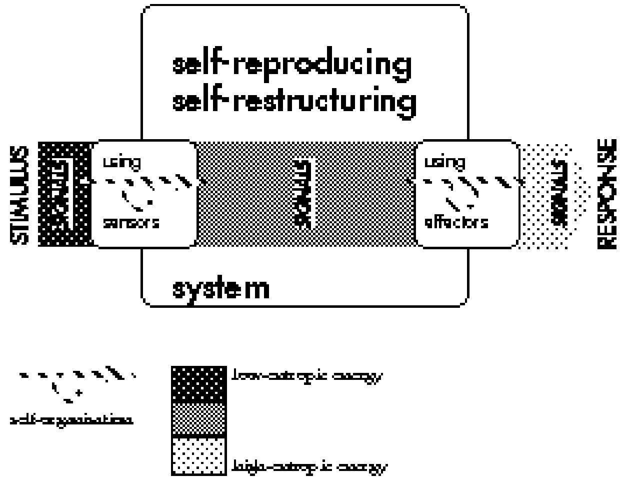

Fig.6

3.4.3. The genesis of anticipation

Social systems (another special category of autopoietic systems) exhibit even greater adaptability: they alter their environment to suit themselves. That is to say, their field of influence is characterised by a feedback loop, through which the systems can create the conditions necessary for their re-birth. They are re-creative" systems, because they make a degree of freedom or themselves due to further differentiation of the self-organisation cycles. The behavioural decisions are no longer identical to the representations, but now are conveyed with the knowledge only via a phase transition (see fig. 7).

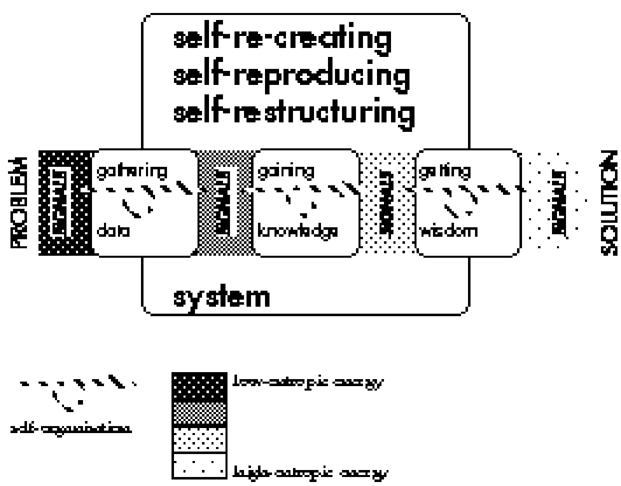

Fig. 7

An inner model of the relationship to the environment enables the systems to anticipate to some degree the results of their actions.

3.5. Merging the layer model and the phase model

We can now reconcile the statements made about systems in terms of a layer model (3.1. - 3.3.) with those made about evolution in terms of a phase model (3.4.). A precondition for this is the making compatible and fusing of the separate lines of research into the self-organisation of evolutionary systems (this has yet to be done). Self-re-creating systems should be seen here as a special type of self-reproducing systems and in turn the self-reproducing systems as a special type of self-restructuring systems (see fig. 8).

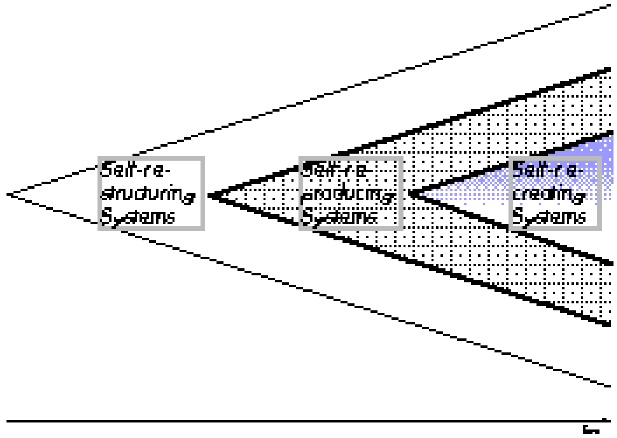

Fig. 8

In each phase of evolution a new moment appears which becomes characteristic of a layer for more highly developed systems and gives the entire layering of this system its nature (see fig. 9).

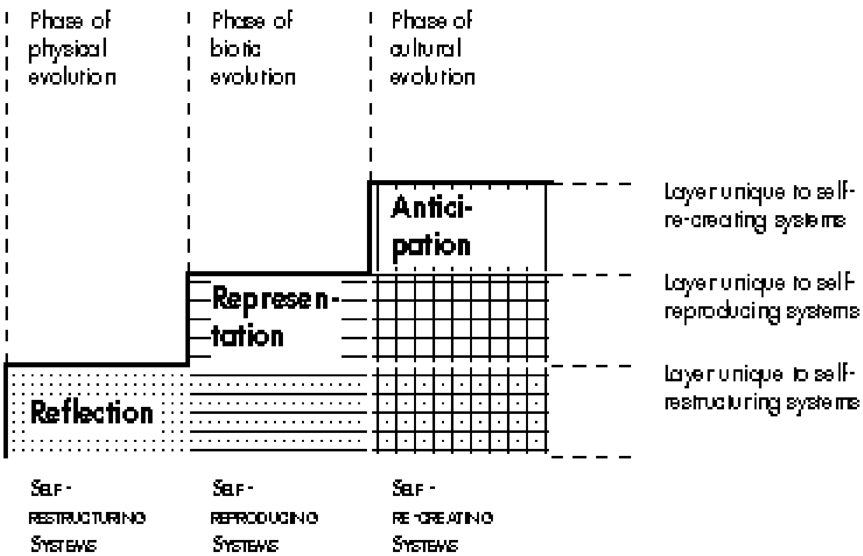

Fig. 9

Reflecting is a common feature of self-organising systems, the use of representations is typical of all living systems, and choosing one of several options on the ground of anticipation is essential for human systems.

4. Revival of the ancient information concept

Due to research into the connection between information and self-organisation, there is a chance that the reified picture of information will be replaced by another view. The reified view (a picture which arose from Shannon and Weaver's channel model) assumes that information is something outside a system, which will be solely transferred into one system or another. This picture, which is still expressed by the behavioural-school-type pragmatic concept of information will be replaced by a view that relates information to a referential system and to the processes in which the system is being structured, adopting one state or another, and interacting with its environment. It sees information primarily as a moment of these processes and only secondarily as the result of these processes.

Information processing does not mean a process which can be formalised and mapped in a mathematical function and is therefore computable. Rather, it is a process by which novelty emerges. It is bound to a certain system which is capable of organising itself. In the course of self-organisation novel qualities come into being which characterise several levels of information.
Information is involved in self-organisation. We believe one can speak of information in the situation where the deterministic connection between cause and effect is broken up, that is, where a system's own activity comes into play, and the cause becomes the mere trigger of self-determined processes in the system, which finally result in the effect which is constituted by the reaction of the system to an event, by the response of

it to a stimulus, or by the solution to a problem in short, where the system makes a decision and a possibility is realised by an irreducible choice.

Information processes leave traces in a system, i.e. in its structure, in its state, in its behaviour. These traces can be the starting point for a further information process, relating to another system, in which it accompanies the system's self-organisation. The traces are sometimes called structural information", which can be potential" (as the starting point for a possible informing process involving another system) or actual" (as the finishing point of this process). The process itself is known as functional" or kinetic" information (i.e. relating to a system, information in movement, dynamic process-information).

The concept of information thus stimulates the meaning it had before it was reduced to a term denoting simply a message as the Greek aggelia" did. Originally, Informatio" in Latin meant not just the result of an action or a process, but the action/process as well, namely informare". In-formare" meant bring into form", give shape to", and the subject could be man with matter or man as object, the subject could be god with matter or man as object, and the subject could be nature with nature itself as object. This notion sounds astonishingly modern, if we see humans as part of nature, and assume that god does not intervene in natural processes an anticipation of the very concept of self-organisation of today. And to the ancient thinkers the forms which gave shape to matter used to mark differences in quality, that is, in-forming meant a process, as a result of which something new appeared.

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