

EXTENDED CONCEPT OF KNOWLEDGE FOR EVOLUTIONARY EPISTEMOLOGY AND FOR BIOSEMIOTICS

Hierarchies of storage and subject of knowledge

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Abstract

A dominant view of evolution is that genes play a central role in it. What is important in genes is not the material, DNA, but the information that they contain. The relevant concept of information is the concept of meaningful information. This kind of concept of non-mental meaning is studied in evolutionary epistemology (EE) and in biosemiotics. However, it turns out that there are a number of relative concepts that demand similar non-mental redefinitions. Concepts of knowledge, meaning, interpretation, and subject are extended so that they are applicable to both human and non-human actors.

Keywords

Action, adaptation, biosemiotics, epigenesis, evolutionary epistemology, information, knowledge, levels of evolution, phylogenesis, selection theory.

THE INFORMATION IN GENES

The standard neo-darwinist scheme of evolution consists of three parts: *variation*, *selection*, and *reproduction* (or heredity). The 'scientific common sense' -view has specified it as follows: the variation takes place at the level of genes, different genotypes are selected on the basis of their phenotypic outcome, i.e. organisms with different genotypes are selected, and when these selected organisms transmit their genes to the next generation through reproduction, the species evolves. After the discovery of DNA the emphasis has increasingly been transferred into the genetic level. Especially G.C. Williams and Richard Dawkins (Williams, 1966, Dawkins, 1976) have propagated very influentially for genetic reductionism

according to which not only variation is at the genetic level, but so too is selection: 'selfish' genes are ultimately selected, and in consequence, gene pools are evolving. Although this kind of reductionism is a controversial doctrine, almost everybody seems to accept that genes or DNA play a central role in evolution.

As Dawkins has noticed, genes, identified with pieces of DNA-strings, are 'good replicators'. Replicators are defined to be entities with three characteristics: 'fidelity, longevity, and fecundity' (Dawkins, 1976). However, mere material of DNA (or RNA) does not yet make a DNA-string a gene, but it is its *structural order* or *information* that is essential to making it a gene. This has been pointed by many biologists and philosophers (e.g. J. Hoffmeyer, D. Hull, A. Sharov, and even Dawkins), but the point is still often overlooked. But what kind of information is in question? It cannot be the mere physical or statistical information, which can be measured by objective and quantitative measures. It is true that the concept of statistical information is relevant in cell-division, in which the cell replicates its chromosomal DNA. The 'fidelity' of replication as well as the 'longevity' in the form of copies follow mainly from the physical characters of DNA (and from its cellular environment). But even if the fidelity of replication is an important factor in cell-division, it is not sufficient to make DNA essential for (the evolution of) the living world. The third property of a good replicator, 'fecundity', is strongly dependent on its capability to affect its micro- and macro-environment, e.g. a DNA-string can be a replicator only in a cellular environment. Protein synthesis is the major channel for DNA to affect its environment. And it is the *particular* order of nucleotides in a DNA-sequence which is important in protein synthesis, and on which the 'fecundity' of DNA is dependent. Therefore, it is the *contentious* or

meaningful information that is in a central role when a DNA-string is considered as a replicator.

We can use a common metaphor and consider DNA-strings as *codes* — as coded messages from past to present (or from present to future). Genes can be seen as DNA-codes, packages of information that were encoded in the past, and that are 'meant' to be decoded. Thus, there are (at least) two semiotic processes that are connected in genes: the *encoding*, the formation of the order of the DNA-code, and the *decoding*, the *interpretation* of a DNA-coded message. This code-metaphor gives us one further argument for regarding DNA-strings as 'good replicators'. The 'meaning' of DNA is *digitally* coded, and digital codes are highly resistant to disturbances (Hoffmeyer & Emmeche, 1991, 134-135) — not only DNA, but also its 'meaning' is replicated with great fidelity, and can be preserved from generation to generation.

It is not only the purely objective characters of DNA-strings that make them replicators. Even the 'meanings of DNA' are meaningful only for certain cells — these 'meanings' have effects only *subjectively interpreted*. DNA does not replicate (nor produce proteins) by itself — it does not *do* anything by itself— it just exists. (Hoffmeyer, 1996, 50) DNA must be in a *living cell* that does the work by dividing itself. And it does make a difference which type of cell the DNA is in, whether it is in a liver-cell or in a muscle-cell, or in an amoeba or in a neuron located in a human brain. If we consider a DNA-string being a gene, it is the 'subjective' information-content of this DNA-string that makes it a gene. An arbitrary sequence of nucleotides (DNA 'as such'), or any 'freely floating' DNA-sequence, cannot be considered as a gene. DNA needs an *interpreting subject* and/or an *appropriate environment* if it is to work as a replicator. Therefore, the relevant concept of information is the *information that means something for somebody* (the formulation is due to Gregory Bateson, cited through Hoffmeyer, 1996, 66).

If a gene cannot simply be identified with some DNA-string, the idea of genetic reductionism becomes muddled. However, it is not at all clear what kind of 'meaning' associated within a DNA-string makes it a gene, and what or who could be that 'somebody' (and in what sense). There is a real danger to take these metaphors too literally, and as a consequence to load them with spiritualist metaphysics or religious mysticism. I think this danger is one apparent reason why this kind of 'contentious-informational' approach has not always been favoured by scientists. The naturalistic explications of these mental metaphors are not obvious. Still, there are two

mutually relatively independent and for the most part naturalistic lines of thought that have both considered this kind of aspect of DNA: *evolutionary epistemology* (EE) and *biosemiotics*.¹ In both of these the active role of phenotypes is emphasized. In EE, the knowledge of the non-conscious knowers is discussed, and respectively in biosemiotics, non-human interpreters of meaningful signs are considered. I think biosemiotics is at its best when it considers how the DNA-codes are decoded. The evolutionary epistemology (EE) is, in turn, at its best when it has considered *what* has been encoded in DNA, and also *why* it has been encoded. I try to combine the best parts of both approaches, and conclude the explication of a general concept of knowledge.

KNOWLEDGE IN GENETIC CODE

Knowledge and adaptations

The standard philosophical conception of knowledge defines knowledge as a *true well-justified belief* or *proposition*. Knowledge is achieved, at least in standard empiricist dogma, by some learning process, either through perception or through the adoption of such a tradition that contains previously gathered knowledge. In the tradition of EE followed here, an analogy between evolutionary *adaptation* through natural selection and the increase in *environmental knowledge* is emphasized. More specifically, this knowledge is not simply about the environment, but rather about the relationships between the knower (e.g. organism) and its environment. When natural selection makes changes in genetic information, this is interpreted to be a knowledge process, and if this change is adaptive, it means the increase of knowledge. Genes can code environmental knowledge that is *not* learnt individually but is innate or *a priori* for the individual organism.

Although it has been more common to use Darwinian 'logic of natural selection' (variation-selective-retention-and-reproduction) as an algorithm of learning in

¹ EE does not form a very uniform tradition. I am following the line founded in the 40's and 50's by Konrad Lorenz and Donald T. Campbell. Henry Plotkin represents here the 'second' generation that relies on the base made by Campbell and Lorenz. Thomas Sebeok is often named as the founding father of biosemiotics, even though Jacob von Uexküll (who was the teacher of Konrad Lorenz) is also mentioned as its predecessor. Still, I am referring the recent writings of Jesper Hoffmeyer, Claus Emmeche, and Alexei Sharov.

the human sphere,² as in many evolutionary theories of the development of science, the analogy may become better understood if it is viewed the other way round. Adaptation through natural selection can be seen as a kind of learning process, as an *evolutionary learning*, where lineages, populations, or species (but not individual organisms) are considered as individuals that are learning about the conditions of the survival of their 'members' — these 'collective individuals' are 'testing' their environments by their 'individual individuals'. These supra-individual learning processes explain how individual organisms have got the 'a priori'-knowledge.³

It must nevertheless be stressed that natural selection is not necessarily adaptive, as e.g. Richard Lewontin has pointed out (Lewontin, 1978). Every evolutionary change cannot be labeled an evolutionary adaptation. All the changes in genetic information cannot be associated with (evolutionarily) learned *knowledge*. As is the case with humans, also 'erroneous' information can be adopted. Natural selection causes changes in the gene pool of a population through differential reproduction (i.e. the relative proportion of the DNA of the most numerous reproducers increases). However, the adaptedness is not the property of gene-compositions (or single genes)⁴ but of single phenotypes. Adaptations can be inherited through genes, but both the encoding and the decoding of respective DNA-codes are essential factors in adaptations. It is not enough that environmental information becomes encoded into DNA, but the code must have real effects in epigenesis (i.e. in the translation process from DNA into a phenotype) resulting in functional advantages for the developing phenotype (see e.g. Johnston & Gottlieb, 1981) — not all DNA-strings are func-

tionally effective or even become 'visible' in ontogenesis.

It is the concept of adaptation (or of adaptive learning) that is essential in the extension of the concept of knowledge, not evolution, selection, nor learning *per se*. The proper way to understand the idea of evolution of knowledge in EE, is to identify the *growth of knowledge with adaptation*, or with *increasing fit between an organism and its environment*. Like Donald Campbell, I am also searching "for redefinition of the problem of knowledge as a subtype of cases of fit between *x* and *y*." (Callebaut, 1993, 416) When an organism or something is adapting itself to its environment, it is gathering knowledge about its environment (or about its relation with its environment). However, I have not seen this redefinition properly made anywhere. It is quite odd that in EE this basic concept is not thoroughly specified.

The concept of knowledge

A genetic code is a paradigmatic example of a structure where one kind of environmental knowledge through adaptation can be stored, and how it is coded. Clearly, if we are talking about 'environmental knowledge coded in DNA', this kind of knowledge cannot be a belief or even a proposition. The traditional concept of knowledge is not appropriate. The criterion for the knowledge-content of DNA has to be specified as the adaptedness of the developing phenotype. The 'meaning' of DNA is thus purely functional, it must also be 'visible' at the phenotypic level, and it is meaningful only for the cell that is interpreting it. Therefore, a DNA-code cannot be either true or false, unless we give some pragmatist definition of truth as 'usable' (and 'profitable'). It does not need any justification either — a loose analogy between justification and adaptation can be drawn, but the subject is missing, for whom DNA is supposed to be justified in adaptation.

The main reason why the traditional concept of knowledge is too restricted for the DNA-code is its anthropocentric idealism: justification and 'beliefness' depend on the *rational consciousness* of the knower; truth seems to be connected to *propositionality* that furthermore refers to *human* language, and to its 'immaterial', mental meanings understood by some conscious *mind*. Because EE is at its heart a naturalistic program, we need a more 'naturalist' or 'realist' concept of knowledge — consciousness of a knower cannot be a distinctive feature of it. We need *real* knowledge of *real* (wo)men concerning the *real* world, and existing in the *real* world. However, my aim is not to

replace the traditional concept of knowledge totally, but to *extend* it so that the extension covers both the traditional and more realistic definitions of knowledge — the standard definition must be included as a special case. If we do not consider ourselves as mere consciousnesses or minds, we may ask two questions. What kinds of knowledge do we as *living beings* surely possess, and why do we have the kinds of knowledge we surely possess?

It has often been said that one of the central themes in classical epistemology has been the fight against skepticism — do we have any real knowledge at all? If we do not limit ourselves by the traditional concept of knowledge as belief (or proposition), we can give a certain answer, yes we do! There are many things that we certainly can do (if we just want to) — in many respects we are capable of doing as we wish — we *know* enough about our world *to be able to act* in it. The ability to act successfully presupposes the knowledge how to act successfully. Discursive linguistically expressed justification is not always necessary — if the ability to act *is* (successfully) *demonstrated*, no argument can overcome this ultimate proof of knowledge. This kind of demonstrable knowledge connects us to other forms of life — every living creature needs at least some knowledge how to act successfully (in its environment). Of course, knowledge does not determine the action it enables, it is just the precondition for the action. Although an action can be seen as a presentation of knowledge, the actual action is not necessary for the existence of knowledge — knowledge is *potential action, the power to do*. We can associate knowledge with power by using the concept of power in quite a general sense, as an *ability to do* something. Both concepts are still considered as properties of individuals — it is just that the subjects of power (potential actors) and of knowing (knowers) are equated. These subjects do not *need* to be conscious either of themselves or of their actions (but of course they may be). How should then the idealities of the traditional concept of knowledge be realized? And what features of it can be preserved? The first estimate is the following.

1. There must be a real *subject* of knowing, a *knower*.
2. Knowledge is about something, it must have an *object* that is and *known*.
3. The known is represented in some *structure* as its *order*. Knowledge *exists* as a *structural order*.
4. There must be some correspondence between the knowledge and the known. The structural order that carries the knowledge have to be formed in a

process where the fit between it and its object has increased.

These are very general characterizations, but they lend themselves to many different subjects of knowing and to many different structures of knowledge stores. The traditional concept of knowledge as well as environmental knowledge coded in DNA fulfill them. However, there are more species of knowledge in existence than only those two. Still, there is much to be said about the concepts of subject, object, structure, and correspondence by considering DNA-coded knowledge.

Dual coding in living systems

Biosemiotics forms a more general frame of reference than EE. The central idea is that life consists of semiotic processes. The interaction between a living system and its surroundings is not considered as causal chains of the necessary causes and effects, but as sign processes — and signs are not interpreted just by humans but by other organisms too.

Jesper Hoffmeyer (together with Claus Emmeche) considers the biosemiotic theory in which the living systems are dually coded. Every living system must be represented within two codes, one digital and one analogic. The peculiarity of living systems, as compared to artificial ones, is their property of self-creation. The role of DNA is to carry an independent self-description that is needed for the reproduction of a system, and because of its digitality, DNA-code works well as a *memory* that assures the identity of the system through time. (Hoffmeyer & Emmeche, 1991, 125-126) But, because digital codes have a strong resistance to disturbances in replication, they are not suitable for interaction with the rest of the world. The life of a system consists of *actions* in its world — living systems do not live in a vacuum, but they and their surroundings (that includes other living systems) are mutually interpenetrated. The phenotypes are the *analog codes* of living systems being necessary for action, i.e. for *life* in the world. This pair of codes, DNA-cell (or genome-phenotype), is common to *all* living systems — humans included.⁵ (Ibid. 126)

In Hoffmeyer's dual-code-scheme, biosemiosis can be divided into horizontal and vertical dimensions. The sphere of the horizontal semiosis of life is composed

² For example Campbell explains all the apparent cases of increased fit between two systems in terms of one abstract principle: "For Selection Theory, Darwin's natural selection inspires an abstract "variation-selective-retention-and-reproduction" algorithm appropriate to all examples of increased "fit" between one system and another. Biological evolution is only one such exemplar. Trial-and-error learning, radar, sonar, computerized problem solving, and human thought are others." (Campbell, 1987, 143)

³ This idea of looking at adaptation through natural selection as a form of learning is inherent in Konrad Lorenz's ideas about the origin of Kantian synthetic *a priori*: "something that has evolved in evolutionary adaptation to the laws of the natural external world has evolved a posteriori in a certain sense." (Lorenz, 1941, 183)

⁴ The 'parasite DNA' that has no phenotypical effects is an exception — it can be said to have adapted oneself only to its cellular environment (see Orgel & Crick, 1980). A string of 'parasite DNA' is a replicator, but there is not much sense to say it is a gene.

⁵ For humans (at least), there is another important dual-coding (and it is much better known): *language* (digital) and socio-cultural behaviour (analogic).

of all the semiotic interactions between analogically coded living systems and between any living system and its (analogic) environment. The vertical dimension concerns the communication between genomes and phenotypes *inside* one living system. The sphere of the vertical semiosis of life is composed of all the translation processes between the digital and analog codes inside each system. For a system to live (or survive), its digital code must be translated into the analog one. This epigenetic translation process (from digital to analogic) brings about the ontogenesis of an organism. On the other hand, there is also a back-translation process (at the level of population) from analogic to digital by the differential reproduction of phenotypes (i.e. by natural selection). Back-translation processes result in phylogenesis, in changes in gene frequencies (in the gene pool). These translation processes are not mere deterministic mechanical transformations, but they really are genuine sign-processes, the processes of subjective and context-sensitive *interpretation*.

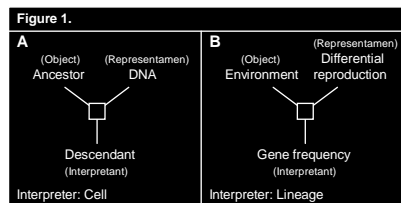
Signs of vertical semiosis transferring the knowledge

The vertical biosemiosis gives a fine example if we ask *how* the subjects without mental sphere can really know their environment. As noted earlier, if we consider DNA-coded adaptations to be environmental knowledge, it is not enough to consider the encoding, but the DNA-code cannot be said to code *adaptations* (or *knowledge*) until it is decoded (or until its decodability is, at least, a real potential in the respective system). Decoding, the epigenetic translation from DNA to phenotype is essential, and its acting subjects, the interpreters, are cells. If we consider epigenesis in connection with adaptations, the (Peircean) triadic concept of sign may be better than the (Saussurean) dyadic one. At least Hoffmayer and Emmeche, and also Alexei Sharov (1997) use it, even though not in the original sense given by Peirce. (For example, Peirce aborted the concept of interpreter from his semiotics.) I have found Sharov's modification (figure 1) more promising than Hoffmayer's and Emmeche's original one. In Sharov's version Peirce's idea about the chaining of signs is better preserved. The interpretant should be able to take the role of representamen in another sign that would then represent the *same* object as the first sign.

The *interpreter* of epigenesis (translation from digital to analogic) is the *cell* containing the DNA-code — in sexually reproducing species, the subject is a *fertilized egg-cell* (*zygote*). *Cells* are the only entities

in which the 'DNA-sign' can really work as a sign, i.e. in which —and *for* which— DNA has some meaning or value.⁶ However, the *zygote* is only the 'first' subject (in multicellular organisms) — after cell-division the proper subjects are descendant cells that are interpreting the same code (i.e. almost identical copies of the original DNA) in a different, *multicellular* environment. The *primary sign* (i.e. the 'representamen') that is interpreted is naturally the DNA-code. Because the DNA does not solely determine the translation, the translation process from DNA to developing phenotype is a true interpretation process. Translation depends both on the interpreter's *manner* of translation (i.e. on the ontogenetically developed properties of the cell that are in principle historically unique), and on the *context* of interpretation (on environmental influence).

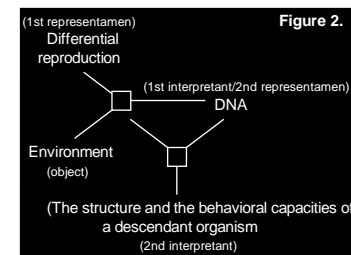
The *interpretant* of a DNA-sign is the *reaction of interpreting cells*, i.e. the individual development of a descendant organism or its ontogenetic trajectory (see figure 1A). In sexually reproducing species, the DNA of a *zygote* is a combination from the DNA of its parents. And through the previous interpretations of that parental DNA, the parents have been construed as the ('final') interpretants of their DNA. Because this argument can be applied to previous generations too, the *object* that the DNA of an organism represents for the cell-interpreter can be defined as the *ancestor organisms* as a whole.



The back-translation from analogic (phenotypic) to digital (genetic) code happens on a different level (figure 1B) — its subject of interpretation (*interpreter*) is a *population* or a *lineage* in an evolving population (or a *kinflok*, a flock of germs, as Hoffmayer and Emmeche suggest, 1991, 146-147). The *object* is the *environment* or the *ecological niche* (of the lineage). The lineage 'sees' the environment through differential reproduction of its organisms so that the *primary sign* or representamen is the *differential*

reproduction. The result of this 'seeing', the *interpretant*, is *changes in gene frequencies*. (Sharov, 1997) However, Sharov's interpretation of the back-translation may not fulfill the conditions of being a triadic sign. As odd as it first might sound, there is no problem in seeing differential reproduction as a sign that represents the environmental conditions for the lineage (although it may represent a number of other conditions too). But does the lineage really *interpret* it? Or are those changes in gene frequencies (Sharov's 'interpretant') the *direct* (causal) *consequences* of differential reproduction, and not the real interpretation of differential reproduction? Or moreover, are they even the *same* phenomenon, but just described at different ontological levels?

I assume that there is a proper sign-relation between the environment and differential reproduction. But even if such a sign-relation could never be defined satisfactorily (in triadic form), and there were just two dyads one after another (or just one dyad), Sharov's 'pseudo-sign' is sufficient for the demonstration of an extension of the concept of knowledge. Signs presented in figure 1 can be chained. In figure 1A, the DNA of a *zygote* represents the 'ancestors' or 'parents' of the *zygote*, but in figure 1B, the genotypes of these 'ancestors' represent the environment of the lineage in which the *zygote* is involved through differential reproduction. It does not really matter whether this connection between the environment and the genotypes of 'ancestors' appears to be only a pseudo-sign, because we can still compose a new sign (figure 2). DNA represents (among other things) the environments of its ancestor-organisms, and that relation of representation appears as a construction of an organism that would be 'competitive' in the past environments of its lineage (this is of course only a statistical property). What is important is that now we can say that DNA contains meaningful information about the past environments (of its ancestors), i.e. *environmental knowledge*, for the cells that constitute the organism.



PHENOTYPIC STORES OF KNOWLEDGE

Nested hierarchies for memory

In EE, DNA is really just an example of knowledge — albeit a good one because of its close analogy with human languages, both work as digital codes. Gene pools are not the only stores of non-linguistic environmental knowledge. There are other stores too that are evolving, not in genetic, but in phenotypic evolution. In the Campbell-Lorenz-Plotkin -style EE the dominant idea is the *nested hierarchy of levels of knowledge-processes* (see Campbell, 1974).

The idea of nested hierarchy is basically systemstheoretical. Lorenz, in particular, has stressed that there is a trend in evolution to form more and more complex systems of (knowledge-processing) organizations. The emergence (or as Lorenz prefers to call it, the *fulguration*, Lorenz, 1973, 47) of a new level of complexity appears when a group of already existing systems starts to work together so that the whole starts to control the functioning (and reproduction) of its parts. When an integral system is formed it usually gets some totally new (functional) properties that are not reducible to the functioning of the parts. New emergent properties pop up in a unique historical accident. Now, one can wonder *why* new levels have emerged at all. Most likely the fact is partly coincidental, but there can also be certain selection pressures affecting the formation of new levels.

The idea of nested hierarchy drafted above does not as such contain anything peculiar to EE. But in EE (at least for Campbell and for Plotkin), it is common to unite at least *three* hierarchies: the genealogical hierarchy of *descentance*, the hierarchy of *containment* or *embeddedness*, and the hierarchy of *control* or *connection* (see Plotkin, 1988, 150-151). Moreover, when this is connected to the concept of adaptation, we can also find a continuity between genetic adaptation and knowledge in all its senses pertaining to human rationality. When organisms adapt themselves to (changes in) their environments, they have to adapt in different time scales, and this may be one cause why new levels of organization emerge (Plotkin, 1987, 85). Since DNA forms a digital code, the knowledge stored in DNA remains stable over several generations — it takes several generations to achieve any significant directional changes in a gene pool. In fact, it is a virtue for life that DNA forms such a stable structure. Chromosomal DNA serves as a long-term memory-bank for the organism so that knowledge already compiled is not forgotten too easily.

⁶ A *zygote* is *not* the product of its DNA. A *zygote* is needed beforehand to 'read' DNA-coded information. (Hoffmayer & Emmeche, 1991, 144)

ly. The discussion about vertical biosemiosis in previous sections concerns only that basic level, i.e. environmental knowledge stored in chromosomal DNA.

From the point of view of the individual organism however, organisms must also adapt themselves to more rapid environmental changes, in time-scales shorter than their lifetimes. In genetic adaptation organisms are adapted to their species or population specific environment. The only possibility for individual adaptation within an individually specific environment is in phenotypic adaptations. Environmental knowledge of an organism must not only be *stored* in a stable form (in genes), but there must also be mechanisms to *update* it. This need for the updatability of environmental knowledge can be seen as a selection pressure that has given rise to more and more complex hierarchical phenotypic organizations. (Plotkin, 1987, 84)

Henry Plotkin has (together with F.J. Odling-Smee) produced a theory of nested hierarchy of knowledge storing,⁷ which has four levels (Plotkin & Odling-Smee, 1981). The gene pool of a population forms a first level store. In that primary level the knowledge is in the form of DNA-sequences. Like Hoffmeyer, also Plotkin has recognized that the genes do not determine solely the development of an organism, but additional information is gained from the environment during epigenesis — genes give some liberty for development. This liberty or variability facilitates the existence of the second level: the developmental system, or the system of '*variable epigenesis*', stores the knowledge in the phenotype as a whole. Although the question is about individual adaptation at this second level, the knowledge is not usually updateable, only compensatable. The updateability of individual adaptations is the central characteristic of the third level. The ability to forget is a prerequisite for this, and therefore the organisms with the third level must have certain special structures for knowledge processing and storing, e.g. a central nervous system. *Individual learning* from experience becomes possible at that third level so that the knowledge of it could, if necessary, be updated in much shorter time-scales than that of the individual lifetime.

The knowledge stored at the third level is not *heritable* unless *social learning* is possible. Social learning forms the fourth level, a *socio-cultural level*. Plotkin and Odling-Smee insist that there are three

conditions necessary for socio-cultural adaptations. 1. There must be a *group* of animals in which each individual is capable of learning. 2. This group must have at least one *non-genetic channel of communication* available to it. 3. The information transmitted by the sender through the non-genetic channel of communication has its origin in individual learning, and it is also received by a process of individual learning — i.e. the level of individual learning is required for the emergence of the socio-cultural level. (Plotkin & Odling-Smee, 1981, 230-231) The socio-cultural evolution establishes the fourth level, because it brings along more effective means for individual adaptation — learning from other learners expands an experience beyond an individual experience both temporally and spatially. However, it must still be noted that not all the learned habits etc. are adaptive. The third and fourth levels just make it possible to gain environmental knowledge faster and further afield — misinformation can also be gained and shared!

About the restrictions of EE

There are a number of weaknesses in evolutionary epistemological theories as in Plotkin's one drafted above. The most serious one is a common one, the lack of the proper definition of knowledge — sometimes it is talked about as if the traditional 'true well-justified belief or proposition' were a suitable definition, but most times it is not. Besides that, especially in Plotkin's theory, the subject of knowing, the knower, is quite unproblematically defined to be an individual organism. Point of view is restricted to concern only individual organisms.

The first observation is that in the level of genetic adaptation, it is not the *individual* organism that is *gathering* knowledge, but it is the lineage, the population, or even the whole species that acts as a subject. Although the part of the genetic knowledge is present in every individual genome, it is both gathered and stored collectively into a gene pool. The *users* of the DNA-coded knowledge are nevertheless individual organisms. At the genetic level we can, again, see two interconnected processes at different levels, as discussed in earlier sections: both decoding (from analogic to digital) at the level of population and encoding (from digital back to analogic) at the individual level are needed to define adaptation, and knowledge.

The socio-cultural level brings along another problem. At this level the knowledge is also stored in a kind of 'pool', a cultural pool, and the same questions arise here as at the genetic level. What kind of beings

are the real subjects of socio-cultural knowledge? In Plotkin's theory, every adaptation in socio-cultural level is an adaptation in the level of individual learning too. There is nothing problematic in this if we are restricted to consider only individual organisms as subjects of knowledge/adaptation. But this is most probably too restrictive a definition for the socio-cultural level of knowledge (see e.g. Campbell, 1981). If we think about social innovations that reorganize the social community (e.g. its division of labor), we can see that their potential adaptability is not necessary individual. The social community together with its environment can form a self-organizing system, where the community and the environment give shape to each other so that their mutual fit-ness increases. The process can be said to be adaptive, even though the environmental information can not be said to be transmitted through one individual experience. This kind of phenomenon is evident in social insects (see Bonabeau et al. 1997), and I cannot see any reason why this kind of adaptation cannot be available in mammal societies including human ones. Because the subjects of this kind of knowledge are not individual organisms but rather their collectives, this kind of socio-cultural adaptations are totally ignored by Plotkin. Thus, especially at the first and the fourth levels, the subjects of gathering, storing, and applying the knowledge may not be the same kind of entities.

The third common weakness for most evolutionary epistemologies is that only two ways of inheritance are considered: genetic inheritance and social communication. There are, however, also other 'mechanisms' of inheritance that may well transfer adaptations from parents to offspring as mentioned in Douglas Wahlsten's criticism (Wahlsten, 1981, 256). Many of the cytoplasmic nonnuclear organelles and structural details (e.g. mitochondria and cell membrane) are reproduced without gene-interaction — these replicate using existing structures as templates. The position of a structure in a cell can also be transmitted to descendant cells.⁸ Thus, the cytoplasmic structure of an egg-cell has, at least in principle, a capability to store heritable knowledge — the female parent replicates herself in sexual reproduction as an egg-cell. This kind of criticism (concerning the undetermined role of an egg-cell) does not nevertheless oppose biosemiotics where the egg-cell has the most central role as a subject of interpretation.

The extended senses of meaning, subject, and knowledge

It has become evident that when studying knowing of, and signs meaningful for *non-human* subjects, we need to give up certain conceptual common sense intuitions. Because biosemiotic subjects do not (in general) have any sort of mind (nor consciousness), we have to redefine the concepts of meaning, subject, and interpretation (of a sign) 'naturalistically', i.e. avoiding anthropocentric or mentalistic pre-understanding of these concepts.

What then is required for the concept of subject? First of all, consciousness has to be dropped as a defining character of subjectivity. We are interested in the kinds of subjects that are capable of interpreting signs. Therefore the minimum requirement is that this kind of subject must be able to 'perceive' signs (specific to the subject), i.e. it must be able to differentiate a sign from 'non-significant stuff' (and from other differentiable signs). The second requirement is that the object, which is represented by a sign for a subject, has to be 'meaningful' or 'significant' for the subject, i.e. the subject has to *react* to the sign appropriately. There must be some subjectively active component through which the sign has an effect on the subject, an effect of significance for it. I would like to define this 'appropriate reaction' as a result of the interpretative act. The (subjectively interpreted) *meaning* of the perceived sign, the *interpretant* in Peircean terminology, becomes thus defined as the (appropriate) *reaction of an interpreter* when the sign starts to work as a sign, i.e. when the sign starts to represent the object for the interpreter — or when the interpreter interprets the sign.

These two characterizations might be enough for the concept of subject, but usually some kind of autonomy of subject is provided. Hoffmeyer's (and Emmeche's) notion about this autonomy is justified by a cosmological-existential question that concerns the beginning of life. Who (or what) was the subject of the process that created the first subject? The answer is obvious (if God is excluded): this subject must be the first subject itself — the first subject must be capable of creating itself. It must contain the distinctions necessary for its own identification — a kind of self-representation. (Hoffmeyer & Emmeche, 1991, 125-6) The sense that the 'autonomy of subject' gets here is the following: a subject in order to be a subject must contain a self-representation, or self-description, by which it is capable of (re)creating itself. The 'self' of (analogically coded) living systems is represented digitally in their DNA.

⁷ While Campbell (1974) and Lorenz (1973) have studied the levels of *processing* the knowledge (they have 10 or more different ways of gathering knowledge), Plotkin pays more attention to *stores* of knowledge, and gets a reduced amount of levels.

⁸ In addition, the milk may transmit viruses, antibodies, etc. from mother to offspring in mammals.

The subjects of translation processes in vertical biosemiosis, cells and lineages or populations, are fine examples of natural subjects. But they are only the ends of the line, there is number of other subjects, the subjects of horizontal semiosis that are interacting with their surroundings by receiving and sending signs.⁹ It is the horizontal semiosis that is relevant for the levels of phenotypic adaptation/knowledge in Plotkin's nested hierarchy. In Hoffmeyer's theory, horizontal communication was mostly analogically coded (or at least non-digitally), and analog codes could not preserve knowledge (nor any content of information) for long times. This matches perfectly with Plotkin's hierarchy, because the phenotypical levels were needed for the range of updatability that digital codes cannot have. This also emphasizes the exceptional status of human languages in phenotypical evolution — they can be exploited in digital communication. Through languages interpreted as digital codes —and especially through *written* languages— knowledge and any information can be stored with relative reliability even for thousands of years. The main problem in interpretation of, say, ancient texts, is not in these texts, but rather our poorly preserved knowledge how to *decode* them. This is understandable, because the knowledge concerning the decoding of written text is usually *analogically* (or at least non-digitally) coded in cultural practices.

The organs in multicellular organisms may turn out to be subjects of horizontal semiosis, because they perceive their surroundings and react appropriately. But at least, the individual organisms are subjects that are receiving and interpreting signs from both the living and non-living world. Set theoretically speaking, all the subjects of knowledge or of biosemiosis are cells or are composed of number of cells. But whether or not their functioning is reducible to the level of individual cells, many of them are none-the-less working as unified semiotical subjects, which are sending and receiving signs, and reacting into them. Hoffmeyer talks about *swarming subjects* that are self-organized groups of minor subjects capable of coherent collective functioning. Multicellular organisms are in fact 'swarms of swarms' of subjects. "The swarm of cells constituting the human body should be seen as a swarm of swarms, i.e., a huge swarm of overlapping swarms of very different kinds. The minor swarms again are swarm-entities, so that we get a hierarchy of swarms." (Hoffmeyer, 1997,

940) This idea of swarming subjects can be extended even further into the social level, as in the criticism of the restrictedness of Plotkin's fourth level of knowledge stores discussed in the previous section.

Now we can give a somewhat more definite answer to the four questions that define the central characteristics of the extended concept of knowledge. 1. Who knows? What is the *subject* of knowing? 2. What is known? What is the *object* of knowing? 3. What is knowledge? Where is it, and how is it there? 4. How is knowledge achieved and stored? There is, after all, not much in general that can be said about the subject and object of knowledge. Extra limitations and reservations are necessary if some specific form of knowledge is concerned. But what can be insisted generally is that

1. the subject, the *knower* is capable of acting as an *interpreter* in semiosis. It does not have to be a mind or any self-conscious being — it is enough that it is living with a certain kind of autonomy.
2. The *known*, the object of knowing is the *object of a triadic sign*. However, the object can be as undifferentiated an entity as 'an environment' or 'a niche'. The object itself does not have to be 'directly' sensible of the subject.
3. Knowledge is stored in some *structure* as its *order*. The material of a structure is not essential, and it is not required to be linguistic or mental — DNA, cytoskeleton, neural network, or social practice may suit as well. However, this structure has to be accessible or interpretable to the knower — quite often the structure is part of the subject, but not necessarily (as is the case with writing). It is the *order* of a structure that represents the object — the order or information that can be copied and transformed into other structures.

Finally, as we noticed earlier, every signification process is not necessarily a knowledge process, and the above formulated characterizations do not yet differentiate adaptive from non-adaptive information. Mere representation of an object does not constitute the knowledge about the object. Therefore,

4. knowledge (a structural order) must have been formed in a process in which the *fit* between the structure and the object of knowledge has increased. This fit takes the form of *functional resemblance*, not 'structural isomorphy' or 'one to one correspondence' between interpretant and object. The final test of knowledgeness of a structural order is the successfulness of the actions it brings about. It is not enough to insist that know-

ledge is learned (either individually or evolutionarily), rather it is its effects in action that matter.

This extended definition is very general, but it is applicable to various kinds of knowing subjects. The traditional concept of knowledge remains as a special case;¹⁰ knowledge that is not in the familiar, propositional form of linguistic or mental representations can be called *structural knowledge*. It must be noticed that the concept of truth is not applicable as a normative criterion for structural knowledge. For example, the way in which genetic information coded in DNA represents (or 'corresponds' with) the world cannot be considered without the interpretation made by the zygote (and by its descendant cells). It is the adaptedness of the descendant organism that 'measures' the content of knowledge in its DNA. The application of the concept of truth would be totally absurd (without a pragmatist redefinition of truth).

The same can be said about most phenotypic stores of knowledge (at least those which are analogically coded). The concept of truth is not applicable until the store consists of linguistically structured concepts, i.e. propositional knowledge. Even though languages are considered as digital codes, also structural knowledge may be stored in linguistic structures. For example logical or stylistic structures in languages may quite well be capable of storing knowledge about, say, cultural sensitivities of people. The only criterion for structural knowledge is its applicability, i.e. its capability to successfully perform an action. Therefore, the real *object* of the knowledge (regardless of its possible propositional content) is the part of the world over which the knowledge gives *power*.

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⁹ The subjects of vertical semiosis can, of course, be subjects of horizontal semiosis too. For example, cells interpret their DNA in protein synthesis (vertical semiosis), but they also communicate with other cells, e.g. by hormonal signs (horizontal semiosis).