Cognitive Evolution

Contribution to the Handbook on Evolution

by

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"Nothing in Biology makes Sense
except in the Light of Evolution"

Of course: particularly in cognitive sciences.

Content

1. Introduction

One may ask what kind of rationale can justify a handbook on evolution in so many different areas. We might answer that there is a sort of unity to evolution, saying that the various evolutions have more in common than just the fact that something evolves. In some cases this is easy to show, in others not and in still others we believe that there is no commonalty at all. I think we should focus our attention on whether the various areas are inherently linked to each others and on why and how, rather than writing independent essays on the state of the art in the various areas. As to cognitive evolution, this means that we accept - tacitly or explicitly - the premise that cognitive evolution is the continuation of organic evolution by equal or (perhaps) other means. Cognitive capabilities contribute to survival as much as organic tools do. There seems to be no a priori reasoning why cognitive evolution should 'use' different strategies than organic evolution. when to embark upon cognition. This applies at least for the cognitive 'hardware', i.e. for the various sense organs. It seems, indeed, reasonable to believe that sense organs evolved according to (neo-)Darwinian principles to increase their sensitivity for physical input data.

But does it hold also for the 'software' concerned, i.e. for the mental interpretation of the sensorial input (i.e. for our perceptions) which we use to come to useful decisions? Does it hold also for the regularities we find in our perceptions which we condense to what we call the laws of nature? Does it hold also for the higher, scientific interpretation of what we experience and which we use to construct our scientific world picture?

How relevant is the fact that we can transfer knowledge not only genetically but also culturally? That is, do the evolution of science and culture the same principles as organic evolution? Or do we have to follow S.J. Gould (1979), F.v.Hayek (1983) and P. Medawar (1988) in saying that organic evolution is Darwinian whereas cultural evolution is Lamarckian?

What about epistemology in its quality as physical metatheory: can we follow D.T. Campbell (1974a) who speaks of a 'natural selection epistemology'? If so, what sort of metaphysical commitment such as realism do we have to make before we can allow nature to select the way we see it? And if selection really does came into play: to what extent does it act on the mental mechanisms that transfer the sensorial input into knowledge, or does it act primarily on what is brought about by these mechanisms, i.e. on the resultant theories? In other words: what is the relationship between the so-called 'literal' and 'analogical' version of evolutionary epistemology? The 'literal' version emphasizes that the cognitive mechanisms evolved biologically and thus effect what kind of innate knowledge can be acquired. This is described by M. Bradie (1986) in his 'evolution of cognitive mechanisms program' (EEM) and M. Ruse (1986) in the 'Darwinian approach to epistemology'. The 'analogical' version emphasizes the aspect that human knowledge (in analogy to organic evolution) is governed by natural selection processes. This is represented by D. Campbell's (1974a and 1974b) 'natural selection epistemology' as well as by M. Bradie's (1986) 'evolution of theories program' and the 'Spencerian approach' by M. Ruse (1986). We will return to this point when discussing more generally how action and perception may be linked to each other.

And what about the teleological question? According to general understanding epistemic evolution progresses towards a goal (truth). So does scientific evolution which is said to be teleological in character, in so far it will converge (though in sometimes rather roundabout ways) toward the hoped for end physicists call the „*theory of everything*" (J.D. Barrow 1990), In contrast organic evolution obviously has no specific focus towards which all species will converge, the „*pride of creation*“ so to say (D.T. Campbell, 1974a).

Another discrepancy, as already emphasized by Piaget (1974), is that we see organic evolution in terms of autonomous internal modifications (mutation, recombination etc.) to which the external world reacts by means of selection mechanisms, However, in cognitive evolution we speak in terms of an autonomously existing and changing world to which intelligent beings react by forming theories and learning. So, the attribution of actio and reactio is opposite in the theories we use to describe organic and cognitive evolution. Here is another difference: in the organic area we can modify our environment by means of inborn or technologically acquired tools (assimilation) with a view to modifying the selection pressure so as to cope more easily by our adaptive efforts (This is a rather successful tool in all instances where we have no time to wait for evolution to increase our adaptive competence). In the cognitive area the selection pressure is given by the laws of nature ("a theory is 'true' and by this successful if it reflects the laws of nature"). So far these laws are seen to be ontologically objective (and invariant in time), cognitive evolution, as opposed to organic evolution, has no chance to modify its selection pressure. If so, cognitive evolution would be the better playground for adaptionists because there are a clearly defined objects of adaptation, whereas organic evolution contributes considerably to constructing its own adaptive boundary conditions.

In addition to the mechanisms and the 'software' in the narrow sense that we use to improve our knowledge, we have to deal with the more general strategies applied. This is, first of all, induction (though the success of inductive reasoning is an entirely unsolved problem). Next to induction, rationality enjoys highest credibility under the various cognitive strategies. To improve and strengthen the methods of rational thinking is indeed seen to be of general utility, not only in science but also in the world of day-to-day living. From what we understand as the success of rationality it is often derived that it must be based on the constitution of the world we live in, and, consequently, that the world's order can be decoded only by means of rational methods. From this assumption, then, we conclude that even whena consciously applied rationality can be excluded (as in the workings of the subconscious or the behaviour of animals) the success of strategies or the applicability of organs is guaranteed only insofar they meet rational criteria, i.e. insofar as they are 'ratiomorph' (E. Brunswik, 1955). This means that strategies and construction principles (concerning both the physical and the cognitive context) have to consider all relevant facts in the same manner as an accordingly informed analyst would do.

The question here is: are there alternatives to rational thinking that are nevertheless useful in the human context?

We see that there are discrepancies between the various theorists advocating the discussion of cognitive evolution within the wider context of general evolution and those attributing a strategic autonomy to cognitive evolution. This would be of minor relevance insofar we can describe both evolutions by means of similar notions and categories such as natural selection..

But it becomes problematic if we would find out that notions such as the Darwinian/Lamarckian-dichotomy cannot be applied equally well in the cognitive area, or in the area of induction which obviously cannot be 'translated' into a sort of organic analogy. We cannot deal here with all the previous approaches science has brought about to solve one or the other of these problems. Those who are interested in this may find ample information in the Blackwell Companions to Philosophy, particularly in "A Companion to Epistemology" (J. Dancy, E. Sosa, Ed., 1992) and in "A Companion to the Philosophy of Mind" (S. Guttenplan, Ed., 1994). Rather, I will concentrate on approaches that, in my opinion, throw some light on the contradictions involved, hoping that this will provide us with new evidence for the concept of the ‘unity-of-evolution’.

2. The Equivalence Postulate

At the beginning of all efforts to see the development of cognition in biological terms, i.e. as cognitive evolution, was the idea that there is a certain equivalence between elements of the two evolutions. In particular some have postulated that adaptational processes in the organic area correspond to the acquisition of knowledge in the cognitive area (Equivalence postulate, see G.P. Wagner, 1984). This led to comparing the organic and cognitive devices concerned. Phylogenetically acquired cognitive devices, such as the interpretation of perceptions, have

been compared with organic instruments such as homoeostatic mechanisms, antlers or limbs. It was the idea of Lorenz (1971 p. 231_262) and Popper (1973 p. 164) to class theories and organic devices under the common aspect of survival tools and considered both to be theories in the broader sense (defined below). This suggests that we need to distinguish between two kinds of theories:

a) *Theories in the structural sense*. They are considered to be a picture, an image or a mapping of a given or created object. This understanding of a theory is mainly found in the natural sciences and in mathematics. Such theories are considered to be true insofar as they are isomorphic with the structures they describe. Structural theories require that the objects concerned have an independent if not ontological character.

b) T*heories in the functional sense*: Lorenz (ibid.) and Popper (1973 p. 164) suggested to pending the notion of theory to include all kinds of problem solving instruments. This concept of theory would include physical theories in the proper sense in so far as they help us to master technical problems and to control physical nature; the inborn categories of space and time we use to interpret perceptions and to coordinate mechanical activities; limbs as instruments for locomotion; biological species as an instrument to meet the particular requirements of a special biotope; and social communication and social entities as tools to meet the requirements of a wider social environment.

All these various kinds of theories we shall call theories in the broader sense, as opposed to rationally generated theories in the usual sense such as physical theories. The latter can be both structural theories (if they claim to depict structures of the world) and functional theories (if they can provide us with correct predictions).

The alleged equivalence between organic devices which have to meet functional requirements and cognitive tools which have to provide us with true statements on the world is here reduced to the equivalence between functional and structural theories.

Functional theories are better the more they meet the given requirements. Structural theories, however, are better the more isomorphic they are with the structures they have to depict. It is common understanding that this is equivalent in the sense that a structural theory which is isomorphic with the structures of reality (Popper (1982) speaks in terms of truth and verisimilitude) also has functional qualities. In other words, structurally true theories are considered to be functionally helpful theories. The opposite is not necessarily true. A theory that is seen to be structurally false may nevertheless provide us with useful forecasting power. (Example: Galileo many of the regularities of the paths of the planets. But lacking the concept of Newtonian gravitation, he came to a false conclusion in explaining the paths of the planets as circular inertial orbits around the Sun).

The alleged equivalence of structure and function or of truth and helpfulness is the main legitimization of all empirical science. Although we often start in many practical cases from functional experiences that we try to explain a posteriori by means of structural theories, the general strategy for mastering nature, particularly in the basic sciences, is to search for the structures of nature. This is considered as a heuristic imperative. Hence it follows that an independently existing nature as summed up in the notion of reality is the only possible source of competent criteria for evaluating any empirical theory.

Then, theories in the usual sense must be teleological in character. Their progress is said to be guided by the structure of reality or, more precisely, by boundary conditions that reflect these structures, rather than being the result of autonomous independent development. Scientific evolution, therefore, must converge - not necessarily monotonously but at least asymptotically - toward a final state that will constitute the definitive and correct description of nature.

Davies (1990b) sees this view as follows:

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Let me express this point in a somewhat novel way. Hawking (1979) has claimed that 'the end of theoretical physics may be in sight'. He refers to the promising progress made in unification, and the possibility that a 'theory of everything' might be around the corner. Although many physicists flatly reject this, it may nevertheless be correct. As Feynman (1965) has remarked, we can't go on making discoveries in physics at the present rate for ever. Either the subject will bog down in seemingly limitless complexity and/or difficulty, or it will be completed."

What has been said here can be summarised as follows: The alleged relationship between structure and function means not only (1) that a theory's structure determines its functional qualities, but also (2) that the structure of what we call nature will determine á la longue the theories we have to apply in order to cope functionally with this nature.

The first allegation says that the functional success of a theory may depend on its structure. But from its success we cannot conclude that a theory is true as long as the only criterion is nothing but its success - except we agree that ‘true’ and ‘successful’ are synonymous. (Similar reasoning applies to fitness which could be considered the organic analogue of truth: If fitness is defined by nothing but its contribution to survival it is synonymous with survival and cannot be an independent category, i.e. we are led to the well known tautology of the ‘survival of the fittest’).

The second allegation is based on the suggestion that a problem would determine the methods needed for its solution, i.e. that functional adaptation determines the structures and procedures by means of which adaptation will be achieved. This is obviously not true. Horses and snakes, for example, though they may have developed in exactly the same physical environment, have entirely different organs of locomotion which have no structural element in common. So, the hooves of horses can not be considered, as suggested by Lorenz (1966), to be a kind of image of the steppes on which they live. (see Diettrich, 1989, 1992)

3. Our inborn world view

To the cognitive tools (as comprised in what R. Riedl (1980) called the cognitive apparatus) belong what we usually view as metatheories, i.e. the categorical reference frame we use to describe the world. Metatheories are neither universal metalanguages by means of which we can portray all we like nor do they determine the theories brought into existence under their authority. They rather constitute important boundary conditions. A metatheory saying that the world is made of particles having independent identity and moving around in a 3-dimensional (3D) space cannot deal with subatomic processes. In the same sense cells can be seen as metatheories for metazoa. Cells, of course, do not determine a certain phenotype, but they constitute boundary conditions. For example, because cells do not know remote interaction, plants and animals must be physically compact entities as opposed to social organisms which are made of men who can interact verbally.

Before discussing how metatheories came into being and whether selection mechanisms are involved we have to have a more detailed look at what metatheories are. Describing something, whether by means of language, a theory or mathematical formulae, means a notional mapping within a notional reference frame, i.e. within a metalanguage, metaphysics, metamathematics, or, more generally within a metatheory. (The theories that themselves do the mapping within a metatheory are called object-theories). Such a reference frame is a prerequisite for any description, in the same way as spatial localisation requires a geometrical reference frame. However, it is not always necessary to be explicitly aware of the metatheory concerned. Particularly in ordinary languages all people make unconsciously, but more or less correct, use of the same (or nearly the same) metalanguage. Otherwise no meaningful communication would be possible. For a long time philosophers (particularly in analytical

philosophers) generally felt that the imperfection of our philosophical speaking is mainly due to the lack of an objective metalanguage, or at least to the fact that people would not use exactly the same metalanguage. Accordingly, striving for an objective metalanguage was seen to be the good approach to finishing epistemology. It was a bitter experience when Gödel (1931) showed that a definitive, objective metalanguage for mathematics in form of objective axioms is impossible and that similar conclusion would apply for any descriptional tool, including language in general. We will derive here from a constructivist evolutionary epistemology (CEE, O. Diettrich, 1991) a conclusion that physics also cannot be based on a definitive set of objective laws of nature (the axioms of physics, so to speak).Then we will be able to say: that neither is there an objective metalanguage from which we can derive all true statements, nor are there axioms from which we can derive everything in mathematics, nor are there objective laws of nature (and, therefore, no "theory of everything") from which we can derive everything what physically can happen in nature. Or, in other words: there is no definitive world view. Neither is there an absolute reference frame in space (as we know from Einstein), nor are there absolute notional reference frames whether in language, mathematics or physics.

3.1. Induction

The most enigmatic element of metaphysics is that unexperienced experiences could be derived and predicted from experienced experiences by means of induction. Thinking in terms of induction is the most elementary and the most frequently used strategy for organising our life. Whether in day-to-day life where we have to make our usual decisions on the basis of incomplete data or unconfirmed hypotheses, in science where we have to conceive theories on how to extrapolate empirical data, or in philosophy of science where we try to find a basis for teleology or determinism - inductive thinking dominates all we do, and it is the most successful of all the mental concepts people apply.

The obvious and uncontested success of induction is one of the greatest fascinosa philosophy of science was ever confronted with (Stegmüller, 1971). Despite all philosophical efforts, we are more or less still in the same position as the one described by David Hume 250 years ago: Universal laws can be justified only by induction which he took to be unjustifiable, although natural to us. A. F. Chalmers said (1982, p. 19)

Faced with the problem of induction and related problems, inductivists have run into one difficulty after another in their attempts to construe science as a set of statements that can be established as true or probably true in the light of given evidence. Each manoeuvre in their rearguard action has taken them further away from intuitive notions about that existing enterprise referred to as science. Their technical programme has led to interesting advances within probability theory, but it has not yielded new insights into the nature of science. Their programme has degenerated.

Nearly the only progress achieved up to now is in clarifying and specifying the problem itself. The key notion in this context is what Wigner (1960) called "The unreasonable effectiveness of mathematics in the natural sciences" meaning that it is difficult to understand why so much of the complexity of the world can be described by such relatively simple mathematical formulae. Davies (1990a) has a similar idea in mind when following an idea of Solomonoff (1964) he said:

All science is really an exercise in algorithmic compression. What one means by a

successful scientific theory is a procedure for compressing a lot of empirical information about the world into a relatively compact algorithm, having a substantially smaller information content. The familiar practice of employing Occam's razor to decide between competing theories is then seen as an example of choosing the most algorithmically compact encoding of the data. Using this language, we may ask: Why is the universe algorithmically compressible? and why are the relevant algorithms so simple for us to discover?

Another version of the same question is "how can we know anything without knowing everything?", and, more generally: "Why is the universe knowable?" (Davies 1990a).The most typical examples are the correct prediction by means of linear extrapolation. Here, again, the development of certain systems can be compressed into the most simple (i.e. linear) relationship.

However, Popper (1982, p. 4) goes further in criticizing the notion of induction: despite all practical success of inductive thinking, according to him natural science should dispense with induction completely, because it cannot be justified. His argument is that a general principle of induction can be neither analytic nor synthetic. Were it analytic it could not contribute to the growth of knowledge and therefore would not be inductive at all. Were it synthetic it would have to be justified by another inductive principle of a higher order which would lead to an endless regression.

3.2. Reality

The above and many other positions concerning induction have one thing in common: they arise from our intuitive conviction that there is some reality that exists independently of us which we have to recognise without having any a priori idea what it may look like. In other words: all these positions arise from the claim to organise our lives according to an independent reality that is to be described in terms of its structure. With Popper (1973), our way of coping with reality is comprised in the term "growth of knowledge" to which induction must contribute and which can be defined only in the context of some reality about which we may accumulate knowledge.

Davies takes a more explicit stand (1990a):

There exists a real external world which contains certain regularities. These regularities can be understood, at least in part, by a process of rational enquiry called scientific method. Science is not merely a game or charade. Its results capture, however imperfectly, some aspect of reality. Thus these regularities are *real* properties of the physical universe and not just human inventions or delusions. ... Unless one accepts that the regularities are in some sense objectively real, one might as well stop doing science."

The nearly generally agreed view that the problem of induction can and must be solved only within the framework of an ontological reality is the most influential metaphysical element in all sciences. Even more: induction would not be a problem at all if it were not expected to expand our knowledge about a real world. This argument, however, becomes problematic when carried out within the so called **e**volutionary **e**pistemology (EE), even though EE was developed with the particular view of acquiring a better understanding of human categories of perception and thinking, i.e. of our physical metatheory. The classical version (as I call it) of EE (Vollmer 1975) declares that these categories such as space, time, object, reality, causality etc. result from evolution in the same way as organic elements and features do. This, in

classical parlance, means that in the same way as organic evolution is guided by adaptive forces, cognitive evolution is the result of adaptation to the independent structures of an ontological reality. Campbell (1973) speaks in terms of a "natural-selection-epistemology". The general argument goes as follows: the theories we have designed to describe the structures of reality are surely incomplete or may have other strong deficiencies _ reality itself, however, has been developed as a category of human thinking just because of the ontological character of outside reality. The fact that we think and act in terms of reality is taken as a proof that a sort of reality must exist. What is done here is to explain the formation of the category of reality by means of reference to its own content, i.e. to the existence of an ontological reality. In addition to the fact that such reasoning would lead to circular inference is an even stronger objection: The existence of an ontological reality may, of course, have been a good reason for mental evolution to emulate it by creating a corresponding category of thinking. This argument, however, can not be reversed. That is, we cannot say that human mental phylogeny never would have come up with the category of reality if there were no such thing as an ontological reality, so long as other reasons can be found that are functionally conceivable and phylogenetically plausible even though they do not refer to an ontological reality. (see Section 4)

Most people, upon hearing that reality may not be really real would argue that ignoring the existence of tables, trees, traffic lights or what ever we find in our environment is unacceptable. Of course - but these are objects or facts which we can, at least in principle, alter or displace according to what we intend. Let us call this ‘actuality’ (Wirklichkeit). In contrast, we will speak of ‘reality’ (Realität) as something that can neither be ignored nor be modified by anything we do. According to classical thinking this notion applies in a strict sense only to the laws of nature. Indeed, we are fully subject to the laws of nature: it is not advisable to ignore them nor can we modify them. So, disputing the ontological character of reality is reduced here to saying that there can be no definitive or objective laws of nature. (It is evident that this view has no solipsistic consequences which people sometimes see when realism is disputed in general.) We will discuss this in detail in chapter 4. on the cognitive operator theory: what we call the laws (or the properties) of nature will depend on our cognitive apparatus in the same way as in physics the properties of objects depend on how we measure them.

3.3. The Conservation of Identity

Another apriori (also from classical physics) is that identity is conserved in time. That is we do not consider the thought that something canl loose its identity and then be ‘reborn’ later. We rather say that an object was invisible for a while, or that two equal (but not identical) objects have been involved .Identity cannot be interrupted without the object’s losing its character.

3.4. The 3D Structure of Visual Perception

To see the world in 3D allows us to distinguish between the (visible) reduction of size due to physical compression and that one due to enlarged distance. But we cannot say that our space for visual perception is 3-dimensional because the world itself is 3D-in character, or that apes that do not see the world in 3D were unable to jump from tree to tree, and, therefore, could not survive to become our ancestors as Konrad Lorenz (1983) said. It is easy to show that appropriate and successful survival strategies could well be based on 2D or 4Dl perception spaces, independent of how many degrees of freedom are actually available.

With 2D perception we would not know the phenomenon of perspective. Things are small or things are big, but they don not seem to be small because they are more distant and they do not seem to be big because they are nearer, because distance to the observer belongs to the third dimension which is excluded here. But objects, nevertheless, would shrink if we used our legs to move backwards and would enlarge if we went forward. So, with 2D perception we would develop a world view according to which, not only our hands and mechanical tools can modify objects but also our legs. With such a perception, an ape may well be able to jump from branch to branch. The only thing he has to learn is that he has to grasp the branch seen just when its size and position meet certain typical values. If the perceived size of a branch doubles after three steps, the ape must know that he will arrive at it after another three steps and then has to grasp it. If he has learnt to do so, an external observer would find no difference between the movement strategies of such an ape and those based on a 3D perception. (It is evident that physical theories based on the inborn world view that objects could be 'deformed' not only by means of our hands but also by means of our walking or jumping legs would have no similarities with the theories we are used to use).

We can explain this by another example: let us imagine locally fixed plants that have eyes, can see and may have acquired a 2D perception. They would tell you that they have smaller and bigger companions. For us this would be due to different distances, but not for these plants. As soon, however, as they learn to communicate and would tell each other what they see, they would find out that what is small to one observer, might well be large to another one. After some perplexity they may construct a theory of relativity of size, saying that size is nothing absolute but depends on the relative position of observers - difficult to understand for someone who is used to living in a 2D perceptional space. Exactly the same thing happened to physicists when empirical evidence forced them to construct the theory of special relativity saying that time intervals are not absolute but depend on the relative motion of the observer - difficult to understand for someone who is used to living in a Newtonian world. (By the way, this analogy can even be extended: the (relativistic) limit to speed in the 3D world ($v \leq c$) corresponds to the limit to length in the 2D world, because length can be defined only by means of an aperture $\alpha \leq 180°$).

The question whether modifications of visual perceptions should be interpreted geometrically or physically is well known from another case in physics: the orbits of planets can be considered as the effect of explicit gravitational forces (the physical solution) or as geodetic lines within a 4D space (the geometrical interpretation according to the theory of general relativity). Because these are merely different interpretation of the same observations we cannot decide between them on empirical grounds, nor was adaptation or selection relevanαt when the cognitive evolution of primates had to ‘decide’ whether to see the visual world in 2D or 3D. In other words: perceptional spaces and systems of categories are purely descriptional systems that may tell us something about how we see the world but nothing about the world itself. So they cannot be the outcome of adaptation to the world. *From this it follows that our epistemology cannot be a natural selection epistemology*. This applies the more as adaptation values cannot be attributed to single characters (E. Curio, 1973; W.J. Bock, 1980). Some obviously counterproductive characters can nevertheless survive, so long as other characters compensate for its weakness. What counts is the fitness of the organism as a whole. So, that we are surviving quite well with a 3D perception space cannot be taken as an argument that this is due to adaptation

4. The Cognitive Operator Theory

That our natural epistemology cannot be an natural selection epistemology in Campbell's

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sense does not dispense with the need for explaining why the evolution of our natural epistemology went just this way and not another one. In particular, it does not exclude the suggestive idea that organic and cognitive evolution must be linked to each other, or even more, that organic evolution has brought about cognitive evolution, i.e., that cognitive evolution may well be considered the continuation of organic evolution by other means. From this one may suggest that a good theory of evolution is required to describe both organic and cognitive evolution in a strictly coherent way.

To understand cognitive evolution from an organic point of view, we will start here from a constructivist extension (CEE, Diettrich, 1991) of classical evolutionary epistemology (EE). The particularity of the CEE is based on a methodological element used mainly in physics, the so-called operational definition of physical terms. This is not without delicacy. The usual dilemma regarding evolutionary and constructivist approaches to epistemology is that physicists in particular have difficulty in getting used with these ideas. The epistemological approach used here goes just the opposite way: It is physics which transfers one of its most important modern elements (i.e. operational definition) to cognitive considerations rather than constructivism imposing its ideas on physics.

What does a operational definition mean? As is well known, classical physics failed to accommodate the phenomena of quantum mechanics and special relativity primarily because it got involved with a non verifiable syntax brought about by the use of terms that had not been checked as to whether they could be defined by means of physical processes.

In our day to day life this epistemological refinement is not necessary. We have a clear understanding of what the length or the weight of a body means, and we do not need confirmation from a tape measure or a scale for carrying on with our lives. However, the situation is different with microscopic distances.. Here, first of all, we have to decide what kind of experimental facility we will use to define length or momentum. Physicists say that properties are defined as invariants of measurement devices. This even applies to the order in time of events which, under normal conditions, can easily be defined and detected. At very high speeds, however, the topology of events may depend on relative motions, as we know from the theory of relativity.

Since this kind of experience can be repeated again and again, it suggests a generalization that can be summarized as follows: properties of whatever kind and of whatever subject have no ontological quality. Instead they are defined by the fact that they are the invariants of certain measurement operators. This contrasts with classical thinking in which properties are used for the objective characterisation of objects. One of the most important properties we usually attribute to properties, namely, independent existence, is based simply on the assumption of their independent ontological quality. In everyday life this is incontestable. The length of a body and its colour exist independently of each other and can be measured separately. This does not necessarily apply in subatomic regions, as we know. The position and momentum of microscopic particles cannot be measured independently of one another. Physicists learned from this that theoretical terms have to be defined operationally, i.e., they have to describe nature by means of theories in which terms are accepted only if they can be defined by certain experimental facilities, rather than by means of theories in which categories and notions are defined by protophysical common sense.

The crucial step of CEE is to suggest that not only theoretical terms have to be defined operationally, but also observational terms as well as mathematical and logical terms.

Theoretical terms are defined as invariants of operations represented by physical measurement devices.

Observational terms, comprising both the visually perceived regularities (patterns) and those we condense into theories and into what we call laws of nature, are considered to be

invariants of phylogenetically evolved mental cognitive operators. These operators are physiologically implemented somewhere in our brain and can be considered a kind of cognitive measurement device: measurement objects are the sensorial inputs and measurement results are perceptions, i.e., views, and, within these views, certain regularities, structures or patterns, rather than numbers or pointer positions. Therefore, the entire system of laws of nature we have derived from these regularities cannot be objective entities but only mental constructs.

In this context the often-discussed dichotomy of observational and theoretical terms is reduced to a rather secondary difference: observational terms have developed phylogenetically in the unconscious parts of the human brain, whereas theoretical terms are the outcome of conscious and rational efforts. Nevertheless, observational terms remain privileged as the basic elements of any higher theories. We can modify theories according to observational data, but we cannot modify the genetically fixed mental operators and their invariants according to the requirements of special situations.

It is useful to realize that organising our perceiving and thinking in terms of invariants is not only a view suggested here by physics. As shown by J. Piaget (1967) it might well be an old inborn tendency in human cognition. According to him cognitive functions construct invariants in all areas where this is necessary for their operating. Even when this is not directly suggested by actual experiences, invariants are attributed to objects and the outside world rather than seen as the outcome of cognitive functions. When dealing with the physical theory of Hamilton-Jacobi (see below) we will see that this is not the only instance in which something invented by physicists acquires a deeper meaning when seen from inside of cognitive sciences.

5. The Operational Definition of Space, Time and Causality

5.1. Space

The most crucial consequence of what has been said above, is that space, time and causality, which according to Kant are the necessary categories on which all external appearance is based, are not the only possible (and therefore necessary) categories. They are rather the phylogenetically evolved features of human perception and interpretation, defined operationally as invariants of certain actions and transformations. Let us look at this in more detail.

Following Piaget (1974), *the spatial metric* of our perceptional space (and therefore the topology comprised) is operationally defined by means of motion. The identity of extended subjects, therefore, is defined as an invariant of locomotion (Üxküll, 1921: "A body is what moves together as a unit"). This definition is probably the main reason for the major difference between what we call space and what we call time. Time is said to flow in an irreversible way; no one can retrieve any part of the past. We cannot move back and forth between two points in time. But we can do so quite well between two points in space. If we say we travel from point A to point B and than back again to A, we mean that the A we started before arriving at B, and the A to which we arrived after leaving B, are not only equal but identical. To say this is, however, is possible only if we can distinguish between ‘equal’ and ‘identical’ and if what we call identical is not influenced by our travel. This means that identity is defined as the invariant of motion. And exactly this is the point. Only on grounds of such a definition can we call a change in spatial positions reversible, or more precisely: only on the basis of such a definition can we distinguish between the repeated return to the same A and travel along a sequence of equal As, i.e. between periodicity in time and space.

In a similar way, locomotion can change the visually perceived environment. We can

transform the perception we call ‘forest’ by walking into the perception we call ‘city’. But this is not what we are accustomed to saying. It is more common speak in terms of an environment which, apriori, is multidimensional in character, i.e., comprising at the same time several structures which differ, first of all, in what we call their spatial positions. What we achieve, then, by means of our legs, is not a modification of the environment. We just ‘go’ to places consisting of different structures and therefore experience different perceptions. What we call the multiplicity of the world, thus, is defined as invariant to changing our positions in that world. From the functional (and CEE) point of view, mentally generated spatial views belong to the most elementary theories we have at our disposal, by means of which we can forecast perceptions when walking - in the same way as the temporal structures stored in our memory inform us about what we can expect when repeating certain actions. So, both the formation of visual patterns and the formation of memory are first of all modi of extending life competence.

5.2. The arrow of time

Within the context of our day to day experiences we have a very clear understanding of what past and future is. Past is what embodies all the events we have experienced. Past is the source of all knowledge we have acquired. Future is the subject of our expectations. Future embodies the events which may happen and for which we have to await to see if they really will happen. How can we express this by means of physical theories? Or, more precisely and according to the operationalisation concept: are there devices or processes that can operationalise the terms ‘past’ and ‘future’, i.e. the arrow of time?

Many efforts have been made in this direction (H.D. Zeh, 1984). The result is short and disappointing: in all cases where it is said that the arrow of time has been operationalised it can be shown that the direction of time was already contained implicitly in the preconditions of the experiment. A typical example is the following: shaking a box with black and white balls placed in order according to their colour will always lead to disorder and never again to order. In physical terms: Entropy increases in time and never decrease. Entropy, therefore seems to operationalise the arrow of time. But in this instance, the result will depend on what we do first, separating the balls or shaking them. Shaking before separating leads to order. Shaking after separating leads to disorder. So we already have to know what the terms ‘before’ and ‘after’ mean before we can do the experiment which is to tell us what ‘before’ and ‘after’ will mean. Another example: a hot physical body left in a cooler environment always cools down. But this applies only if the collision processes between the atoms involved are endothermal, i.e. if the kinetic energy of the colliding partners are higher before the collision than after. However, if we have exothermal processes which are characterised by the fact that the kinetic energy of the particles involved is higher after the collision, then the body will heats up rather than cooling down. Here again we have to know what ‘before’ and ‘after’ mean in order to define the collision process which will define the result of the experiment which is to define the arrow of time.

These are particular examples. I. Prigogine (1979, p. 220) has shown in a more general way that irreversible processes in thermodynamics cannot help us to operationalise the arrow of time: the existence of the so called Ljapunow_function - which is closely related to macroscopic entropy - is a prerequisite for the distinction between past and future also in microscopic systems. Unfortunately, the Ljapunow_function is ambiguous with respect to the arrow of time. It can be constructed in a way such that equilibrium will be achieved in the future in accord with classical thermodynamics, but it can also be constructed so that the equilibrium will be ‘achieved’ in the past.

From all this one can make the hypothesis that in principle the arrow of time cannot be operationalised objectively, i.e. it cannot be derived from what we call nature. What ‘past’ and ‘future’ mean, then, can be described only by means of a sort of mental operationalisation. The following definition, for example, may be suitable: from two perceived events A and B, A is said to be before B if we can remember A when B happens but not B when A happens. Of course, past is what we can remember but we cannot remember future. This ‘mentalisation’ of past, present and future, I think, is very close to what Einstein (published 1972) may have had in mind when he wrote to his friend Bosso "that these categories are sheer illusions".

5.3. Causality

In order to constitute causality we must be able to identify patterns of events. If several events, say A, B, C, and D follow one another always at typical intervals independent of when the first one occurs (i.e., if the pattern is an invariant of translation in time), then we say that there must be a causal relationship between the events concerned. Otherwise the perceived regularity could not be explained. Causal relations, then, are defined as invariant patterns of time (H. Reichenbach, 1924). This, however, requires more than just having a topology of events as provided by our memory. We also must be able to distinguish between shorter and longer intervals of time, i.e. we need a time metric defined by a mental metric generator

implemented physiologically somewhere in our brain. For example, the fact that we say lightning is the cause of thunder but not the contrary, is based on the fact that the time between lightning and the next thunderclap is usually much shorter and varies less than the time between thunder and the following lightning strike. But the length of time intervals can be defined only by means of a time metric. If our time metric generator were such that would be accelerated after a flash of light and retarded after an acoustic event we might well come to the conclusion that thunder is the cause of lightning.. *The mental time metric-generator is therefore responsible for the causal order established and for the prognostic capability derived from it.*

The specificity of the metric generator has direct effects on the laws of conservation we record in physics (energy, momentum, etc.). Following Noether's theorem, these laws can be derived from the invariance properties of the equation of motion: invariance under a translation in time (i.e., physics is the same yesterday and today) implies the conservation of energy; invariance under translation in space (i.e., physics is the same in America and Europe) implies conservation of momentum; invariance under spatial rotations implies conservation of angular momentum. In other words: from the homogeneity of space follows the conservation of momentum and from the homogeneity of time follows the conservation of energy. What 'homogeneous' means, however, is exclusively a matter of the mental metric-generator concerned. This applies also to the other conservation laws which, therefore, are human specifics rather than objective properties of nature. As seen below, the conservation laws constitute what one can call the cognitive reference-frame we use to describe actions and what those actions will bring about. Other conservation laws based on other cognitive operators would effect a different cognitive phenotype, but this would not mean that the methods and life strategies based on other operators would be less consistent or efficient. What is excluded, however, is communication between representatives of different cognitive phenotypes such as (possibly) between terrestrial and extraterrestrial beings (see chapter 7).

6. Induction and the Compressibility of Observational and Theoretical Terms

Perceptions (and observations) are related to each other according to what we call the

regularities perceived. These regularities, as we have seen, are the outcome of special mental operators. A (scientific) theory on the relation between observations, therefore, can be "true" (i.e. it can extrapolate the data observed correctly) only if it would emulate the generating mechanisms. But how can we emulate these mechanisms if we do not have any access to the brain where they are implemented and if we have no means to analyse them otherwise? What we have is nothing but mathematical methods which - astonishing enough as Wigner said - would work very effectively in helping us to extrapolate observational data. Then, the conclusion is near at hand that there is a certain homology between the mechanisms generating mathematical, logical and other theoretical terms and those generating observational ones. This would explain, of course, why observational extrapolation (i.e. waiting for the observations expected or doing the experiments required) may lead to the same result as the mathematical extrapolation of observed data does. A helpful contribution to solving the problem of induction, therefore, are plausible hypotheses on a common metatheory of mathematics and observational terms.

The stated equivalence of observational and theoretical terms requires that we approach mathematics and logic under the same constructivist aspect as we do the empirical world. There is already a certain tradition of constructivist approaches (Lorenzen, 1975) having in mind mainly a better foundation of mathematics: only if we knew how things have4 developed can we understand why they are as they are. Unfortunately it is not enough to find a ‘generative mathematics’ which generates all the mathematical rules or regularities we know because there is no guarantee that it would also generate those we may yet find in the future. The only guarantee for generally succeeding is that we find a solution which emulates the actually implemented mental mechanisms. This generative mathematics, however, as well as Chomsky's generative grammar, is inaccessibly located in the subconscious parts of cognition. All we know and all we have access to are their results. From them, unfortunately and as a matter of principle, we can not conclude the generating mechanisms. This is why it is so difficult to concretize generative grammar producing more than just one or two grammatical regularities or rules.

To deal with the compressibility of mathematical terms means to pose the question: why can we describe the results of rather complex mathematical operations by relatively simple expressions? How can we extrapolate ordered sequences of mathematical operations by explicit formulae, i.e., why does the principle of mathematical induction work? That this is a serious problem is known - at least in principle. Mathematicians generally acknowledge that Peano by means of his five axioms has considerably contributed to understanding the world of natural numbers - particularly the fifth ("If the natural number 0 has some property P, and if further whenever n has P then so does n + 1, than all natural numbers have P") is the basis of mathematical induction, which is one of the most important procedures in practical algebra. However Hofstaedter (1979) has rightly remarked that this does not provide a criterion to distinguish true from false statements on natural numbers. He asked (ibid., p. 229):

How do we know that this mental model we have of some abstract entities called 'natural numbers' is actually a coherent construct? Perhaps our own thought processes, those informal processes which we have tried to capture in the formal rules of the system, are themselves inconsistent!"

Well, at least in the constructivist context, they are not inconsistent as this term is not explained. But the possibility remains that the formal rules we have established do not correctly or completely emulate the informal thought processes (i.e. what we called mental operators). The ongoing success of mathematical sciences, however, make it rather probable

that mathematics is a fairly good theory of what the mental operators can bring about. It may even be a correct or true theory if the mental operators in the course of cognitive evolution, contributed implicitly to their own conscious formalisation, i.e. to the development of mathematical and logical thinking. In other words: mathematics succeeds by means of compressing theoretical terms (e.g. by means of mathematical induction) because the mechanisms of generating theoretical terms and those compressing them are closely related to each other due to a special cognitive co-evolution having the effect that compressed and uncompressed terms behave alike and therefore are interchangeable.

The fact that large amounts of empirical data can be described by a relatively simple mathematical formula, by a simple view or regularity or by just a few words (i.e. by a theory in general), we explained by their compressibility. On the other hand we can consider these formula etc. to generate the data in question in the sense that we can derive the data from the generating theory. Within the framework of constructivism, however, there is nothing that is not generated, whether by a physical or biological process, by a theory in the proper sense or by a mental operator generating what we perceive as regularities or laws. Compressibility, therefore, is not a special feature of some data or entities we have to investigate or to wonder about. It is rather the central characteristic of constructivism. The generating mechanisms (and only they) can tell us how we have to extrapolate given data or what we can conclude from certain observations, i.e. how we can apply mathematical or empirical induction. Without generating mechanisms both extrapolation and induction are merely arbitrary - and therefore useless and meaningless.

The difficulty of classical approaches to the problem of induction follows from the idea that the operators generating the regularities of our perceptions are seen exclusively as non-mental external mechanisms. We say: regularities (such as symmetries) are in the outside nature and not in the way we see it. According to this it is generally understood that we have to extrapolate data from celestial mechanics according to the effect of gravitational forces as contained in Newton's laws. But we find it strange to understand why we usually succeed in extrapolating much sensory data perceived according to a regularity identified by means of nothing but the data given themselves - as if the regularity of the past and the future data were caused by the same reason. But exactly this is the case. There is of course a causal reason generating these regularities, but it is not an external reason as gravitation is said to be. It is rather the internal mental operators generating the regularities in question. This is the very legitimization of empirical induction. Because this applies for any kind of regularity, so also the laws of classical mechanics as described by Newton are nothing but emulation of mental operators by means of what we call explicit external forces. What still has to be explained, however, is how to deal with the regularities we find in areas such as elementary particle physics etc. which hardly can be expected to be 'inborn' as the regularities of classical mechanics. This will be done in the section 8.1 on physical extensions of cognitive operators.

7. Communication, meaning and the compressibility of semantic terms

If all structures we perceive are only human specific artefacts that can only be defined as invariants of cognitive operators, then this concept must apply also to the perception (or interpretation) of language structures, i.e. as a physical object cannot have objective properties that can be used for an objective description, neither can verbal texts have an objective interpretation. Than the question arises as to whether a text can carry an autonomous message, and if not, what the notion of communication means.

According to common understanding communication means that certain structures, for example texts, will be transferred from the sender to the recipient where they will actuate text

specific reactions. The text will enable the recipient to draw conclusions insofar as he has understood (i.e. analysed) what we call the meaning of the text. Meaning, then, is something encoded in the text. For the recipient, therefore, meaning is an externally defined structure. A similar view is held by Hofstadter (1979) who believes in the general possibility to decipher context free messages. For him (p. 165) "... meaning is part of an object (or a text) to the extent that it acts upon intelligence in a predictable way."

This implies conceding to ‘meaning’ the status of an objective property in the sense of realism. Further to this, within the framework of the CEE, the notion of analysing a structure to identify the structure's inherent meaning is not explicable. Structures can be generated but not analysed. What we usually call an analysis refers to other structures that are generated by the same operation and that we, just because of this, perceive as "similar".

Both theories and their meaning (in their quality as invariants of cognitive operators) are mental artefacts. Their effect is that they connect data or statements with each other - and here they have a monopoly: there is no other possibility to connect data and statements except within the framework of a theory or a known meaning. From one sole observation we cannot derive a second observation except by means of a theory that is able to do this. From the fact, for example, that one has seen up to now only white swans says nothing about the existence of black ones, unless there were a theory saying something on this matter. (Diettrich 1989, p. 78). Nor is it possible to derive from an isolated statement a second statement without having knowledge of the context of meaning. If we nevertheless try sometimes to derive statements from each other then this is only on the basis of tacit assumptions concerning the context..

Under these circumstances, to perceive a text or any other structure can only mean to reproduce it through the recipient's own generative means. If these means are insufficient, they have to be modified accordingly by the recipient himself. This is what we call learning, and the text that has effected this is called a piece of information. Information is something the recipient did not know before, i.e. what he or she could not reproduce by their own means. To understand a text shall mean that the recipient is not only able to reproduce the text but also to draw the same (or similar) conclusions from it or infer the same texts as the sender. But what does it mean to make inferences and especially inductive inferences within the context of constructivism? In common thinking all things that can be derived from one another by extrapolation or by inductive inference, just by this, represent certain relations. Under constructivist aspects, however, relations of any kind can be defined only through common generative mechanisms (operator, theory etc.).

We can now say: a recipient will understand a text in the sense intended by the sender if he or she not only reproduces the text but does so by the same (or similar) mechanisms as used by the sender. Only under these circumstances the recipient has, further to the text in question, also have all the other texts at his disposal to which the sender could refer, i.e. they can both draw the same 'conclusions'. Strictly speaking this does not require that the generating mechanisms are structurally equal as long as they produce the same. But because they do so, more or less, with all men it can be assumed that this is due to their phylogenetically acquired common metatheory. In this case they would not only be functional but also structural homologa.

Let us summarise: to say that the recipient has understood the meaning of a text means that the recipient has interpreted the text within the same theory that the sender has used to generate the text, or, in other words, that the recipient has decoded the text in the same way as it was encoded by the sender.

A prerequisite for communication is that those concerned have the same (or at least a similar) cognitive phenotype. Only then could they think in terms of the same categories and deal with the same things and phenomena, about which they can inform and talk to each other

by pointing to the object in question or by means of interpreters. In other words: the perceived worlds of those who want to communicate with each other must be largely isomorphic. This occurs when Chinese and European speak with each other - however different their languages are in detail. If this condition is not met no communication is possible. If one of them deals with objects having an identity defined as invariant of motion within a (3+1)dimensional space time continuum (as we do), but the other one describes objects as being the eigenvector of certain operators in Hilbert-space (as may happen with certain extraterrestrials), i.e., if the partners in communication use different defining operators, nothing could be compared. Here, the perceived worlds are not only furnished with different objects but also are syntactically structured in different ways.

Some years ago, on a NASA rocket launched into space was mounted a copper plate engraved with some elementary information about humans and the terrestrial environment. This endeavour was based on the assumption that the same laws of physics would apply everywhere in the universe and that extraterrestrials, however else they might be structured, had to adapt to these laws and, therefore must developed equivalent cognitive structures in the course of their evolution. But since the laws of nature, as we have seen, characterise our cognitive and empirical phenotype rather than the world we live in, humans will identify the same laws of nature where ever they are in the universe. From the human point of view the laws of nature are indeed universal because humans, so to speak, carry their own laws with them where ever they go. The same would apply for extraterrestrials. They as well would identify laws of nature which, from their point of view, would be as universal as ours but which would not necessarily be the same. Even when visiting the earth, there would be no reason for them to modify their world view and the laws included in it towards our laws of nature. By this reasoning, the prerequisite for the success of the NASA experiment is not met, because extraterrestrials, if any, cannot adapt themselves to laws which are not their own. This does not mean that we could not come to a kind of working arrangements with extraterrestrians if we met them. After a period of cohabitation we might learn how they behave in given situations. This might lead to a modus vivendi. But we cannot understand them, i.e. we cannot extrapolate their behaviour to new and unknown situations. Understanding is possible only on the ground of similarities, but not necessarily cognitive similarities. If such beings were physically closed and of more or less fragile structure and not fixed in the ground like plants but rather could walk or fly around, they would have to avoid collisions with other objects like we have. Then we could understand their habits of moving at least to a certain extent.

The question of the compressibility of the world (i.e. why observational data can be successfully extrapolated and, therefore, why induction works) can be transferred into the linguistic area (Diettrich 1997). We can speak of the compressibility of language and we can ask why we can extrapolate texts semantically, i.e. why we can draw correct conclusions from a text. The problem of induction, then (how can we successfully generalise physical data transmitted from nature?), corresponds to the problem of communication (how can we successfully generalise verbal data transmitted from other persons?).

We see here the parallel between sensory and linguistic perception. Both result from mental operators acting upon sensory or linguistic stimuli, respectively. The invariants of both operators present themselves as structures. In sensory perception we perceive this structure as regularities that allow us to complete observations, or, as we would say in most instances, to extrapolate perceived data. In linguistic perception, we perceive the structure produced as meaning which allows us to draw the "correct" conclusion from the text given or, as one could say, to extrapolate the text semantically. Regularities and meaning or extrapolation and logical inference, respectively, are analogues categories in the sensory and

linguistic area.

8. Extensions

8.1 Physical Extensions of Perceptions and the Notion of Reality

Typical of most empirical sciences is the use of instruments and measurement devices (measurement operators) by means of which we extend the range of natural perception in ways similar to those we use to extend our inborn physical capabilities by means of tools and engines. Here we have to distinguish between two important types of extensions (Diettrich, 1994a).

We will speak of **quantitative extensions** if the inborn perception operators and the measurement operators commute in the sense of operator algebra. Here both operators will have a spectrum of invariants (i.e. eigenvectors) that can represent each other. This means that the results of the measurement operations can be presented in terms of invariants of the inborn cognitive operators, i.e., in terms of our classical world view.

We will speak of **qualitative extensions** if perception operators and measurement operators do not commute. Here, the results cannot be presented in a classical manner and require new, non-classical theories. Because the set of possible measurement devices is, in principle, unlimited, it can never be excluded that qualitative extensions of previously established operators will bring about modifications of the previously established world view and of the theories associated with it. So there will never be a definitive world view and there will never be a definitive 'theory of everything'. No objective laws of nature will ever be formulated. Those laws that we have, we have 'constructed' in a human-specific way in the course of human evolution; they will never converge towards a definitive set of laws except within the context of a limited set of operators, i.e., if we desist from further experimental research exceeding these limitations. What we actually do when we do science is construct a world that we believe we analyse by doing science. In other words: ‘analytical’ in the sense of deepening our knowledge is characteristic of science only within quantitative extensions.

The notion of a theory of everything is equivalent to the notion of reality. Reality, to our understanding, is independent of what ever we do or can do. So it must be characterized by objective laws of nature. We have seen that there are no objective laws of nature. But further to this, the notion of reality cannot even be defined operationally (and this is what we require of all meaningful scientific notions). To require of reality structures that are independent of all human action, i.e., structures that are invariant under all possible operators, would deprive reality of just the specificity necessary for being a non-trivial notation. The operator that is to define reality must be resistant against anything humans can do, i.e. it must commute with all other operators. Unfortunately, only the trivial unity operator meets this requirement. A nontrivial reality can thus result only by being invariant under particular operations, such as all the operations applied up to now (rather than all possible operations). In this situation, reality would reflect all the perceptions and experiences mankind has ever had and made. This is exactly what we have in mind when we speak in ontological terms about a reality that -- according to our current knowledge -- has this or that structure. Reality I this sense represents the sum total of our actual knowledge. Therefore let us call it actual reality. That reality can be defined only as actual reality, i.e., with reference to what we experienced in the past does not mean that there is a well defined remainder that we will come to know some time in the future. What we will experience in the future that we can use to bring reality up to date depends on what qualitative extensions we may bring about - and this is an entirely open set. There is not even a guarantee that our knowledge-based competence will increase on and

on. If we are forced to emigrate into an new, unknown biotope it may well happen that our acquired competence is useless and that new tools und means have to be developed.

If we base empirical theories on observations, as we actually do, and if observations are theories as well, then the evolution of science is an entirely internal matter between theories. Whatever we call the structures of reality, it must be comprised in the more elementary theories upon which we base higher theories. Reality, so to say, is the outcome of its own history. This view will allow us to see the realist's main argument in another light: the basic experience of all humans is that our perception contains regularities that we cannot influence. So, they must be objective, the realist infers, and hence it is legitimate to try to condense them into the laws of an objective world. Here, we concede that we have indeed no means of influencing the regularities perceived nor can we alter what we call the (classical) laws of nature - but only so far as the present is concerned. In the past, as we have seen, we intervened well through the phylogenetic decision on the development of the mental operators and by this on the regularities we perceive. The biological development of these operators can indeed be considered finished. What is not finished, however, is the development of possible physical extensions in the form of novel experimental facilities with novel invariants forming novel laws. So, law-making is not generally completed. It rather shifted from the genetic to the cultural level.

Sometimes it is argued that the absence of objective laws of nature would open the door for sheer arbitrariness. This is not true. That a different time metric generator in our brain may replace the 10 variables for which we identified conservation laws (energy, momentum, angular momentum, etc.) with another set of conservation variables does not mean that we would have fewer problems (such as with energy provision). We would just have different ones. The laws we actually find and the categories we actually apply constitute, so to speak, the categorical reference frame we use to describe and to master our real-live problems. The fact that the evolution of our cognitive phenotype might well have brought about another cognitive phenotype with another cognitive reference frame (i.e. the fact that our reference frame and the laws of nature concerned are not objective) does not allow the conclusion that cognitive reference frames are per se irrelevant and therefore could be ignored. Similar reasoning applies for our organic phenotype. That we have just two legs rather than one or three as well is not due to an objective law of nature. It rather is a specificum of human evolution. But this does not mean that we can ignore the number of our legs when walking.

From the functional point of view realism implies the idea that theories and the instances of their evaluation can strictly be separated from each other so that independent evaluation criteria can be found. This view is also the basis for the logicians' notion of truth. In the same way as proximity to reality is seen as the criterion for the success of theories in natural sciences, truth is seen as the criterion for the success of linguistic behaviour in its contribution to the overall behaviour. Accordingly the aim of natural sciences is seen to be to identify the (independent) structures of reality, and the aim of semantics, to identify universal conditions of truth. Yet this concept cannot be realised. We cannot even identify what we called current reality. The genetically and historically acquired knowledge which constitutes current reality, has no doubt a crucial role in the evaluation of theories - but not an absolute role, because it may well happen that a theory may modify the existing views and thus also the authorities of its own evaluation. In other words: the genetic, cognitive and historical burden constitute severe constraints, particularly when implemented in phylogenetically older parts of our cognitive apparatus.. However, the more recently established constraints can sometimes be ignored, at least to a certain degree. A typical example is the revision of previous interpretations of experimental facts and data in the light of new experiences and insights. So, even what we called the current reality fails to meet the minimum demand of common language

practice on reality i.e. to have a general and independent monopoly in all matters of evaluation in scientific or daily life.

From this it becomes evident that what we call reality does not just mean adaptation to an independently extant or ontological reality. Under these circumstances we may well ask why then did cognitive evolution bring about the category of reality? A possible answer to this question is that we have to immunize our perceptions against doubts and distrust, particularly in situations where quick reactions are required. This is exactly what the notion of reality does. Within our day-to-day realism we consider our perceptions as representations of what is real rather than as the outcome of deliberate cognitive interpretation. In this way, time consuming (and therefore possibly dangerous) considerations as to whether these interpretations could be improved on do not arise. Careful reflections on how to interpret the results of physical measurements are no doubt useful. But in view of a freely walking lion to fall into rumination on to what extent our conclusions from the reality position are relevant - this might be risky. So, reality in its quality as the sum total of all we derived from past experiences has to be taken seriously and objectively, and to do so whenever it is required is a very meaningful outcome of cognitive evolution. Thinking in terms of reality can be regarded as a kind of "cognitive burden" incorporated during the course of cognitive evolution. That is,.: in whatever direction our cognitive evolution may proceed, reality remains an irreversible category - similar to the developmental constraints in organic evolution called "genetic burden".

Empirical evidence may suggest to change a theory and, sometimes, even the metatheory concerned. But this is not an exclusive effect of empirical findings. Sometimes a metatheoretical change can be caused by purely theoretical consideration. The evolution of theories and knowledge is generally not predictable because new results do not determine their theoretical interpretation, nor do open theoretical questions determine the experimental measures to answer them. New developmental lines have been created very often in the history of physical theories. Fresnel's interpretation of light refraction phenomena by means of a wave theory (1816) led to the idea of the ether and to the Michelson-Morley experiment, from there to the theory of general relativity, to the mass-energy equivalence, and e eventually directly to modern elementary particle physics and nuclear energy. Fresnel's decision, however, was not a logical ‘must’. Quantum mechanics has shown that neither the corpuscular nor the wave aspect of light have an ontological quality. Rather,they are purely theoretical concepts. Refraction phenomena do not require a wave theory. They can be derived directly from the quantum mechanical uncertainty principle: an atom beam of given momentum passing through a slit diaphragm does not follow the geometrical path because this would mean that both momentum and future location are precisely defined - contradicting the uncertainty principle. Instead, the beam is refracted to an extend exactly predictable by both wave theory and quantum mechanics. This idea could have been derived in principle from the work of W. R. Hamilton (1805-65) who embedded classical mechanics formally into a kind of wave mechanics. Nobody can say where we would be today if Fresnel and his time had not embarked on wave theory. Perhaps we would have neither particle physics nor nuclear energy.

8.2 Algorithmic extensions of mathematical thinking

As already mentioned, CEE requires that not only the regularities we find in sensory perceptions have to be seen as invariants of certain mental operators, but also the regularities we find in logical and mathematical thinking. Indeed, the elementary logical structures and procedures that we find and apply in language are phylogenetically based human

specifications, just like the perceptional structures upon which we will apply them to generate higher theories. In particular, the laws of logic cannot be explained as universalia (in the sense of Leibniz) that on grounds of their truthfulness hold in "any possible world". This view is implicitly held, for example, by Vittorio Hösle (1988) when he writes "the statement S 'there is no synthetic a priori' is obviously itself an a priori statement. So S contradicts itself and its negation, therefore, must be true".

Of course, categories exist that for phylogenetic reasons, are used by all humens. Logic as a scientific discipline deals with the structures that can be constructed on this phylogenetically established basis which we later on furnished with empirical and other theories. Lorenz (1941) speaks of our 'forms of intuition' (Anschaungsformen) which cannot be derived from any individual experience and, therefore, are *ontogenetic a prioris*, but which, however, are the outcome of evolution and so are *phylogenetic a posterioris*. What we call a synthetic a priori reflects nothing but the inborn human specific ways of thinking which outside this framework cannot even be articulated. What is more, no statement at all can be articulated beforehand and outside the framework of human categories. So it is impossible to find statements that can be accepted by any sufficiently complex intelligence, irrespective of its phylogenetic background and which, therefore, can be called universal. Even the question of whether a certain statement expressed by an intelligence A would mean the same as what another intelligence B has formulated, can be answered only if the categories of thinking of A and B can mapped on each other, which is possible only on the ground of a transformation that necessarily is human specific as well. In other words: the notion of universal synthetic a prioris cannot be logically explicated. Statements dealing with the existence of universal synthetic a prioris, as advocated by Hösle, are neither false nor true. They are empty. This is in accordance with the views of Kant, insofar as there are forms of intuition prior to any experience - but only prior to any individual experience, not prior to any phylogenetic experience. The phylogenetically accumulated experience, as represented in our picture of the world, and the categories of our thinking and perceiving are the result of an permanent co-evolution.between inner images and outer world. The idea that what is a priori for the individual is a posteriori for the species was articulated already before Lorenz (1941) by Spencer (1872) and Haeckel (1902). A summary is given by Oeser (1984).

If the cognitive operators generating our perception are phylogenetically related to those generating mathematical thinking, then their respective results, i.e. perceived and mathematical structures, must show certain similarities. This would explain why we can simulate the extrapolation of perceptions (i.e. make predictions) by means of mathematical extrapolations and why the mathematics we use is so well suitable for the description of what we call nature. In this context Davies (1990a) speaks of the 'algorithmical compressibility of the world' and

Wigner (1960) of the 'the unreasonable effectiveness of mathematics in the natural sciences'. From the classical point of view (i.e. within the theory of reality), however, the algorithmic compressibility of the world cannot be explained, and neither, on the same basis, can the success of induction.

If there is really a relationship between mathematics and perception as postulated here, then the phenomenon of qualitative extensions must occur also in mathematics (Diettrich 1994b). This sounds strange, but there is some plausibility to this idea. Similar to the operators generating sensual perception, which can be extended by physical facilities, the mental operators generating our elementary mathematical conceptions can also be extended via higher and more complex mathematical calculi. This is what mathematics does as science. Insofar as higher mathematics is based on appropriate axioms, i.e. (in CEE parlance) on axioms that emulate correctly the cognitive operators, there is no reason, from the classical point of view to believe that this will lead to "non-classical" statements, i.e. to statements that cannot

be formulated within the syntax constituted by the axioms concerned. This view substantiated the confidence in Hilbert's program of the complete axiomatisation of mathematics - or, in the terms used here, the confidence that mathematics can extend itself only quantitatively.

From Gödel (summarized by Nagel, 1958), we know that there are mathematical procedures which, though entirely constructed by means of well proven classical methods, lead to statements representing a truthfulness which can no longer be derived from the axioms concerned. Mathematics has turned out to be as incomplete as classical physics. In either case, nothing but the application of well-tested, sound methods and procedures can lead to results that cannot be extracted from the foundations of these methods and procedures. We must therefore conclude that we cannot be sure that there will be no surprises of a similar kind in the future. Indeed: just as experimental operators, though constructed entirely according to the rules of classical physics, may lead to results which cannot be described in classical terms, there are also mathematical calculi which, as shown by Gödel, although based entirely on well tested axioms, can lead to statements which cannot be proven within the context of these axioms - and this can happen again and again. So we have qualitative extensions in physics as well as in mathematics and we can make the following definitions accordingly:

We will speak of **quantitative extensions** if the truth value of the terms achieved can be derived from the axioms used.

We will speak of **qualitative extensions** if the truth value of the terms achieved cannot be derived from the axioms concerned though the calculi used are completely based on these axioms. When this occurs, the axioms themselves have to be extended in order to make the truth value in question derivable.

Qualitative extensions, be it in physics or mathematics, are purely emergent phenomena that cannot be predicted because, by definition, they cannot be derived from previous knowledge. The blueprints of quantum mechanical devices are entirely classical in character and nothing provoked the idea that the results they may bring about could no longer be interpreted within classical theories. The same applies to mathematics. There is no general criterion telling us if a given calculus will exceed its own axiomatic basis.

With this, the existence of non-classical theories in physics and the incompleteness theorem of Gödel are homologous cognitive phenomena. Neither is there a definitive set of physical theories (i.e. a theory of everything) explaining and describing all (also future) physical problems nor is there a definitive set of mathematical axioms determining the truth value of all possible mathematical statements.

As to qualitative extensions, the only difference between the physical and the mathematical situation is that we already have in physics two non-classical theories (quantum mechanics and special relativity) and that we can say precisely under what conditions we have to apply them, namely (simply spoken) in subatomic areas and at very high speeds. In mathematics we only know from Gödel's theory that there must be non-classical phenomena, but we do not know what they are and, more specifically, we cannot say which operations would bring us out of the classical domain. Is it the notion of cardinal or ordinal numbers, or the notion of set or of infinity, or is it the combined application of these notions that constitute the cause of non-classical mathematical phenomena? Will logic turn out to be as incomplete as physics or mathematics? And what will happen if we deal with more and more powerful computers? Up to now we do not know. But when we do, we will have modern, non-classical mathematics as well as physics.

The astonishment of mathematicians with respect to Gödel's proof continues unbroken. Literature is full of responses to Gödel. Among others the explanation was proposed that the brain's action cannot be entirely algorithmic (Lucas 1961, Penrose 1989). Besides the fact that it is not quite clear what in a neural network such as the brain could be nonalgorithmic, this

kind of reasoning is not necessary at all. What follows from Gödel's proof is only that what certain mathematical calculi can bring about is not necessarily the same as what a combination of them could generate. Similar applies to physics: apparatus, though constructed entirely according to the laws of classical physics, would not necessarily reproduce the laws of classical physics as seen in quantum mechanics (see scattering experiments with atomic rays). But no physicist would draw from this the conclusion that something in our natural sciences could not be natural.

In contrast to physicists who suggested as an explanation for their respective experiences that they had happened upon domains of nature where other and unpredictable laws rule, mathematicians hesitated to admit the idea that mathematical research is empirical in the sense that it can lead to really new discoveries which could in no way have been expected, even not a posteriori. If mathematics had its own specificity as included in the notion of Plato's reality, then, according to general mathematical understanding, this must be something that is included in the very rudiments of mathematics and therefore determines all possible consequences. In other words: if there is such a thing as Plato's reality it must reveal itself by the fact that a consistent mathematics can be based only on particular, well defined axioms (the analogy to the laws of physical reality, so to speak). Once these axioms have been found - as per Hilbert's conviction - they would settle once and for ever the "phenotype" of all future mathematics. Mathematics, then, would be nothing but a kind of craft filling up the possibilities opened by the axioms identified - similar to physics which, according to prevailing understanding could do nothing but look for the applications of the "theory of everything" once it has been found.

In the beginning it was hoped, that extending or modifying the axioms in view of the unprovable statements concerned could solve the problem. Unfortunately the new axioms would be in no better situation, because for any set of axioms unprovable statements may be found. This applies also to physics. Of course, we can modify theories according to 'unprovable' phenomena, i.e. new phenomena that cannot be formulated within the existing theories or metatheories respectively, and physicists did so when establishing quantum mechanics - but this provides no guarantee that similar things will not happen again and again. So, neither in physics nor in mathematics can a 'tool for everything' be found by means of which all relevant problems, present and future, can be solved in a purely technical or formalistic manner.

The relationship between physics and mathematics as suggested by CEE constitutes a certain heuristic balance. Experimental physics is no longer privileged in providing information from the outside world, while mathematics sets it into theories. Instead, hopes are reasonable that a possibly successful study of non-classical mathematical phenomena may be a key to better understanding non-classical phenomena in physics also - and vice versa. In a way, physics and mathematics can see each other as very general theories. So, mathematics could outgrow its role as an auxiliary science, which it has hold from the outset of empirical science, and come into the role of an heuristic partner of equal rights. Strictly speaking, this has already happened. Of course, that we consider the world to be algorithmically compressible reflects nothing but the suitability of mathematics for prognostic purposes in physics. This is what physicists call "the unreasonable effectiveness of mathematics in the natural sciences" which, in the light of CEE, might well be reasonable.

But what, then, are the specifica which mathematics and the world of our perceptions have in common so that the two areas can consider each other as their successful theories? This is difficult to say, because we have to abstract just from these specifics, which is possible only if they themselves do not belong to the most primitive elements of our thinking. The following might be a clue: the fact that we use the same kind to separate ourselves from the outside

world as we use to devide the outside world itself into single subjects, to each of which we attribute an independent identity, belongs to the very beginnings of our inborn ways of thinking.. This approach is not compulsory. Quantum mechanics shows how the entire (physical) universe can be seen as a unity that can be described by a single wave function. Each division of the universe into subsystems is a matter of the categories applied and therefore is arbitrary because phylogenetically acquired categories are not determined either. Our inborn category of identity allows us to separate systems into discernible entities. It is therefore constitutive for the notion of plural (and, therefore, for the notion of set) as well as for the notion of cardinal numbers.

A second clue concerns the relationship between the metrics of space and numbers. According to what Piaget (1970, p. 58) found with children, it is not the category of space which allows us to define motion as mapping a line in space to the scale of time. It is rather motion which generates the category of spatial structure. The most primitive intuition, as Piaget called it, is not space but motion. Just as it is impossible to come from one number to another without a counting (or equivalent) operator, we cannot distinguish points in space except by attributing them to a path of motion. Counting and moving are analogue terms within the genesis of homologue algebraic and geometrical structures. This homology allows us to extrapolate the observations of motional phenomena in an empirically verifiable manner. The continuity of any physical motion for example is a cognitive phenomenon, i.e., it is part of our metaphysics, and is not the consequence of an independent law of nature. Formulating discontinuous motions would require a spatial metric which, on the other hand, is only defined by means of the category of motion itself. Discontinuous motions, therefore, can not be realised within the human cognitive apparatus, i.e. within our metaphysics. By this, the degrees of freedom of actual motions are drastically reduced. The same applies to the compactness of numbers we use to establish metric spaces and (regular) analytical functions in metric spaces. Discontinuity of a set of numbers is defined only within the context of a previously defined metric. So, numbers generated by a metric defining (counting) operator are per se compact. Analytical functions in metric spaces are, therefore, born candidates to describe the phenomena of mechanics. This altogether strengthens the assumption that what Davies called the algorithmic compressibility of the world is essentially based on functional homologies between the mental roots of perceptual and mathematical procedures.

The close relationship between spatial perception and mathematics can be seen also from another example: spatial coding of mathematical notions also from areas outside geometry is probably the very beginning of mathematical heuristics. This includes the visualization of sets as a closed figure with points inside representing the set‘s elements, as well as seeing ordered sets as spatial chains. Similar applies to the basic notions of topology such as ‘exterior‘, ‘boundary‘ ‘interior‘, ‘isolated points’ etc. Even the notion of cardinality of sets comprises a certain geometrical coding. The cardinality of sets cannot be defined operationally because the process of counting or mapping in pairs requires that the elements concerned differ at least in one property defining their identity (for example in their position with respect to the counting device). You cannot ‘pick out’ an element which has not a well defined geometrical position. Similar reasoning applies to the notion of plurality. That something exists in several but equal copies is plausible only if these copies differ in their spatial position. But we cannot replace position as a identity constituting element by, say, colour: we cannot say that several objects have all properties in common - including position - but not colour.

9. Action, Perception, and the Role of ‘Cyclic Variables’ in Cognitive Evolution

The task of perception is to allow the formation of theories by means of which we can predict

the effects of action. Because the effects of action can be presented only in terms of perceptions we can say: by means of perceptions we duscover how perceptions can change under the influence of action. In other words, actions are operators which act upon perceptions.

Within classical realism we say that the effects of our acting is determined by the laws of nature. The effects of our acting, we say, are determined by the laws of nature, and by means of our (natural and experimental) perceiving we acquire knowledge about just these laws. Thus, scientific decoding of nature is seen as the crucial prerequisite for mastering nature. Only through knowledge of its laws can we master nature. This is the legitimization for all natural sciences insofar they aim at the exploration of natural laws.

Searching for the laws of nature was useful when it was done for the purpose of mastering nature. Because there are, however, no objective laws (as we have seen), this way despite all its success is not heuristically legitimate. So there must be yet another link between perception and action that does not depend on the mediation of objective laws. If, nevertheless, we continue speaking about the laws of nature, we can expect that those laws will help us predict perceptions and the perceived effects of action but not that they will provide us with objective statements about the world.

According to classical understanding, action and perception are two completely different categories: action refers to the individual's input to the world, and perception refers to the world's input to the individual. With CEE, however, both refer to the same mechanism with the consequence that there is no essential difference between them. This sounds strange but is easy to illustrate. Visualize a hammer. It is an instrument designed primarily to alter certain objects. But a hammer, in its quality as an operator, also has invariants: objects and properties that would resist the hammer's strokes of a given strength. The hammer, then, can be used to measure mechanical properties such as the strength of materials. So, both perceiving and acting mean applying the same operator. The only difference is that, in the case of perceiving, we seek the invariants of the operator in question, i.e., we look for what remains unchanged under the application of the operators, whereas in acting we seek what changes under the operator's influence. Our inborn world view (i.e., the inborn interpretation of the sensorial input), therefore, depends on the phylogenetic 'decision' about which operators we use to construct the cognitive reference frame and which operators we use to modify what is described within the reference frame. (We already mentioned one of these phylogenetic decisions: using locomotion to give our perceptual space a third dimension rather than using it to modify the size of structures in a 2D world.) The decision made about our actual cognitive reference frame, however, was not an evolutionary accident. It rather was made according to a relatively simple scheme as we will see.

The result of performing a physical measurement (which is an action, of course) is, in physical parlance, the invariant of the measuring process. In other words, we use the invariants of a process to describe the effect of just that process, i.e., we describe the co-variants of an operator by means of its invariants. This can be generalized into the cognitive area. The actions by means of which we explore the world can be considered measurements (i.e., perceptions in the broadest sense). The results of measurements (or, as one could say, the results of our experiences) then are views of the world and theories representing what we call the unchangeable and, therefore, the objective world (i.e., what is invariant under all our doing and acting). If we instead look the covariants of our action, i.e. what changes under the influence of our actions, we have to refer to what we said about the relationship between the co-variants and invariants of measuring processes: the effect of action can be described only in terms of the invariants of action, i.e., in the terms of our world view. *This is exactly the direct relationship between perception and action we looked for and which does not rely on the*

concept of a world with objective laws.

If this is true, then the elementary categories of our perception must be the invariants of our most elementary action operators. But what are the most elementary action operators? They are not, as one might think, our hands and the tools guided by hands. They are, rather, our legs. By means of a few appropriate steps, we can change the environment of the room we are in into the environment of a blooming garden. Of course, we could achieve the same also by using our hands if we used them do the necessary reconstruction work. But this is troublesome and time consuming. So, one of the most important specifically human-operators is locomotion. Our world view, as a result, must be based on the invariants of this operator - and this is indeed true. The most elementary descriptive category of our world view is the identity of extended objects and spatial structures defined as an invariant of locomotion. This provokes the assumption that, from a phylogenetic point of view, the categories of description can be understood only through their capability to cope with the covariants of certain operators. From this it follows that the cognitive phenotype was fashioned by evolution not in order to explore the world but, instead, to extend the action possibilities of the organic phenotype.

Spatiality and the spatial metric, as we have seen, are categories that are necessarily defined by the process of motion. On the other hand, motion cannot be explained without the notion of space in which motion takes place. From this it follows that motion itself must have brought about the mental category of spatial structures necessary to deal with motion. This is exactly what we maintain: what an operator is doing can be explained only in terms of its invariants.

We encountered a similar problem when we dealt with the operational definition of the arrow of time. An operational definition was impossible, because the notion of operators themselves would require a prior definition of the arrow of time. We therefore proposed referring to the memory and to events stored there. But, from the cognitive point of view, events themselves are already operators transferring the status before the event into the status after the event. So events, just like any operator, require prior definition of the arrow of time.

Without a definition of the arrow of time events and all we store in our memory in order to write history remain undefined. Thus, time turns out to be a mental modus which itself needs to have been brought about by operational means. In the same way as the spatial metric was generated by the process of motion (i.e., motion bringing about the category of space which is necessary for describing of motion), the category of time must have been generated by operators (i.e., operators bringing about the category of time which is necessary for describing what operators are).
The approach of describing the covariants of operators by means of their invariants is well known and is often used in physics. Within the framework of Hamilton-Jacoby-formalism, the variables of a mechanical system are chosen so that conservation laws (invariants) will apply for them. With this prerequisite taken care of, the transformations describing the system's development in time can be found easily and explicitly. On the other hand, the conservation laws themselves can be shown to be generated by the transformations considered. So the canonical total momentum (in this paper identified, in a more general way, as 'motion') brings about spatial translation, and the total energy (represented by the Hamiltonian) brings about translations in time. Something very similar applies for quantum mechanics. The system's development in time is generated by the Hamiltonian and the eigenvectors of the Hamiltonian constitute the reference frame by means of which this is described. This means that our elementary cognitive coordinates are what in the theory of Hamilton-Jacobi is called 'cyclical variables' by means of which the motion of force free bodies can be described simply and linearly in time.

Therefore, the existence of conservation laws and the closely related fact that in many cases the development in time of mechanical systems seem to be rather simple (i.e. algorithmicly compressed as Davies(1990 a,b) would say) are not based on objective laws of nature and their always eulogized harmony and simplicity. They are instead related to the permanent co-evolution of acting and cognitive instruments that is necessary for predicting the consequences of acting, i.e. for action management. The perceived simplicity of the world is based on the phylogentic decision to apply those cognitive variables for the description of the effects of elementary acting (such as locomotion) which are cyclic in the sense of the Hamilton-Jacobi theory. Nature appears complex only if we deal with cases in which additional forces with unusual properties depending on various variables will constitute a system with respect to which the 3-dimensional cartesian coordinates of our phylogeneticly acquired world view are no longer cyclic. To predict how such a system will develop in time (i.e. to find the integration of the equation of motion) therefore depends on whether unspecific system variables can be transformed into system specific cyclic variables. In many cases this problem is solved by means of the Hamilton-Jacobi theory.
We can conclude: that physical actions, and the cognitive operators we use to describe them, are brought about by the same organic operators (i.e., organic tools). Perceived patterns or regularities, and the instruments of mathematical thinking we use to describe them are brought about by the same cognitive operators. So mathematical patterns, perceived patterns and the results of our actions are literally homologue in so far as they have a common ontogenetic root, and this is the very reason why they can 'cooperate' so well with one another - as well as being why the various physiological mechanisms brought about each other in the course of organic evolution.

10. Adaptation and assimilation

According to Piaget, assimilation means modifying or using external data in order to meet internal needs. Accommodation means modifying these internal needs so they can be met more

easily. Let us apply the terms assimilation and accommodation to general evolution.
According to the synthetic theory, successful evolution means constructing or modifying an organism so that it can satisfy external requirements. Evolution is thereby understood to precede primarily by means of accommodation, from its early commencement through to human technical and scientific achievements for managing life.

However, what evolves are not only internal needs for meeting external requirements but also the competence for acting, i.e. the capacity for modifying the environment according to previously defined internal needs. Seen in this way, evolution is both accommodation and assimilation -- with an increasing tendency towards assimilation: the more complex and "higher" organisms are, the more difficult it becomes for them to modify the phylogenetically acquired physiological and other basic strategies, and the more likely is it, therefore, that evolution tends toward assimilating strategies, i.e., towards improving the methods for modifying the environment. Warm-blooded animals, for example, do not react to climatic changes by altering their physiologically defined body temperature. Instead they conserve their internal climate by means of better isolation or higher (internal or external) energy investments. Humans, after all, do not react any longer by means of evolutionary accommodation. - whenever a conflict arises between biologically defined human requirements and the environment, the conflict is solved at the environment's expense. (Diettrich, 1995)

One of the most popular methods of all animals for changing the environment is locomotion. Paramecia use locomotion for escaping adverse local conditions. That the relevant environment and its selection pressure is an artifact of the various species occupying it rather

than an objective and external issue was seen already by Waddington (1959, p. 1636):

Animals are usually surrounded by a much wider range of environmental conditions than they are willing to inhabit. They live in a highly heterogeneous 'ambience', from which they themselves select the particular habitat in which their life will be passed. Thus the animal by its behaviour contributes in a most important way to determining the nature and intensity of selective pressures which will be exerted on it. Natural selection is very far from being an external force, as the conventional view might lead us to believe.

Regarded from this aspect, life is a mode of world construction in the sense of Goodmann (1984) rather than a process of exploring the world or of acquiring knowledge about the world as Lorenz (1983) said ("Life is a cognition process"). In other words, evolution seems to aim at assimilation rather than at accommodation.

Actually, however, this view is as biassed as the pure-accommodation view because the capacity for acting and reacting does not represent eo ipso a successful assimilation strategy. Strategies, as well as organic features, must accommodate themselves to given external conditions. This is what accommodation strategies aim at -- not to explore the environment and modify one's constitution accordingly, but to improve the capability of changing one's environment so as to meet the requirements of one's constitution. These requirements, however, mean first of all making optimal use of existing assimilation techniques. So, accommodation must orient itself to the techniques available rather than to the environment concerned. The most elementary example is the evolutionary extension of homeostasis for adapting to a larger variety of external data rather than finding special solutions for each special case. Accommodation, therefore, aims at extending the set of controllable data independent of what is actually required. Whether a species can profit from this strategy or not depends on whether new conditions or a new environment can be found in which these new achievements will pay off. (A cultural example would be basic research that provides solutions for problems which do not yet exist and that will be successful only if appropriate applications or problems can be identified.) So, the interplay characteristic of evolution is not only that between mutation and selection (supply strategy, defined by the supplies and constraints of the environment) but also that between extension of competence and applicability (demand strategy, defined by the requirements and the possibilities of the organism). If we, nevertheless, want to continue using the notion of environment as the instance which articulates the boundary conditions for physical and evolutionary acting, we have to consider it as a construct in a double sense: (1) by acting in the proper sense we can modify the relevant boundary conditions — for example, by means of external heating we can reduce the demands on internal temperature management; (2) by changing the internal requirements the same environment can come to represent different boundary conditions — for example, by switching from anaerobic to aerobic respiration, a previously irrelevant content of oxygen in the atmosphere became the key survival factor. More generally we can say that what counts is the 'distance' between organism and environment and this can be reduced at both 'ends'.

Here we have an analogue in cognition. We said that the cognitive phenotype is entirely a construct of the organic phenotype, which was brought about to extend the functional possibilities of the phenotype rather than to 'recognize' the world or to explore what Vollmer (1975) called the cognitive niche. Nevertheless, here, as well, we can continue using the notion of environment if we consider it (as we did in the organic case) as being constructed in a double sense. (1) We can displace objects, change our position, practice agriculture or construct streets with traffic lights. By all this we change our environment and if we do this in

the interest of our needs, we practice assimilation. By this we construct what we call actuality (Wirklichkeit). (2) How we see the environment, which regularities we register and to what 'laws of nature' we will condense them is a matter of our cognitive phenotype. The development of the cognitive operators up to the development of our world view (including the formation of scientific theories), is, therefore, an act of accommodation to the conditions of actuality brought about by assimilation. Our cognitive environment, thus, is a humanspecific construct characterized by the laws of nature as comprised in the notion of reality.

Nature does not tell us how we have to see it (for example, as spatial objects moving in a 3D world.). It is rather the phylogenetically emerged mental operators and their invariants which define the regularities we perceive and the laws we derive from them. If we consider that the biological development of these operators is complete, but not the development of their possible physical extensions by means of novel experimental devices with novel invariants which require novel theories, then we can say that we continue more than ever to construct the object of scientific research, i.e., reality. Reality, in so far it is articulated in terms of laws physicists formulate and try to explore in order to make predictions possible, is a humanspecific artifact. What we see depends both on what we do and how we interpret the sensory reflexion of our doing.

In strict analogy to the organic case we can say that actuality and reality are the two ends which characterize the cognitive distance between individual and environment. Actuality is the result of our doing (including locomotion), i.e., of assimilation. Reality is the result of our phylogenetically acquired ways of interpreting of experiences with a view to making predictions. So reality is the result of accommodation. Because we cannot describe actuality without a previously defined interpretation of our sensory input, we cannot speak of assimilation without accommodation. Just as in the organic context: the results of accommodation (i.e., the actual phenotype) define what certain assimilating activities will mean for the organism concerned. This applies, as well, in the opposite direction:

accommodation is not possible without assimilation. We cannot speak of reality and its purpose for making predictions (accommodation) without reference to the object of those predictions, the actions (assimilation). The same argument holds in the organic situation: action means the accommodation of assimilation strategies. Action and perception cannot be defined independently of one another. More particularly, it does not make sense to speak in terms of perception or recognition of an independent and objective outside world. In other words: the covariants (effect) of an operator cannot be defined separately from the operator's invariants describing this. This we referred to implicitly when we said that perceiving and acting means applying the same operator and that their only difference lies in whether we ask for the operator's invariants or the operator's covariants. Something very similar holds for accommodation and assimilation. A certain operation can be considered as an act of assimilation if we look for what it may effect in the environment, and as an act of accommodation if we look for how it may change our situation in the environment.

11. Epistemological autoreproduction

The difficulty we have in accepting the notional character of our experiences as humanspecific constructs differs with space and with time. Regarding the notion of space, it is undoubted (except perhaps by naïve realists) that the spatial patterns we perceive are not objective in the sense of their being considered views of real structures, i.e., the world is not necessarily as what it appears to be. With space, we quite readily attribute a reduced objectivity to our world view. Not so with time: We consider the recorded time topology of events to be real. The perceived order of events we consider real. The past is as it was and

noteven God can change it a posteriori, we say. Weizsäcker (1985) called this the 'facticity of the past'. Actually, however, events can only be defined as the results of cognitive or scientific interpretations, just as visual patterns can only be defined as invariants of cognitive operators. Events, as such, have less clearly defined outlines than visual patterns have. A modification of the interpretations of events used (for example, in the presence of a novel theory) may well effect the past. An experiment may have been made in the beginning of this century documenting unambiguously a speed faster than that of light. After the appearance of the theory of relativity, the protocol of the same experiment would have had to be rewritten in using a speed less than that of light. A similar revision would have to be made if evolution would have changed our cognitive operators. But because this has not happened during historical times, the illusion arose of both the facticity of the past and the objectivity of the laws of nature.

The allegation that the historicity of the world is a human specific artifact is the more problematic as it is based (through CEE) just on what is known about biological evolution, which deals explicitly with the historical order of phylogenetic events. Said another way: on the one hand our world view is the construct of our cognitive and experimental apparatus, on the other hand, his world view is exactly what physics and biology refer to, particularly when describing the development of the human brain and the operators established there. So which is the hen and which is the egg? Is it the real world we live in and which developed in the course of biotic evolution up to and including the brain's functions, or is it just these brain functions which bring about the view of a real world as a tool for both articulating and solving our problems? Formulated differently: are perceptions brought about by nature, or is nature a category brought about by our cognitive apparatus? This dichotomy is the reason for the frequent accusations that the EE is circular in so far as interprets not only the categories of space, time and causality in phylogenetic terms but also the notion of reality and nature -- the latter comprising phylogeny itself. So, phylogeny is interpreted by phylogeny, which is circular.

Actually, however, no real dichotomy exists as long as there is certainty that perceptions and nature condition one another by generating one another. This certainty is provided by the fact that our cognitive phenotype constructs a world picture which permits an understanding of the genesis of just this cognitive phenotype by means of evolution within the framework of just this world picture. Thus, not only organic ontogenesis but also cognitive evolution have to be understood as circular, autoreproductive processes in the subsequent sense:

In the biotic area the following holds: the epigenetic system of an organism is what determines how the genome's structure is to be interpreted and expressed into the phenotype. Identical reproduction is possible, however, only if the epigenetic system brings about a phenotype comprising the epigenetic system itself.

In the cognitive area the following holds: the cognitive apparatus (and all the science based on it) is what decides how the sensory input is to be interpreted and which world view is conveyed. The knowledge acquired in this manner is consistent and reproducible, however, only if the cognitive/scientific apparatus generates a world view that includes the cognitive/scientific apparatus itself.

A genome on its own cannot determine the phenotype in the sense of providing a 'blueprint' - it rather represents one of several levels in the process of autoreproduction - nor can the sensory input dictate its own interpretation, and, by this, the reactions it causes. This limitation does not contradict the fact that, within the context of a given organic or cognitive phenotype having a given interpretative machinery, a genetic mutation as well as a new perception may lead to reproducible modifications of our physical constitution or of our theories. This means that, as long as the epigenetic system remains unmodified, a given genetic

mutation will always produce the same phenotypic change; and so long as our cognitive apparatus and our scientific theories also remain unmodified, a given sensorial input will always lead to the same reading. What we have to avoid, however, is concluding that what mutations and perceptions initiate is also what they determine. Determinism is possible only within a given scheme of interpretations, i.e., outside qualitative extensions changing the interpretation concerned. The same limitations hold for adaptation. Adaptation makes sense only as long as there are no qualitative extensions as these will modify the requirements to be met, i.e. the selective pressure. The world seen as the sum total of the boundary conditions of our acting is subject to a permanent actualization, as acting aims at changing just these conditions in order to make further and more ample acting feasible. This begins with the organic phenotype which defines the constraints for evolutionary 'acting', which in turn changes the constraints for further evolution (‘evolution’ meaning the evolution of its own boundary conditions). And it ends with the cognitive phenotype that defines, through our world view, which kind of scientific acting is possible due to which the world view itself may be affected -- a paradigmatic shift in the sense of Kuhn, so to speak. The world as object of adaptation can be defined only for the time between two 'paradigmatic changes', i.e., between two qualitative extensions.

Circularity, a devastating objection for any theory within the context of classical realism, becomes (in the sense explained here) a necessary prerequisite for any complete constructivist approach. A world view brought about by a cognitive phenotype is consistent if and only if the world concerned enables the genesis of the cognitive phenotype. The role of circularity constitutes the key difference between realism (of whatever kind) and constructivism as presented here. Realism requires life-mastering methods to be consistent with an independent outside world. A constructivist interpretation of the world as proposed here, however, needs only to reconstruct itself. To avoid conflict with what von Glasersfeld (1995) and others called radical constructivism I would rather speak in terms of 'complete constructivism' in characterizing CEE. The various epistemologies mentioned here can be explained more clearly when they are classified according to how they meet their functional requirements:

1. *Structural approaches*. The most elementary position taken is that cognitive constructs (perceptions) have to delineate correctly the structures of the environment, because the strategies devised to meet the requirements of the environment are believed to be derivable from those structures. This is the basis for most kinds of *realism*. Physical knowledge is reliable (i.e., it allows verifiable predictions) if and only if it is ‘true’, i.e. if it is derived from perceptions and their ‘true’ theoretical interpretations. Both perceptions and true theories are seen to depend on the structure of an external world. Knowledge when true, is irreversible, additive and converges towards a complete and definitive set of laws of nature. The progress of knowledge is based on inductive inference. The success of induction cannot be explained in the structural picture. If epistemology is seen as a matter of cognitive evolution it is understood that acquired mental categories (reality, space, time,...) depict ontological categories. This was the starting position of *Evolutionary Epistemology(EE)* (Lorenz 1941, Campbell 1974a, Vollmer 1975, Riedl 1980, Oeser 1984, Wuketits 1984)

2. In *functional appaches* (Wuketits, 1998), particularly in ‘radical constructivism (Glaserfeld 1995), as well, cognitive constructs have to contribute to meeting the requirements of the environment, not necessarily by means of delineating environmental structures but rather functionally. The notion of ‘truth’ (in the structural picture) corresponds to the notion of ‘viability’(in the functional picture) (Glasersfeld, 1995, p. 22). Physical knowledge is reliable (i.e., it allows verifiable predictions) if it is derived

from perceptions (or phenomena) that depend on an external world and their interpretation by means of theories which no longer must be true but viable. The progress of knowledge is based on inductive inference. (What succeeded in the past will also succeed in the future). The success of induction cannot be explained in the functional picture (Chalmers 1982). If epistemology is seen as a matter of cognitive evolution it is understood as ‘natural selection epistemology’(Campbell, 1973).

3. In *complete onstructivism* in the sense of CEE. physical knowledge is reliable (i.e., it allows verifiable predictions) if it is derived from perceptions and their appropriate interpretation, but neither perceptions nor their (viable) interpretations need the evaluation by an external world. The most elementary prediction, i.e. prediction by means of linear extrapolation, is possible only if the development in question is linear in time. For this it is sufficient and necessary that the phylogenetically acquired observational terms are ‘cyclic variables’ (in the sense of Hamilton-Jacobi) with respect to the elementary operators of human action. This line of thought has resulted in the metatheory of classical physics, i.e. in the mental notion of time, space, spatial identity, locomotion, momentum etc. and in the 10 conservation laws of classical mechanics. More sophisticated actions (particularly qualitative extensions) require ‘non-classical views’, i.e., a redefinition of our notional reference frame, i.e., a redefinition of what we consider to be an observation or a phenomenon with a direct effect on what we call the laws of nature. The structure of our perceptional world therefore will depend on what humens can do by natural or technical means and it changes according to possible qualitative extensions brought about by novel experimental development. Knowledge is irreversible, additive and convergent only within quantitative extensions. Outside it will

depend on what non-classical metatheory we will use to respond to the qualitative extension concerned. The progress of knowledge within quantitative extensions is based on inductive inference. Induction succeeds because and as long as we describe the ‘world’ in terms of cyclical variables. An epistemology comprising the notion of time and development in time is consistent if it can explain its own genesis. (autoreproductivity)

12. Is Cultural/Scientific Evolution really Lamarckian?

Seldom has a scientific idea survived with greater persistence in general and learned education than that of the Lamarckian character of cultural evolution, as opposition to organic evolution which according to everything one reads from empirical sciences is Darwinian:

S.J. Gould (1979): "Cultural evolution has progressed at rates that Darwinian processes cannot begin to approach. Darwinian evolution continues in Homo Sapiens, but at rates too slow that it has no longer much impact on our history. This crux in the Earth's history has been reached because Lamarckian processes have finally been unleashed upon it. Human cultural evolution, in strong opposition to our biological history, is Lamarckian in character. What we learn in one generation, we transmit directly by teaching and writing. Acquired characters are inherited in technology and culture. Lamarckian evolution is rapid and accumulative. It explains the cardinal difference between our past, purely biological mode of change, and our current, maddening acceleration towards something new and liberating - or towards the abyss."

P. Medawar (1988): "Cultural Lamarckism has a great inherent plausibility, because social evolution is so obviously Lamarckian in character - we learn generation by generation and can propagate our learning to the next generation."

F. von Hayek (1983): “The development of culture is completely based upon the transfer of aquired characters which modern Daewinism has good reasons to reject for the developmental processes of organisms. If at all to draw a biological parallel, the theory of cultural development has to be called Lamarckian (transl. by the author)

But what, exactly, does Lamarckian evolution mean? To speak in terms of inheritance of acquired characters is not very enlightening. All characters have once been acquired, either genetically, i.e. by genetic mutations, or culturally, i.e. by means of learning; and all characters are inherited, either genetically or culturally. So, the inheritance of acquired characters can hardly specify a relevant difference between Lamarckian and Darwinian evolution. What we really have in mind when comparing cultural and organic evolution is something different: knowledge as a particular subject of cultural evolution is seen as something which is brought about by means of procedures which usually guarantee a certain usefulness, whereas the value of genetic mutations is entirely a matter of chance. Let us try to transfer this into a definition which is general enough to be applicable in the organic/genetic context as well as in cultural:

An evolution (of anything) is Darwinian if it follows the principle of trial and error, i.e. if it starts from accidental modifications that subsequently are selected (or more generally: evaluated or interpreted) according to independent criteria.

An evolution shall is Lamarckian if a calculus is applied by means of which modifications can be produced which will be considerably more successful than purely accidental modifications - a calculus that, for example, makes it possible to meet given (external) requirements in a target oriented manner such as a genetic reproduction of "acquired characters" i.e. of any proven phenotypic modification brought about in a living organism during its own lifetime; or a theory which will allow reasonable planning rather than Darwinian trial and error.

According to these definitions we have to distinguish clearly between the genesis of modifications which can be Darwinian or Lamarckian, and their subsequent dissemination which has nothing to do with Darwin or Lamarck. That "what we learn in one generation, we transmit directly by teaching and writing" as Gould said, does not qualify cultural evolution as Lamarckian. Genetic achievements (i.e. modifications which passed selection) also are transmitted directly to the next generation. A difference, of course, is in speed and in the potential number of individuals involved. In cultural evolution, particularly in the times of telecommunication, it is possible to communicate within seconds with everyone, whereas genetic information can be exchanged only between mates (leaving horizontal gene transfer aside), and to "inform" the entire population with individual genes takes many generations. So, cultural evolution proceeds indeed very much faster than genetic evolution, but this is because genetic and cultural knowledge use different ways of disseminating their modifications and has nothing to do with the way in which the modifications concerned have been brought about.
What, then, are the differences between the genetic and cultural techniques of generating innovations or changes, and how significant are they? The transformation from the genome into the phenotype is done by what since Waddington (1957) and Riedl (1975) is called the epigenetic system, meaning, briefly, the totality of the developmental processes involved (see M.J. Katz, 1982). The epigenetic system is highly specific. It rejects not only any alien genome (interbreeding between species is impossible) but also otherwise inappropriate (i.e. lethal) mutations. So, the epigenetic system has two functions: on the one hand, it translates

the genotype into the phenotype according to very specific rules (a Lamarckian process, so to say), and on the other hand it selects the purely accidental mutations according to their appropriateness for the various levels of the developmental process - a Darwinian mechanism, as long as the mutations do not change the epigenetic system itself.
Preselection of inappropriate input data is not reserved for organic evolution. In a "cultural" situation that we cannot master with available tools, many ideas cross our mind. We immediately identify some of them as unrealistic. Others will turn out to be inappropriate only after careful comparison with the theories we know. Only a few will pass all our checks (and, when relevavt, also those of other persons). So we use these to approach the problem. H.A. Simon (1983, p. 40) said:

According to the behavioural theory, rational choice may require a great deal of selective search in order to discover adaptive response. The simplest, most primitive search processes require that possible responses be first generated and then tested for appropriateness. The generator/test mechanism is the direct analogue, in the behavioural theory of rationality, of the variation/selection mechanism of the Darwinian theory. Just as in biological evolution we have variation to produce new organisms, so in the behavioral theory of human rationality we have some kind of generations of alternatives - some kind of combinatorial processes that can take simple ideas and put them together in new ways. And similarly, just as in the biological theory of evolution the mechanism of natural selection weeds out poorly adapted variants, so in human thinking the testing process rejects ideas other than those which contribute to solving the problem that is being addressed.

There are further parallels between genetic and cultural evolution. New ideas or theories that are produced by our own imaginatiion or reasoning, correspond to mutated genes in biology. Critical evaluation of these ideas in the light of all we know (consistency test) corresponds to the selecting evaluation by the epigenetic system. Evaluation in the light of experiments made in the outside world corresponds to the usual Darwinian selection by the physical biotope.

Evaluation in the light of what other people know or believe means natural selection by the social environment (i.e. competition). The result could be called individual (genetic or cultural) learning. If we adopt, however, foreign ideas which usually have the advantage of already having been tested by other persons' experiences, and combine them with our own concepts, then this corresponds to the adoption of proven genes within the framework of sexual communication and their subsequent recombination. This we will call social (genetic or cultural) learning. So, the term individual/social refers to the source of data (Did I learn myself, or did I let others learn for me?), whereas the term genetic/cultural refers to the type of data concerned (Is the result stored in my genes or in my "memes"?). In an exclusively cultural context social contacts and social learning are always cultural, which has sometimes prompted people to replace the term "social" by "cultural" (see Callebaut, 1987). Then, however, when drawing the parallel to organic evolution, genetic learning by sexual recombination and reproduction has to be called a cultural phenomenon, which would be against all scientific terminology.

All theories, plans or developmental processes have a certain range of competence inside which they act in a well planned, predictable and proven manner - Lamarckian processes according to the definition given. Outside this range, however, they can succeed only according the possibilities of Darwinian trial and error. For the embryogenesis based on a special genome, for example, the competence ends with the production of a viable organisms. Whether a certain organism, once it has been produced, will survive in its physical and social

environment or not, is outside the competence of the epigenetic system. Here the only method organic evolution can apply is that of trial and error, (whereas the Lamarckist believes that the developmental process can at least partially respond also to external requirements). Something similar applies to culturally acquired theories. Economic and social theories, for example, may tell us what particular budgetary or employment measure will increase inflation, but their competence is not sufficient to fully predict the outcome of more complex measures in full generality. The consequence is that policy, despite all scientific efforts, is largely a matter of trial and error. So, whether we have to call a modifying process Lamarckian or Darwinian does not so much depend on the process itself but rather on whether we look at the process from inside or outside its competence. The terms Darwinian and Lamarckian, therefore, describe aspects rather than qualities.

If we look at two different processes, one from inside, the other from outside their competencies, than it is evident that we see different phenomena but these need not reflect possibly existing real differences. It is as if one would compare the physical hardness of two metals, one below and one above the respective melting point. This we have to keep in mind when comparing genetic and cultural evolution: if we speak in terms of theories and knowledge to be transmitted culturally to the next generation, we mean proven and tested theories, i.e. the result of cultural learning, and not the uncontrolled and unproven outcome of fantasy and intuition. We have to compare these proven and tested theories with the results of genetic learning i.e. with the proven genetic modifications that have already shown their ability by producing an organism that can survive and reproduce and, therefore, "will be transmitted to the next generation". Gould (and others), however, look at cultural evolution from inside its competence and at genetic evolution from outside, i.e. they compare culturally acquired theories that have already passed all checks with spontaneous genetic mutations that still have to pass all testing. If at all, the latter has to be compared with culture, policy etc. by looking from outside the competence of the theories by means of which we try to guide social development. Then the evolution of culture would be Darwinian, driven by incompetent human action in the same way as organic evolution is driven by "incompetent" mutations. So, to try to distinguish organic and cultural evolution by means of the terms Darwinian and Lamarckian is based upon a kind of semantic confusion. (see Diettrich, 1992)

13. Physical and social problem solving in cognitive evolution

To this point we dealt with cognitive evolution mainly from the point of view of how to manage the sensorial input or to identify laws of nature, i.e. how to solve the problems of our physical environment. Cognitive capabilities we saw mainly as tools to improve our physical fitness. The more time, however, we spend in social clusters the more we have to cope with social problems and the more we have to improve our social fitness.

‘Fitness’ is defined as the quality that contributes to the survival of a species - in the narrow sense if only genetically determined qualities are concerned, and in the broad sense if also culturally inheritable forms of behaviour and capabilities are also considered, including the scientific and organisational skills of *Homo sapiens*. although not customary, we will attribute fitness also to theories or strategies if they succeed for a long time and under a variety of conditions. A sufficient condition of biological survival is a high reproduction rate, but it is not necessary: it is easy to show that under conditions of profitable social cooperation maximal procreation might be counterproductive and that a restricted and modest reproduction rate could be a better guarantee for long-term survival of the species concerned. Somatic cells in metazoan, that would forget this and reproduce maximally like "free and independent" cells will die as cancer cells. To a certain degree humans (as well as some socially organised animals)

have also acquired the status of somatic cells. They still propagate (and, of course, they must do so) but mainly according to certain social criteria and not so as to maximise their genetic output. Indeed, few of us would invest all our biological and social resources in bringing up as many children as possible. We are cultural individuals in so far as we strive for cultural rather than for genetic immortality (sensu Dawkins, 1982), i.e. we want our scientific, cultural or social merits to survive in human practice or public memory rather than to continue our specific genetic lineage. We strive for a lasting contribution to the ‘culture-pool’ rather than to the ‘gene-pool’ of our society. Some groups even explicitly resign (via celibacy) from genetic propagation at all to be culturally or socially more efficient. They recruit their members by social integration instead of by biological replication.

Yet, fitness is a theoretically fruitful notion only if it is more than just a synonym for the ability to survive, i.e. it must manifest itself also in other qualities from which one could then draw conclusions as to the species' future position. Otherwise, one would run into the wellknown tautology of ‘survival of the fittest’. It would be sufficient, for example, if we could deduce from a species that survived until now that it must have developed so many survival skills that it will have a good chances of succeeding also in the future. But this is exactly what we cannot do. Special species have developed special skills tailored for the special difficulties of the past, but not necessarily those of the future - and particularly not for those they have brought about themselves by what they tried in the past. The more sophisticated and comprehensive are the problem-solving techniques a species has engineered, the more sophisticated and comprehensive will the problems that will result as an unintended byproduct, and the more expensive and troublesome the efforts needed for mastering the new problems. Nearly all problems mankind has nowadays result from the success our ancestors had in solving their problems. Under these circumstances it is not at all evident that humans, despite all their problem-solving capabilities, have less reason to worry about their future than many of the eukaryotes. What is more: because the risk of colliding with the boundary conditions of our existence grows with increasing effort and investment, we may become victims of irreversible life threatening long-term consequences, it cannot be excluded that progress understood as intended for the conservation of species, and we may well find that progress undertaken for the conservation of the species will turn out to be counterproductive. What looked ingenious in its time may have been the first step into a dead-end street.

This can also be described somewhat differently. There seems to be something that can be called risk-homoeostasis (Wilde, 1982). All successful evolutionary solutions of problems diminish the extinction risk of endangered species. On the other hand species are tempted to load new risks on the strategic reserves just acquired. The net security yield, therefore, may be zero, or even negative when overcompensation occurs. Animals, for example, that cannot only walk but also fly should, under otherwise equal conditions, be better adapted then those which can only walk or only fly - but only so long as their greater competence will not entice them to occupy biotopes where both walking and flying are required for survival, so that the loss of one of these abilities would be fatal. The driver who wastes the security benefits from the additional technical facilities of his automobile, such as ABS brakes, by driving at a correspondingly higher speed (a behaviour which unfortunately is very common as insurance companies confirm) is not much better off.

This principle is very general: the number of potentially fatal problems humans have brought about by merely completely exploiting their various capabilities is not much less than the number of capabilities themselves, because solving any problem-implicitly results in the generation of new problems which are often are more complex as they derive from a solution that must have overcome the previous problem. In terms of ecology, the greatest problem of mankind is probably the waste management of man's capabilities.

Although we saw that neither organic tools nor theories have a definitive or universal value we firmly believe that there are at least general strategies which are useful and therefore recommendable in any situation, even though their long term profit may be reduced by the mechanisms of risk-homoeostasis - functionally "true" strategies so to say, similar to structurally true propositions on the real world. Improving and strengthening the methods of rational thinking is of general utility not only in science but also in the world of day-to-day living. From what we understand as the success of rationality we often conclude that it must be based on the constitution of the world we live in, and, consequently, that the world's order can be decoded only by rational methods. From this, then, we conclude that even in those cases in which consciously applied rationality seems to be excluded (as in the subconscious or with animals' behaviour) the success of strategies or the applicability of organs is guaranteed only insofar as they meet rational criteria, i.e. insofar as they are 'ratiomorph' (Brunswik, 1955). This means that strategies and construction principles (concerning both the physical and the cognitive context) have to consider all relevant facts in the same way as an accordingly informed analyst would.

To derive the "rational structure" of our world from the success of rationality and to conclude retrogressively that cognitive methods can survive only when being ratiomorph reflects the allegation that rationality results from cognitive adaptation to the real world (Campbell’s "natural-selection-epistemology"). Because, however, the notion of an independent reality evaluating the efforts of those dealing with it, cannot be explicated as we have seen, the success of rationality can hardly characterise the world as it is but only the class of rationally solvable problems. Thus, the ability of rational thinking cannot represent a value per se based on the particular constitution of the world. Its utility can be defined only in the context of the various applications concerned. Indeed, the high reputation rationality has enjoyed since the Enlightment, particularly in the context of science and technology, is mainly based on mankind's decision to favour just those values (such as the physical mastering of nature) that can be satisfied only by means of rational methods. The development of these methods, in turn, stimulated technology based cultural achievements such as telecommunication, which, in turn generated incentives for further research in this direction. This statement holds rather generally: there is an inherent coevolution between all means and their application in general behaviour, cognition and culture, as well as in organic life. It refers to rationality and control of nature (or more particularly: to basic research and technological applications), biological limbs and manual intelligence, visual sense organs and space-time perception, physical theories and experiments or culinary tools and feeding habits, and so on. None of these tools would make any sense or could be evaluated except in the context of the applications that they had evolved with. In particular, we cannot say that species with rational capabilities would necessarily dominate all other species. With a view to the large number of unsolved human problems based primarily on a lack of social coherence rather than of scientific knowledge, we cannot exclude that societies specialised in intuitive (and therefore irrational) social problem management would, in the long run, be better off than societies with a high scientific standing but without the necessary feeling for what the social consequences of science can be.

From another line of thinking we attain at the same conclusion. For a long time in human history, the world man had to cope with was the physical environment and physical were the problems man had to master in order to survive. The fight against cold, hunger and disease dominated human striving for ages, culminating eventually in modern science and technology solving nearly all of our classical problems. With respect to the scientific possibilities available, mankind is largely saturated. With increasing social communication, however, the relevant environment is shifting more and more from the physical to the social environment

thus opening up an entirely new set of requirements. Looking at the course of a typical day, it is obvious that we spend the most effort in meeting social boundary conditions, such as in making money or finding acceptable balances with other peoples' interests, rather than to grapple directly with physical needs. Even though scientists deal explicitly with the physical structure of our environment, They do so to survive in the academic rather than in the physical world. In the long term this may reduce the general curiosity about scientific/technological issues and the perception of the physical environment in favour of a sharper comprehension for societally relevant matters. Under these aspects, the high strategic importance we attribute to scientific and technological capabilities is a relic from times where the mastery of nature was the prevailing requisite for survival. Nowadays, most of the problems we have and even more of those we will have in future are social in character or can be solved only by social measures. So it may well be possible that the (Western) cultural dominance of the science of nature which followed the religious paradigm is a fading episode in man's history replaced by what one could call the societal paradigm.

I would hesitate to see in the present widespread anti-science movement, as manifested particularly in the fields of nuclear energy and biotechnology, a first indication for a paradigm shift in the sense discussed above. On the one hand, these attitudes refer to fears and concerns about fatal applications or otherwise risky consequences related to mismanagement, lack of control or neglecting the non-renewable character of many resources, rather than to a general reevaluation of the goals to be achieved by science. On the other hand, however, the fact that science has become an issue on the public agenda makes it clear that science is going to shift from being a pure survival tool such as agriculture was, towards one of the societal "enzymes" which constitute the mechanisms of social development as described by Luhmann (1990).

For the time being one of the most severe difficulties mankind has ever been confronted with is environmental pollution which is no doubt physical in character. However, even pollution is first of all a social problem because it requires socially reasonable responses to diminish the output rather than scientific effort. Scientific solutions, however ingenious and effective, cannot eliminate the mechanisms of risk homoeostasis, i.e. they cannot prevent a counter-productive increase in detrimental production so that, after a while and despite all technical environment protection skills we have, pollution will rise to historical levels again – or even higher. Unfortunately there are many similar problems in which the often fascinating scientific success in fighting them prevents us from looking at the real, i.e. the societal, solution.

14. Summary

We dealt with two different kind of approaches to cognitive evolution and evolutionary epistemology. Let me call them the classical and the non-classical one.

The classical approach is based on the categories of our inborn world view such as subject/object, space, time, causality and even reality. That these categories are inborn imparts great inherent plausibility to this approach. It is as with physics. Classical physics is based at the same categories and just this is the reason why we really can ‘understand’ it, whereas quantum mechanics - however well it may do - remains outside its mathematical framework a notionally inexplicable matter. Yet the point is that we do not really need to understand physics as long as it helps to master nature - whereas it is problematic to explain cognitive evolution by means of the notion of reality which has been brought about by just cognitive evolution itself. Cognitive evolution may have had good reasons to ‘convince’ us that it is useful to describe the sum total of past and present experiences in terms of what we call the laws of nature. But evolution did not tell us that these laws would converge towards definitive

and universal versions. This is an anthropomorphic allegation. Because evolution at the same time ‘told’ us that everything has to have a cause, we invented ‘ontological reality’ to comprise among others the universal laws of nature. This invention (however heuristically dubious it might be) was a paying investment. To believe that what we see is real rather than the output of mental interpretations restrains us from time-consuming reflections on how appropriate our interpretations are, which accelerates many decision-making processes. Realism also legitimizes all scientific efforts to identify and analyze the structure of nature. Any empirical experience can be seen as a lasting contribution to the decoding of nature. Because, from the realistic point of view, the structure of nature is definitive and of finite complexity, realism supports the idea that science is not a matter of endless striving but can be completed - at least in principle (theory of everything). Even epistemologists are made more comfortable by the thought that our inborn epistemology might have been evaluated by selection of a real nature and its laws. But realism is first of all a theory made to explain the definitive and objective character of the laws of nature. As a theory, however, realism cannot endow its own subject, reality, with ontological authority. In particular, it cannot declare its own subject to be the reason or justification of why it itself came into being. Further to this, realism, defined by objective laws, became more problematic when it turned out that the laws of nature are neither objective nor definitive.

The non-classical approach tries to explain the well documented links between action and perception and the possibility of predictions without reference to an intermediate independent reality. If the independency of reality is based on the objectivity of laws of nature we must first of all find a possibility to explain these laws as human specific artifacts.

Here we can profit from physics: after the experiences physicists made with quantum mechanics, they agreed that properties of physical objects have no ontological character but are defined as invariants of measurement operators. This must apply also for physical laws which can be seen as the properties of nature and which are thus defined as invariants of the cognitive apparatus as a whole. This was shown by referring to the cognitive operators comprised somewhere in our cognitive apparatus which transform the physical input of the sense organs into perceptions. The regularities that we perceive and condense into what we call the laws of nature, can then be considered to be the invariants of cognitive operators. A typical example: the law of energy conservation can be derived from the homogeneity of time and thus depends on the time metric generator in our brain. Experimental physicists extend our cognitive operators by means of measurement operators. If both operators commute in the sense of operator algebra the measurement results can be described in terms of the inborn cognitive operators, i.e. in classical terms (quantitative extensions). Otherwise (qualitative extensions) non-classical theories have to be designed. As qualitative extensions can never be excluded, physics cannot be completed. Similar reasoning applies in mathematics: because it (according to Goedel) can never be excluded that the axiomatic system has to be changed, mathematics cannot be completed. The idea that the laws of nature are defined as invariants of the cognitive apparatus and that they cannot be seen as condensations of the experiences we had with an external world, is very close to what H. Cruse (1999) had in mind when he wrote in a paper on the external and the internal view in cognitive sciences: “We do not have the experience, we are the experience”.

As to the predictability of the results of our acting we again can profit from physics. Whether a variable in a physical system will evolve linearly in time (and therefore can easily be predicted) or not depends on the variable used. According to the theory of Hamilton-Jacobi in many cases transformations can be found so that make some of the variables ‘cyclic’, i.e. they change linearly in time. If cognitive evolution had managed to provide us with perceptional variables that are cyclic with respect to our elementary actions, then it is clear

why we can extrapolate or predict the perceptions caused by our actions such as locomotion. A generalisation of this relationship between action and perception leads to what Davies called the algebraic compressibility of the world. That so many and complex features of our world can be described in rather simple mathematical formulas might well be based on functional homologies between the mental roots of perceptual and mathematical procedures. The most promising effort of the approach proposed here aims at a coherent description of organic, cognitive and scientific evolution. However, the price to be paid is high. We have to accept that the laws of nature are phylogenetically acquired human-specific artefacts; that there is no 'natural selection epistemology' (in the sens of Campbell, 1974 a); that there will be no complete set of physical theories ('theory of everything') and that there will be no meaningful context-free communication (such as with extraterrestrial beings). On the other side, some explanations are offered that could hardly have been expected from outside the cognitive operator approach: the incompleteness of physical theories and the incompleteness of mathematical axioms discerned by Kurt Gödel have the same cognitive roots - the algorithmic compressibility of the world (which is equivalent to the success of induction) is due to the homology of cognitive mechanisms and the mechanisms of mathematical thinking. Of particular interest is the link between organic and cognitive tools: if cognitive tools are to describe the covariants of an operator (i.e., what the operator effects), they have to be designed in terms of the operator's invariants (a principle which has been re-invented by physicists within Hamilton-Jacoby and quantum mechanical formalism). Cognitive evolution (including the epistemology here applied), therefore, is therefore brought about by organic

evolution (and by the evolution of experimental tools) rather than by trial and error and selection. And, vice versa, organic (and experimental) evolution is guided by the possibilities provided by cognitive tools. I addition to this we have shown that improving our scientific knowledge must not necessarily be the definitive goal of cognitive evolution. To the extent that our environment will be defined more and more by social boundary conditions rather than by physical ones, it may well be possible that in the long term, competence in social problem solving will be more relevant than scientific skills.
Let us summarize here in a synoptic view how the approach used enables us to describe the major elements of organic and cognitive evolution in a coherent way:

Organic Evolution

Cognitive Evolution

A1 Organic structures are invariants of the reproducing operator (epigenetic expression of genetic structures). A genetic mutation may bring about (I) a certain phenotypic modification in a reversible and unambiguous manner (defining mutations) or (II) it may interact with the epigenetic system and by this may induce a sequence of non identical reproductions. Whether I or II will occur (i.e., whether there is a reversible or an irreversible mutation) depends on whether the epigenetic system is invariant under the mutation concerned or not.

B1 The structures of perceptions are defined as invariants of physical operators (represented by physical or organic devices) or of cognitive operators (implemented in our brain). Whether the other operators we apply are measuring or acting operators depends on whether they will commute with the defining operators or not

A2 It is wide-spread understanding that organic evolution has to meet the requirements of the environment (**Adaptation**).

B2 It is wide-spread understanding that cognitive evolution aims at identifying laws of nature to which we condense the perceived regularities in order to allow predictions **(Adaptation)**.

A3 Accordingly, only appropriate adaptation will be honoured by natural selection.

B3 Accordingly, only when the laws of nature concerned are sufficiently known, predicting (and, therefore, meaningful planning) is possible.

A4 On the other hand, evolution brings about acting skills and tools in order to modify the (external) environment in order to meet better the requirements of the organism. Novel actions are called qualitative if their effect can no longer be mastered by established means but require novel tools and strategies (e.g.: emigration from aquatic to terrestrial environment requires new limb structures).

B4 On the other hand, scientific evolution may extend the inborn cognitive operators by means of measurement operators in order to improve our knowledge of the laws constituting the (external) nature. These extensions will be called qualitative if they require novel, non-classical laws defining a different world view.

A5 So, the discrepancy between the organism and the environment can be reduced from both ends, by **Adaptation, (internal solution)** and by **Assimilation (external solution)**.

B5 So, deficiencies in predicting can be reduced by improving our knowledge within the framework of established natural laws, i.e. by **Adaptation (internal solution)** as well as by modifying the laws representing the world by means of non-classical modifications of the world view. **Assimilation (external solution).**

A6 Actions can be realised only when based on the action operators given or their combinations.

B6 Predictions can be realised explicitly only when expressible in terms of variables which are cyclic (and therefore linear in time) with respect to the operators ruling the system.

A7 The higher organisms have evolved, the more they refer to **assimilation**. (Man, when confronted with physical problems, counts exclusively on external solutions, rather than to wait that evolution will provide him with better **adaptation**)

B7 The higher organisms have evolved, the more they refer to cognitive *assimilation*. Men, when confronted with qualitative physical extensions, would respond by non-classical modifications of the world view rather than by expensive *adaptation* of conventional theories such as D. Bohm's 'hidden variables' designed to keep quantum mechanics classical). Primates constructed a 3-diemsional world for the management of locomotion processes rather than a 2D or even 1D dimensional world as invented by kinesthetic animals.

A8 As evolving species modify their environment the selection power will not be static. Evolution, therefore, will not converge towards a definitivum or optimum - the pride of creation so to say. (**No definitive species of universal competence. No completion of organic evolution**)

B8 As qualitative extensions of inborn or otherwise established cognitive operators can never be excluded, there will be no definitive set of theories (**No theory of everything**). From applying this concept to the inborn operators of mathematical thinking and their algorithmic extensions it follows that there will be **no definitive set of axioms** as shown by Gödel. **(No completion of cognitive evolution).**

A9 There is no objective acting strategy: whether walking, running, crawling, swimming or flying is best for locomotion depends on the organic phenotype.

B9 There is no objective theory. What a theory describes and how it does depends on the inborn (or scientifically extended) notional reference frame, i.e. on the cognitive phenotype.

A10 An organic phenotype (and the action tools comprised) cannot be **"true"**. When to survive it must **reproduce**.

B10 A cognitive phenotype (and the theories comprised) cannot be **"true"**. It rather has to **reproduce**, i.e. it must be able to explain its own genesis.

A11 The **variety of organisms** is subject to the boundary conditions of cells. The variety of cells is subject to the boundary conditions of molecules, etc.

B11 The **variety of perceived regularities** is subject to the boundary conditions of metaphysics. The variety of metaphysics is subject to the boundary conditions of metametaphysics etc.- up to neural structures, and from then on as in the organic case

A12 **The success of Organs** is specific to species.

B12 Truth is specific to the metatheories concerned

A13 Organisms from different species cannot communicate **genetically** i.e. interbreed.

B13 Different cognitive phenotypes cannot communicate **semantically** (e.g. verbally)

A14 **Genetic mutations**, once they passed all internal and external selection mechanisms, (epigenetic evaluation, physical viability of the phenotype, sexual and social evaluation) **can be transferred directly to the next generation. As to Darwinism/ Lamarckism, there is a strict balance between organic and scientific evolution.**

B14 **Scientific ideas**, once they passed all selections (by existing knowledge, empirical evaluation and evaluation by the scientific community), **can be transferred directly to the next generation. As to Darwinism/ Lamarckism there is a strict balance between organic and scientific evolution.**

A15 Organisms with a novel phenotype must not necessarily meet the requirements of their actual niches. They can emigrate into more appropriate ones, i.e. they can find a better application for their phenotype. **(Solving given problems vs. opening new oppotunities)**

B15 Basic research must not necessarily generate solutions for existing problems. But new applications may be found where the results achieved are helpful. **(Applied research vs. basic research)**

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