The biological boundary conditions for our classical physical world view

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Abstract

It is shown that the laws of nature providing us with cognitive survival competence are not objective properties of the world but rather depend on the previously acquired phenotype in the same sense as the acting competence of organisms depends on the previously acquired organic phenotype. For example: the law of energy-conservation can be derived from the homogeneity of time. But homogeneity in time is defined by how our internal clock (which is part of our phenotype) is constructed. Cognitive evolution is subject to the boundary condition that will result in a world view (i.e. physics) that has to be invariant under all we do within this world-view. As locomotion is the oldest and most important capability of our ancestors our world view must be invariant first of all under locomotion, i.e. it has to be Galilei-invariant. Emmy Noether has shown that this is sufficient to derive the 10 conservation laws of classical mechanics. The other so-called laws of nature are defined as invariants of physical measurements. Therefore, cognitive evolution itself has brought about what we call the laws of nature and therefore cannot be subject to these laws as advocated by Campbell.

1. Introduction

It is an old understanding in evolutionary sciences that our cognitive phenotype evolves in similar ways as the organic phenotype does. Both are subject to boundary conditions based on the structure of an independent outside world. The central terms are adaptation to and selection by the environment. How the process of adaptation acts in the case of the organic phenotype is described by the theory of Darwin: the central topic is blind variation and selection. The cognitive analogue is described by Campbell=s *natural selection epistemology* (1974), saying that the development of human knowledge is driven by a process analogous to biological natural selection in the sense that the possible fit between our theories on the world and the world itself can be seen as a process of trial and error.

But trial and error is a little bit too simple an explanation for complex matters such as the organic or the cognitive phenotype. First of all, the environment is not that dominant as people usually think. The selection pressure which a certain habitat will exert on an organism living there does not depend alone on the structure of the habitat. It depends as well from the structure of the organism itself. 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 (Diettrich 1989: 22). And, accordingly, entirely different will be the selective pressure they have to meet. Horses (among others) have to improve the elasticity of their limbs and the strength of their muscles. Snakes have to improve the surface friction of their skin.

That evolution is not exclusively a matter of assimilation according to the selection pressure was seen already by Waddington (1959: 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*..

So we can say: further evolution depends on previous evolution. Riedl (1975) speaks in terms of the >genetic burden= which a species has to consider when further to evolve. This we can generalise: problems (such as locomotion on steppe-like landscapes) do not determine the methods of their solution - or, what is the same: many different organic phenotypes can live in the same habitat. They all have brought about different solutions, so to speak. The opposite inference cannot be made either. We cannot derive from a >solution= the kind of problem for which it was made, nor can we see for what purpose a technique an organ is to be used (before we have seen it) - particularly not if there is more than one possibility. A bird's bill for example could be suitable for picking corn, cracking nuts, fighting or climbing. In the organic area there seems to be no relation between problem and solution. The consequence is that organic evolution has no specific focus towards which all species will converge, the `*pride of creation*= so to say.

Here we come to a massive conflict with cognitive evolution. According to common understanding cognitive evolution (in so far it aims at mastering the physical environment) is confronted only with the structure of nature represented by the laws of nature. Generally speaking: the cognitive phenotype is the better, the better it will recognise and interpret the laws of nature. Transferring what we said on organic evolution to cognitive evolution would mean that there is no link between the theories we construct to master the world and the structure of the world to be mastered. I.e., we had to admit that epistemic evolution does not necessarily progresses towards a goal, i.e. towards a definitive set of natural laws (i.e. towards *>truth=* or towards a *>theory of everything= (Barrow 1990),* the *>pride of science=* so to speak.) In deed this would be hard to accept. We may admit that theories are not pictures of the world in the sense of downright realism, but we firmly believe that theories on nature have to meet requirements which are defined exclusively by the outside world so that living in an entirely different world (á la Leibniz) would require entirely different theories. Indeed, most scientists would flatly reject the idea that there is no link between the world and our theories we use to master the world (i.e. between problem and solution). This - so they fear - would lead directly into the "everything goes" trap.

This classical view is based on the assumption that our perceptions can contribute to mastering nature only if they are correlated to nature either structurally (depicting realism) or functionally (constructivism). In either case, therefore, it holds that our perceptions and the theories we derive from them are statements on the world in the sense we just mentioned.

This is equivalent with the view that there is a clear distinction between perception and action: - perception, by means of which we generate knowledge and theories on a predefined outside world, and action, by means of which we operate on just this world and by this change it. This view, however, is difficult to hold in physics (particularly in quantum mechanics) where measuring (i.e. perceiving) is itself a kind of acting. Measuring is carried out by measuring devices acting as operators on the objects in question. Measuring results, i.e. the structures we 'see', are defined as invariants of the measurement operators. This means that there is no essential difference between acting in the literal sense and acting by means of measurement operators. It was a far reaching decision of physicists to accept, as far as possible, objects, features or other theoretical terms only if they can be defined by means of a measurement process. This was triggered by painful experimental evidence showing that the usual protophysical definitions of theoretical terms by means of common sense may not be suitable to describe subatomic or relativistic systems. Theoretical terms have to be defined more precisely, and best is to do it by means of measurement devices. This is called the operational definition of theoretical terms.

Objects are defined by their properties and properties are defined as invariants of measuring operators. So, also objects are defined by means of operators. As we can neither measure a property nor act upon the object in question without the preceding application of defining operations (i.e. defining the properties which characterise the object in question), we can conclude: all we see and do is a matter of interaction between three different kinds of operators - defining, measuring and acting operators. In other words: what a perception is going to tell us, or what an acting will bring about depends on how the object perceived is defined.

2. The relationship between action, perception and definition

The concept of action, perception and definition need some elaboration before fully understood. Acting (be it acting by our self or acting by other subjects or systems) means everything which modifies perceptions. Acting can be acting in the literal sense such as modifying a physical object and by this changing what we see of the object as well as acting such as by means of our locomotion limbs and by this changing the perceptions concerned due to perspective phenomena. The only direct access we have to objects are perceptions. Then we can use the notion of operators acting on perceptions and transforming them into other perceptions. For saying so it is not necessary to declare that perceptions are perceptions *of* something or that perceptions would tell us something about matters which *exist* independent from our perceiving them. The only important matter is the interaction between action and perception. For explaining this in more detail we will apply here a formalism which is quite similar to what is used in quantum mechanics:

φ, χ, … be normalized vectors in Hilbertspace and represent perceptions.

O, P, … be Hermitian operators in Hilbert space and represent operators acting on perceptions.

λ_i (i = 1,2,...) be the (real) eigenvalues of Hermitian operators.

Let us consider all the perceptions φ_i (i = 0 1,2,...) which are invariant under the action of an operator O:

(1) $O\,\varphi_i = \lambda_i\,\varphi_i$

We will call a subset of eigenvectors φ_i of O the O-representation if any perception ψ can be described as a linear combination of the φ_i :

(2) $\psi = \sum \alpha_j\,\varphi_j$

Our saying is that ψ is defined by O.

Formula (1) can also be read in another way: if the φ_j are defined by another Operator, say N, which commutes with O (i.e. ON = NO, or, what is synonym, which are commensurable with O), then (1) represents a measurement process and the λ_i are the possible measurement results. This relationship is symmetric. Both O and N can be defining or measuring operators respectively. In the O-representation we can measure by means of N, and in the N-representation we can measure by means of O.

If N and O do not commute (NO $\neq$ ON), then N will transform a perception (which is eigenvektor φ_i of O) either into another eigenvector φ_j of O or into a perception χ which is no longer an eigenvector of O at all. In this case we will call N an acting operator rather than an measuring operator. The same applies for the opposite direction. So, we come to the

Operator's lemma: whether an operator can be used for measurement or for action depends on whether it will commute with the operator defining the object in question or not

To make this point clearer let as pose the question as to whether our walking limbs are acting or measuring operators.

In a 3D world furnished with objects which are defined as invariants of spatial transformation, locomotion is an measurement process (when walking around an object the various views perceived will inform us on the objects shape, i.e., we will 'measure' the shape). For someone who sees the world in two dimensions (i.e. for someone who does not know perspective phenomena), however, locomotion is an (remote) acting operator because it modifies the shapes concerned. What does that mean?

To see the world in 3 dimensions 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 of visual perception is 3D because the world itself is 3D in character, and that 2D-apes which do not see the world in 3 dimensions were unable to jump from tree to tree, and, therefore, could not belong to our ancestors as Konrad Lorenz (1983) argued. It is easy to show that appropriate and successful survival strategies could well be based on 2D or 4D perception spaces, independent from how many degrees of freedom are actually available.

With a 2D perception we would not know perspective phenomena. Things are small or things are big, but they don not seem to be small because they are more distant and they would not seem to be big because they are nearer. Distance to the observer belongs to the third dimension which is excluded here. But objects, nevertheless, would shrunk in size if we use our legs to go backwards and they would enlarge their size if we go forward. So, with a 2D perception we would come to a world view according to which not only our hands and mechanical tools can modify objects but also our legs. So walking limbs were acting operators. This must not lead to the conflict mentioned by Lorenz. 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 envisaged just when its size and position achieved certain typical values. If the perceived size of a branch will have doubled after three steps, the ape must know that he will arrive at it after another three steps and then has to grasp. If he has learnt to do so he may well survive in forests and an external observer would not find any difference between the moving strategies of such an ape and those based on a 3D perception. So, whether walking is a measuring or an acting operator depends on whether the objects in question are defined as invariants of 3D or 2D transformations. It is evident that physical theories based on an inborn 2D world view where objects could be 'deformed' not only by means of our hands but also by means of remote forces brought about by our walking or jumping legs would have no similarities with the theories we are used to use. Such a world view - and this is the point - must not be less successful than ours is. Also organic organisms can be seen as an answer to the question of how to survive in a given habitat. That many different of them can live together shows that they all are well prepared to survive although they may be entirely different.

The relation between 2 and 3 dimensions we can explain by another example: Let us imagine locally fixed plants that have eyes and can see and which 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 big 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 live in a 2D perceptional space. Exactly the same happened to physicists when empirical evidence forced them to construct the theory of special relativity saying that time intervals are nothing absolute but depend on the relative motion of the observer - difficult to understand for someone who is used to live in a Newtonian world. (By the way, this analogy can be even extended: the (relativistic) limitation of all speeds in the 3D case ($v<c$) corresponds to the limitation of all lengths in the 2D case, as these can be defined only by means of the aperture $\alpha < 180$).

That certain modifications of visual perceptions can be interpreted as a perspective (or geometrical) phenomenon or as a phenomenon of explicit physical action, is well known from another case in physics: the orbits of planets could be considered as the effect of explicit gravitational forces (the physical solution) as well as the curved geodetic lines within a 4D space (the geometrical solution as proposed by the theory of general relativity).

As all this is just but a different interpretation of the same observations we cannot come to a decision on empirical grounds nor was adaptation or selection relevant when cognitive evolution of primates had to decide whether to see the visual world in 2 or 3 dimensions. In other words: perceptional spaces and systems of categories are purely descriptional systems which may tell us something on how we see the world but nothing on 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 (i.e. external) selection epistemology as advocated by Campbell.

But, could it not be possible that our epistemology is an internal selection epistemology i.e. that certain elements of our epistemology are easier to realize by our cognitive phenotype than others and therefore are selected in the course of our cognitive evolution? The spatial shape of objects we describe in 3D perception, for example, is something nobody has ever seen. All we see are 2D projections on the retina of our eyes. The spatial character of perceived objects is a cognitive artefact which requires a lot of internal arithmetical efforts to be realised. In 2D perception, however, things are as they appear. So, from the mathematical point of view, two dimensions are privileged with respect to three dimensions. On the other hand, 2D perception requires an explicit physical theory on the correlation between what our legs are doing and what wee see. In 3D perception this is solved implicitly. The correlation concerned is a matter of geometrical perspective comprised in the notion of a 3D space. Therefore we can utter the following view: the fact that our cognitive evolution ended in three dimensions rather than in two can hardly be due to mathematical economy (which, of course would favour 2 dimensions) but rather due to what we will call the principle: of implicit description. I.e.: cognitive evolution tends to take away approved experiences from explicit description and to put it into implicit description, i.e. into the special character of the world view (i.e. metatheory) concerned. Then, the regularities we found are no longer a particularity of the 'world' (which may well be different in a different world) but the intrinsic consequence of the world view we use.

3. World views

A world view is defined by the decision of what we call acting operators and what we call defining or measuring operators. As we have seen, 2D and 3D perceptions constitute different world views as locomotion is *acting* within 2D perception, and *measuring* within 3D perception. Within a world view the relationship between defining, measuring and acting is described by theories. Outside a given world view it is not defined what a theory will mean. A theory shall be called complete if it can describe everything that can happen within a given world view. Then an equivalent saying would be: a world view is characterised by any of its complete theories. A complete theory is another saying for what otherwise is called the *theory of everything*. There is an ongoing debate as to whether there is a theory of everything - the final focus of nature sciences so to speak. Yes, of course, there is one, as we have seen here, but only within the context of a given world view. Outside a world view a theory of everything is not defined. Particularly a context free theory of everything, i.e. outside any world view (and by this objective), is not defined. But just that is what people usually have in mind when discussing the theory of everything. On the grounds of what we have shown here an objective theory of everything does not only not exist – it is not defined and therefore without meaning.

It is as we would try to describe geometrical structures without the notion of metric spaces in order to escape the particularities of the various spatial reference frames. In each of these frames the structures have different characteristics, but it is impossible to define geometrical characteristics without any frame, i.e. without referring to the notion of space.

3.1 Cognitive operators

Within what I called *Constructivist Evolutionary Epistemology* (CEE) (Diettrich 1994a) let us introduce here the so called *cognitive operators*. We will assume that they are implemented physiologically somewhere in our brain and that they transform certain states of our sensory apparatus into what we call perceptions (Diettrich 2001). Their invariants are the regularities we perceive. So, these phylogenetically acquired human specific cognitive operators are the defining operators for all the regularities we see and which are, just by this, human specific as well. Insofar as we condense observed regularities into laws of nature, these laws also are human specific rather than objective. (Example: the law of conservation of energy can be derived from the homogeneity of time. But what homogeneous means depends on our internal clock realised by physiological processes. The law of energy conservation therefore is a human specific artefact). Our inborn cognitive operators define our inborn classical world view and by this the laws of classical physics.

Typical of most empirical sciences is the use of instruments and measurement devices (such as microscopes or X-ray devices) 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 cases (Diettrich 1994a).

We will speak of *quantitative extensions* if the inborn perception (or cognitive) operators and the measurement operators commute. This means that the results of the measurement operations can be presented in the terms of invariants of the inborn cognitive operators, i.e., in terms of our classical world view.

We will speak of *qualitative extensions* if at least one of the measurement operators concerned is incommensurable with one of the inborn cognitive operators. Then the results of these measurements can no longer be presented in a classical manner and would require new, non-classical theories, i.e. theories from non-classical world views. This happened first time with measurements in subatomic areas which led to the establishment of quantum mechanics. As the set of possible measurement devices is, in principle, unlimited, it can never be excluded that qualitative extensions of previously established operators will require 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' (Barrow, 1990; Diettrich, 1994b). 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.

Here is an interesting analogy to mathematics: physical laws from which we can derive everything that can happen in nature (so our classical saying) correspond to the axioms in mathematics from which we can derive everything what can ‘happen’ in mathematics, provided they are complete and definitive (so our classical saying according to Hilbert).

However: 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, we know from Kurt Gödel (see the summary of E. Nagel 1958) that there are mathematical calculi which, though based entirely on well tested axioms, can lead to statements which cannot be proven within the context of these axioms, and therefore have to be replaced by a new set of axioms - and this can happen again and again. So we have qualitative extensions in mathematics as well as in physics. The reason for that parallel may be found in the fact that mathematics can be considered as part of our cognitive phenotype and therefore that axioms can be seen as the mathematical parallel to the natural laws in physics.

With this, the incompleteness of natural laws in physics and the incompleteness of mathematical axioms are homologous cognitive phenomena. Neither is there a definitive set of physical theories (no 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 (Gödel’s incompleteness theorem).

After we have seen here that the laws of nature are not objective but rather are human specific artefacts. We may ask what consequence this may have for the central metaphysical notions such as reality, time (particularly the metric and the arrow of time and causality

3.2. Reality

We have seen, that our inborn cognitive operators are responsible for what kind of regularities we will perceive. – and by this also for the laws of nature we derive from the perceived regularities. This leads to seeing the notion of reality under a different view. Let us distinguish to notions:

1. *Actuality* (Wirklichkeit) means the physical structure of our environment which we should not ignore. Indeed, ignoring trees when running through a forest can be painful. In so far it is close to reality. But we can modify actuality in many cases by means of physical actions.

2. *Reality* is that part of actuality which we cannot modify by what ever means. According to classical thinking this holds in the strict sense only for the laws of nature. Questioning reality in the way we are just doing here therefore means nothing but questioning the objective character of the laws of nature. This is strange enough, but it does not provoke any solipsistic fears which many people share when confronted with what they call anti-realism.

For our day-to-day life this has no consequences. Up to the day where a new qualitative extension of our scientific doing will require to modify our world view the laws of nature we 'found' are stable and definitive and therefore can well represent what we call reality. But we have to keep in mind that this reality has no ontological qualities. It just is a synonym for the totality of the physical laws we found within our phylogenetically acquired special world view.

3.3. The arrow of time

After we have seen that the notion of reality is difficult to hold we have to ask what to do with the other metaphysical notions such as time and causality if we can consider them no longer as belonging to a 'real world'. Particularly crucial is the so called arrow of time, i.e. the direction into which time 'flows'.

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 which we have to await in order 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 which can operationalise the terms past and future, i.e. the arrow of time?

Many efforts have been made in this direction (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 comprised implicitly in the preconditions of the experiments concerned. A typical example is the following: Shaking a box with black and white balls put in order according to their colour will always lead to disorder and never again to order. In physical terms: Entropy (which is a measure for disorder) will increase in time and never decrease. Entropy, therefore seems to operationalise the arrow of time. But in this case the result will depend on what we do first, separating the balls or shaking them. Shaking before separating will lead to order. Shaking after separating will lead 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 will always cool down. But this applies only if the collision processes between the atoms involved are endothermal, i.e. if the kinetic energy of the collision partners are higher before the collision than they are afterwards. If we have however 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 heat up rather than cool down. Here again we have to know what before and after means 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: 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 as described in 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 means, 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".

3.4. Causality

In order to constitute causality we must be able to identify patterns of events. If a number of events, say A, B, C, and D follow each other 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 (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, 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 thunder is usually much shorter and varies less than the time between thunder and the following lightning. But the length of time intervals can be defined only by means of a time metric. If our time metric generator were of the kind that it 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 rather than the other way around. *The mental time metric-generator is therefore responsible for the causal order established and for the prognostic capability derived from it.*

4. The boundary conditions

Up to now we explained that there is a large potential of different and possibly successful world views (one of them is our own phylogenetically acquired and inborn cognitive phenotype) and that their success is not a matter of adaptation to something independent or external. What we did not say up to now is what structure or what properties a cognitive phenotype must have in order to be successful. This is indeed necessary because a completely arbitrary or accidental cognitive phenotype can hardly be expected to be helpful. To begin with, there are two requirements any cognitive phenotype has to meet.

1. The tools we use to describe (i.e. to measure) the results of our doing must be independ from what we do. Otherwise we could not distinguish between what of a modified perception is due to our doing and what is due to a modified description. I.e., our describing tools must be invariants of as many as possible of our acting operators. Constructing descriptional tools which are invariant under these operators is what cognitive evolution should aim at. Then the operators concerned become measuring or cognitive operators, i.e., they identify properties of the objects concerned. Unfortunately we cannot construct a world view without acting operators, i.e. where the result of everything we may effect is (such as perspective phenomena) comprised implicitly in the world view. But cognitive evolution can aim at a world view where at least the most important and most frequently used acting operator will bring about

appropriate invariant defining and measurement operators. Such an acting operator is locomotion (indeed, locomotion is one of the most important and earliest operators organic evolution has created). Here, indeed, cognitive evolution found an appropriate tool: 3D-description. 3D-defined geometrical objects are invariant under locomotion (or, as physicist would say, under Galilei transformations). The properties of these objects, i.e.., their shape is measured by means of perspective phenomena brought about by locomotion. In other words: all the geometrical objects we derive from what we see as perspective phenomena are invariants of locomotion

But this is not the end cognitive evolution has to do here. If we walk long enough it may happen, that the city we just perceived is transformed into a forest. The respective pictures have nothing in common; nothing is invariant. So it seems that what we see is no longer invariant under walking. In order to save the concept of locomotion as a measuring operator cognitive evolution made a big invention: the space. A space is a matter of different places, each one having different properties and different appearances and all existing in parallel at the same time. So, walking from one place to another and by this having different perceptions does not require or does not mean that anything has to be changed or transformed because all the different things we would perceive did already exist before. So, defining visually perceived geometrical objects as invariants of locomotion requires the notion of space brought about by motion. Something similar has been discovered by Piaget (1970, p. 58). With children he found that it is not the category of space that allows us to define motion as mapping a line in space to the scale of time. It is rather motion that generates the category of spatial structure, The most primitive intuition, as Piaget called it, is not space but motion. Here we can clearly see that it is the physical structure of our organism (including walking limbs) that brought about the cognitive category of space rather than the ability to move was brought about by evolution in order to master a previously perceived space. I.e.: the physical structure is the boundary condition for the subsequent cognitive evolution.

2. The central demand on descriptive systems is their suitability for extrapolation, particularly for extrapolation in time, i.e., for prediction. Indeed a description which does not allow of predicting what will happen or what our doing will bring about cannot contribute to survival strategies. Easiest predicting is possible if the variables in question would change linearly in time. If something moves permanently with constant speed it is easy to say what it will do in the next future. Unfortunately, such cases are rare. In most cases the solution of the equation of motion is complex and difficult to handle. Here the theory of Hamilton-Jacobi is useful which allows in many cases to transform the variables in question in such a way that they will develop linearly in time. These new variables are called cyclic.

A reasonable aim of cognitive evolution therefore is to use variables which are cyclic straight from the beginning. First of all: cyclic variables can be derived from conservation laws. We mentioned already. the law of conservation of momentum. In force-free cases. ($mv = const.$) the speed of a mass-point is constant, i.e. the mass moves linearly in time and therefore is cyclic. So, the problem is reduced to finding conservation laws. This problem was solved by Emmy Noether, one of the most famous mathematicians of the 20. century. The so called Noether's theorem links the invariance properties of a system with its conservation quantities: *To every invariance there corresponds a conservation law and vice versa.* The formal statement of the theorem derives an expression for the physical quantity that is conserved (and hence also defines it), from the condition of invariance alone. For example:

- the *invariance* of physical systems with respect to *translation* brings about the law of conservation of *linear momentum*; (and by this the cyclic character of force-free motion)

- the *invariance* with respect to *rotation* brings about the law of conservation of *angular momentum; (and by this the cyclic character of force-free rotation)*
- the *invariance* with respect to *time* brings about the well known law of conservation of *energy*, (and by this the linear metric of time)

All together there are 10 laws of conservation which arise from the invariance of our descriptive system with respect to the Galilei transformation. But invariance under Galilei-transformation, we remember, was synonym for the demand, that our descriptive system must be independent from the most elementary action, that is locomotion. For a physicist it is really astonishing that the 10 conservation laws which govern anything in classical mechanics are not independent laws of nature but are the outcome of the phylogenetic decision to take the Galilei-transformation as a measuring operator.

To derive the properties of a system from its symmetries (i.e. the invariants) is a method very successfully applied in higher elementary particle physics. Here the various particles are defined as invariants of higher forces. Most of them were predicted by sheer invariant considerations – long before they have been found experimentally.

5. Language and mathematics as theories of our world view

What is crucial here is that our theories on what we call the world are not the result of adaptation to the boundary conditions of this world. Theories are rather the outcome of phylogenetic decisions on our cognitive phenotype guided by rather elementary requirements such as predictability or to get a feasible management of our organic capabilities.

Let us demonstrate this with two other kind of theories which we usually do not call theories: language (Diettrich 1997) and mathematics

Indeed, in the ordinary notion of language as rooted in realism, there is no reason to see language as a theory. It rather proceeds on the assumption that language is a universal and objective tool for the description of independently existing objects and processes, being able to convey any usual experience. Certainly, natural sciences sometimes require to extend ordinary language into mathematical areas, but this is not seen to conflict with the neutral character of language. Common sense understands that neither language nor mathematics would have any effect or influence on what it may describe. Mathematical methods, as we know, allow to extrapolate physical data and by this to predict new data, but this is not seen as an achievement of mathematics. We rather believe that it is the special physical structure of the world which would permit its inductive analysis. Experimental physical facilities and the results they produce represent another kind of language. They differ from ordinary written texts mainly by the fact that their decoding would require physical competence whereas the analysis of written communications needs language competence. On the other hand we know from physics that there are no absolutely interaction free relations between object and measurement apparatus, i.e. nature and the methods of its decoding cannot be completely separated from each other. So, strictly speaking, it should depend on the methods we apply what kind of statements we have to make on nature. Scientists try to avoid this difficulty by using only statements which they believe to be general enough not to depend any more on the experimental methods, i.e. on the "language" employed - or, in physical parlance: statements on nature should be invariant under the empirical methods applied. So, the knowledge of what we call the structure of nature is obtained through abstraction from the experimental techniques concerned - like the meaning of a message which could be defined as what is invariant under a change of language. According to naive understanding, language represents a generally unspecific capability independent from whether it is articulated in verbal or mathematical terms or in terms of experimental facilities. Nothing in the specificity of our life experiences is based upon the specificity of our descriptive tools. Language, within the limits of its competence, is seen to be objective and omnipotent. This is what expresses the naivety of the ordinary notion of language: to assume that content can be separated from representation. A similar view on the universality of language (though not necessarily to what is existing, but with respect to what may be intended) is expressed by Searle (1971) in his "principle of expressibility" according to which everything that can be thought, can be said.

Here we have to differentiate the notion of theory. As to compare phylogenetically acquired cognitive devices with organic instruments such as homoeostatic mechanisms, antlers or limbs, it was the idea already of Lorenz (1971: 231-262) and Popper (1973: 164) to see theories and organic devices under the common aspect of survival tools and to consider either of them as theories in the broader sense. This suggests to distinguish between two kinds of theories:

a.) *Theories in the structural sense (structural theories)*: 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. Accordingly, theories are considered to be true insofar as they are isomorphic with the structures to be described. Structural theories require that the objects concerned have an independent if not ontological character.

b) *Theories in the functional sense (functional theories)*: Lorenz (1971: 231-262) and Popper (1973: 164) have suggested enlarging the notion of theory towards all kinds of problem solving instruments. This would comprise 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; social communication and social bodies arising from it as a tool 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).

First of all, language is a functional theory in the sense explained here (Diettrich 1997). No doubt that language is a proved and important tool for solving technical and social problems. But language is also a structural theory insofar as it articulates in a rather precise manner essential parts of our world picture. We can read from language that we experience ourselves as individual subjects who see the world as object: most statements of our language deal with subjects which behave grammatically as if they were individuals themselves (in some languages where necessary, even an "it" will be constructed as an impersonal substitute person). The distinction between noun and adjective shows that we subdivide the world into single objects to which we attribute features which in principle can change - except a special one which is by definition unchangeable and which we call identity. (We have seen above that these and other conservation values have no ontological quality and can be seen only as invariants of certain operators. The category of identity, e.g. has developed phylogenetically as invariant of motion (Piaget 1967) or, as Uexküll said (1921): *"An object is what moves together"*). Prepositions and the forms of predicates disclose our belief that we can attribute to any subject a place and to any event a time. (Now we know that this is not always possible outside the world of classical physics). Conjunctions refer to the causal and logical structures we ascribe to the world, and personal pronouns reflect social categories, (i.e. the view that there are besides ourselves still other beings having principally the same quality of individuality). Many languages transfer nearly all relations into spatial pictures, even causal and modal relations and relations in time. This can best be seen with prepositions which to a high degree derive from local adverbs. W e say *in* an hour, *out* of the question, *beneath* contempt, *beyond* all measure, *through* fear, *under* these circumstances, *on the grounds* of, etc. A plausible explanation could be that our 3D world is very much more widely furnished than the merely one-dimensional categories of time or causality, and therefore is a more fertile source for metaphorical loans. Altogether we can say that there is a subtle correspondence between language and the more general experiences men have made in their wider history. Basic experiences which for phylogenetic reasons are common to all men and which, therefore, do not need to be told to anyone, are fixed elements in the grammar of human languages, (the inborn view, for example, that our daily life acts within a 4D space-time frame is an intrinsic part of our grammar so that in ordinary language other descriptions are even impossible). They form the co-ordinates by means of which the variable and individual parts of our experiences can be notionally localised, i.e. described. Natural languages represent a kind of basic or Ur-theory of the world. In this respect they correspond well to what we would call a theory in the ordinary sense. Those parts of physical knowledge, for example, which we consider to be generally valid we put into the mathematical structure of the theory and in the values of the parameter concerned (i.e. into the "grammar"). The variables of the theory, however, refer to the various possible statements.

Conversely, a language which is not a theory is logically not explicable. The specificity of verbal allegations about the world does not result from the fact that statements describe experiences in a world of given specificity but from the specificity of language itself in its quality as a theory of the world which like any other theory can generate only its own statements. The above mentioned ontological implications of ordinary languages as comprised in our world picture, therefore, are not extensions of an otherwise neutral language which one could eliminate where necessary. Language itself is genuinely a theory. Consequently no general criteria could be established to identify the ontological premises of a theory as proposed by Stegmüller (1969) and other representatives of analytical philosophy, in order to deliberate theories from unrecognized and usually unwanted implications. The critical and very presuppositions of a theory are already embodied in the language applied and its logical structure. What we called the (genetically inherited) Ur-theory is the ontological presupposition of any classical theory. The intention to clear languages or theories of their ontological presuppositions in order to come to a neutral description of nature is based on the idea that the specificity of all description is grounded in the specificity of the objects concerned rather than in the specificity of the describing tools themselves, i.e. it is based on realism. Realism and the idea of ontology-free-languages or theories are equivalent.

Also mathematics have to be seen as a language we use to describe certain specificities of our perception. In this respect mathematics can be as little neutral as ordinary language. Just as with language, mathematics derives its specificity from the cognitive operators which operationalise mathematical terms. So, mathematics can express only special statements. As the constituting operators are inborn and more or less equal for all men, it seems evident for us that their invariants are universal entities. Here, even more than with the categories of our perceptions, it is difficult to understand that the elementary notions of mathematical and formal thinking are purely human specifica. It is rather a very intuitive view that there is something such as a notional reality, sometimes called a Platonic reality.

If we start from the suggesting idea that operators constituting the structures of mathematics and of sensory perceptions (for phylogenetic reasons) are related to each other, then the mathematical structures and the sensuously perceived structures themselves must show similarities. This would explain why mathematics does so well in describing the regularities we perceive, or why the world, as Davies asked (1990), is algorithmically compressible (i.e. why the world despite all its vast complexity can be described by relatively modest mathematical means, or, in other words, why induction is so successful): the physical world - which is the world of our perceptions - is itself, on the ground of its mental genesis, algorithmically structured. Perceived regularities and mathematical structures are phylogenetic homologa. This is the reason why the formulation of (physical) theories in terms of the mathematics we are acquainted with is an essential prerequisite for their capability to emulate the genesis of perception and, therefore, for their truthfulness. From the classical point of view (i.e. within the theory of reality) the algorithmical compressibility of the world or, what is the same, the success of induction cannot be explained.

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 as we have to abstract just from these specifica, what is possible only if they themselves do not belong to the most primitive elements of our thinking. The following might be a clue: to the very beginnings of our inborn ways of thinking belongs the fact hat we use the same kind of cut by means of which we separate ourselves from the outside world, we use to separate the outside world itself into single subjects to each of which we attribute an independent identity. This approach is not compulsory. Quantum mechanics shows how the entire (physical) universe can be seen as a unity which 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 as 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: 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 can 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. It is this homology which 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 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 for 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 *algorithmical compressibility* of the world is essentially based upon 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 means the visualization of sets as a closed figures with points inside representing the set‘s elements as well as seeing ordered sets as spatial chains. Similar applies to the basic notions in topology such as ‘exterior‘, ‘boundary‘ and ‘interior‘ points, ‘isolated’ points etc. Even the notion of cardinality of sets comprises a certain geometrical coding. The cardinality of sets cannot be defined operationally as 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 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.

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 which we find and apply respectively in language are phylogenetically based human specifica like the perceptional structures upon which we will apply them in order to generate higher theories. Particularly the laws of logic cannot be explained as universalia in the sense of Leibniz which on grounds of their truthfulness would 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*. There are, of course, categories which, for phylogenetic reasons, are used by all men. Logic as a scientific discipline deals with the structures which can be constructed on this phylogenetically established basis which we later on would furnish with empirical and other theories. Konrad Lorenz (1941) speaks of our 'forms of intuition' (Anschauungsformen) 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 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 if we want to understand them. So it is impossible to find statements which could be accepted by any sufficiently complex intelligence, irrespective of its phylogenetic background and which, therefore, could be called universal. Even the question if a certain statement expressed by an intelligence A would mean the same as what another intelligence B has formulated, can be replied 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 which 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 well 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. 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).

6. Epistemological autoreproduction

Up to now we discussed cognitive evolution at a rather elementary level, i.e., at a level where tools and strategies are required for avoiding collisions when running through forests or for identifying physical objects and their shapes. But our cognitive ambitions aim at higher goals. We want to get theories explaining us the sometimes very complex relationship between different phenomena. We want to know the causal structure of the world and we want to discover the physical and biological history of nature, up to the various roads of cognitive evolution – and all this should be the result of cognitive evolution. The question, then, is: can cognitive evolution help us to understand cognitive evolution?

Here we will deal with the question how to find possible criteria for a successful epistemology when evaluation by an independent outside reality is no longer feasible.

The difficulty we have in accepting the notional character of our experiences as human-specific constructs differs with space and with time. As to the notion of space, undoubted (except perhaps by naive realists) is 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. Here, with space, we quite readily attribute to our world view a reduced objectivity. Not so with time: The recorded time topology of events we consider to be real. And so we consider the order of events as we have perceived them. The past is as it was and even God cannot change it a-posteriori, we are used to 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 as less clearly defined outlines than visual patterns have. A modification of the interpretations of events used (for example, in the light 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 the relativistic formula which would lead to 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 artefact is the more problematic as it is based (through CEE) just on what is known about biological evolution, and this 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, just this world view is what physics and biology refer to, particularly when describing the development of the human brain and the operators established there. What, then, is hen, and what is 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 which say that the EE is circular in so far as not only the categories of space, time and causality are interpreted 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 through 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. In other words: a world picture brought about by human brains has to explain everything from the big bang, the creation of our world, organic and then cognitive evolution and eventually the development of the world picture itself. I.e., the cognitive phenotype has to reproduce itself in the same sense the organic phenotype has to do. A cognitive phenotype (or a world picture) which meets this requirement we will call consistent. Accordingly, further to the special cognitive phenotype we have acquired, there is an unlimited number of possible (and consistent) cognitive species similar to the many existing or possible organic phenotypes (i.e. species). Also biotic organisms are not required to be ‘true’ but rather to reproduce, i.e. (as biologists are used to say) to contribute to the survival of the genes concerned. Thus, not only organic ontogenesis but also cognitive evolution has to be understood as circular, autoreproductive process 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 will be 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 will effect. 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 as 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 of life mastering methods consistency with an independent outside world. A constructivist interpretation of the world as proposed here, however, needs only to reconstruct itself.

(a) The most elementary position taken is that cognitive constructs (perceptions) have to delineate correctly the structures of the environment, since 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 being 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 derived rationally. If epistemology is seen as a matter of cognitive evolution it is understood as 'natural selection epistemology' á la Campbell

(b) In *radical constructivism* (RC) (Glasersfeld 1995) as well, cognitive constructs have to contribute to meeting the requirements of the environment, but not necessarily by means of delineating environmental structures but rather functionally. The notion of 'truth' is replaced with 'viability' within the subjects′ experiential world. Physical knowledge is reliable (i.e., it allows verifiable predictions) if it is derived from perceptions (or phenomena) which 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 derived rationally.

A more refined version of radical constructivism is from Foerster (2003) and Riegler (2001). Both reject reference to an outside world when using Glasersfeld's term 'viability'. Foerster (2003) argues that what appears to us as objects are equilibria that determine themselves through internal circular processes. Riegler (2001) refers to what he calls 'epistemological solipsismus'.

(c) In 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 if and 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 human action operators. This resulted in the metatheory of classical physics, i.e. in the mental notion of time, space, spatial identity, locomotion, momentum etc. and to the 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., 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 men can do by natural or technical means and it will change 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, i.e. if it is circular. So we can say:

the main specialty of CEE as opposed to RE is that organic boundary conditions have been found that explain important features of our world view.

The main specialty of CEE as opposed to classical realism is that the perceived regularities are explained as invariants of cognitive operators, whereas in classical realism they are explained as (structural or functional) pictures of the regularities of a real world.

7. Conclusion

We have seen that the laws of nature we use do not describe an objective world. They rather are a reference frame for analysing our experiences. They depend on our cognitive phenotype (e.g. do we see the world in two, three or four dimensions?) which in turn depends on our organic phenotype (e.g. can we walk or not? Do we have remote perception?). There are many different organic phenotypes (species) which all are successful survivors. Each of them can bring about several different but successful cognitive phenotypes which are characterised by their specific sets of natural laws. Measurement and other physical devices can be considered as artificial extensions of our organic phenotype. This may modify the set of possible cognitive phenotypes. This happened when experimental evidence forced us to replace our classical world view by the quantum mechanical world view. Similar may happen again and again

From this we can conclude: The structure of an independent outside world cannot provide the boundary conditions for cognitive evolution (in the sense of Campbell's natural selection epistemology) as this structure itself is the outcome of our cognitive phenotype. The only possible source is our organic phenotype. The organic phenotype does not determine the cognitive phenotype but it provides the boundary conditions for its evolution. The same applies for the various hierarchical levels in organic evolution. None of them determines the next higher level but it provides the boundary conditions concerned (or the genetic burden as Rupert Riedl says). Under this aspect cognitive evolution is nothing but a new level in man's evolution.

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The author:
Olaf Diettrich
Centre Leo Apostel, Vrije Universiteit Brussel, Brussels
Ave. des 4 Bonniers, 20
B-1348 Louvain-la-Neuve
Belgium
olaf.diettrich@skynet.be